

The impact of a professional development initiative in numeracy/mathematics on teachers and students in New Zealand

Jennifer M. Young-Loveridge*

University of Waikato School of Education, NZ

Abstract

This paper describes an initiative designed to improve the teaching and learning of mathematics in the early school years in New Zealand. The first part of the paper presents an overview of key features of the numeracy initiative. Data on the impact of the initiative on teachers and students is described. The magnitude of the project's impact on students' mathematical learning is reported as effect sizes, calculated by comparing slightly older students (from the adjacent age-group) acting as a "control" group, with the "treatment" group.

Key words: *professional development, numeracy/mathematics, teachers early school years*

Introduction

In the last couple of decades, mathematics education has undergone major reform worldwide. New Zealand, along with other western countries responded to its relatively poor results on the Third International Mathematics and Science Study (Garden, 1996, 1997; National Center for Educational Statistics, n.d.) by developing a radically different approach to teaching mathematics. Like other western nations,

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work began on initiatives in mathematics that focused initially on the early years of school (Bobis, Clarke, Clarke, Thomas, Wright, Young-Loveridge, & Gould, 2005; British Columbia Ministry of Education, 2003; Commonwealth of Australia, 2000; Department for Education and Employment, 1999; National Council of Teachers of Mathematics, 2000; New Zealand Ministry of Education, 2001). These initiatives share several common features, including professional development programs for teachers to improve the teaching of mathematics, the construction of developmental frameworks to describe progressions in the learning of mathematics, individual task-based interviews to assess the mathematics learning of students, a strong emphasis on students' mathematical thinking and reasoning, and a constructivist/socio-constructivist view of mathematics teaching and learning.

Features of New Zealand's Numeracy Initiative

Professional Development Program for Teachers

A major focus of the numeracy initiative in New Zealand has been the improvement of teachers' capability through ongoing reflective professional development (PD). Teachers have been helped to make sense of research information about the mathematical thinking of their students, reflect on it with colleagues, and make adjustments to their planning for individual students and groups (Bobis et al., 2005). This process continued over several months or even years - in contrast to the "one-shot" PD programs of earlier times. As part of the PD program, teachers were given a series of tools to help them foster the mathematics learning of their students, including a number framework outlining developmental progressions in number understanding, and an individual diagnostic interview for assessing students' understanding of mathematical strategies and knowledge. Professional development workshops, spaced out evenly over the school year, and in-class modelling by mathematics facilitators/consultants have introduced new ways of working with children to support their mathematics learning. Between workshops, teachers were expected to read the project materials, develop new mathematics resources for their classrooms, try out different teaching methods with their students, share ideas with colleagues also

participating in the project, and consolidate their learning before the next workshop. Each teacher was given approximately 16 hours of a facilitator's time, but this did not include additional telephone, email, or face-to-face contact, if and when the need arose. Each facilitator was responsible for approximately 60-90 teachers each year.

New Zealand's numeracy initiative has been underway for almost nine years. Virtually all teachers of Year 1 to 6 students, and most teachers of Year 7 and 8 students (~30,000 teachers of 800,000 students in approx. 2500 schools), have participated in the project. Teachers at the early secondary level (Years 9 & 10) began the project in 2005, with more than 30,000 students participating so far. The implementation of a numeracy initiative on such a large scale has been referred to as "going to scale" (Coburn, 2003).

An important aspect of these initiatives has been the involvement of all staff at the relevant grade levels, rather than just selected teachers. In New Zealand, where the numeracy initiative covers all years of compulsory schooling, a school wanting the PD program for teachers working with its early years students, must make a commitment to involve *all* its teachers, including those working with older students. The usual pattern has been in the first year, to introduce the initiative to teachers working with the youngest students (Years 1 to 3; 5-year-olds to 8-year-olds), and the following year to begin working with teachers in the middle/intermediate years. The secondary initiative has worked slightly differently but shares many common features.

The PD program is consistent with much of the current literature on effective teaching that stresses the importance of assessing what students are ready to learn, then choosing appropriate activities to build on that understanding (e.g., Fuson, Kalchman, & Bransford, 2005; Horowitz, Darling-Hammond, & Bransford, 2005). The program is premised on the idea that teachers need good knowledge of mathematics and ways of helping students develop better mathematical knowledge and understanding (pedagogical content knowledge). The initiative aimed at improving not just the quality of mathematics teaching, but also teachers' confidence.

A distinctive aspect of the New Zealand numeracy initiative has been the development of a separate PD program for teachers working in Maori-medium settings (Te Poutama Tau; TPT). Because many of these teachers are second-

language learners of Maori rather than native speakers, an added challenge has been the need to improve their fluency in Te Reo Maori (the Maori language), as well as work on their subject knowledge and pedagogical content knowledge of mathematics (Christensen, 2003). Although initiatives to improve the mathematics learning of indigenous students have been tried in other countries (e.g., Australia, Canada), the lack of a common indigenous language has been a major barrier to strengthening students' mathematics learning.

Developmental Framework

A key aspect of the New Zealand initiative is a learning framework consisting of progressions (stages) reflecting increasingly sophisticated strategies in several mathematical domains (Bobis et al., 2005; New Zealand Ministry of Education, 2001). The progressions in number reflect the perceived importance of number in the curriculum, and the comprehensive body of research that supports this (Kilpatrick, Swafford, & Findell, 2001). Steffe's (1992) work has been extremely influential in the development of progressions in the domain of number.

New Zealand's number framework comprises a series of stages describing the mental processes students use to solve problems with numbers (*Strategies*), as well as the key pieces of knowledge that students need in order to be able to use strategies effectively (*Knowledge*). Operational *Strategies* include three domains: addition and subtraction, multiplication and division, and proportion and ratios. Number *Knowledge* consists of six domains: forwards and backwards number-word sequences, numeral identification, knowledge of fractional numbers and basic facts, and understanding of place value. Broadly speaking, there are two different kinds of strategies: counting strategies and part-whole strategies (see Figure 1). The first five stages on the framework consist of increasingly sophisticated counting strategies that can be used to solve problems. Although Stage 1 marks the beginning of counting, students at this stage are not yet able to use their counting skills to solve problems involving the joining or separating of two collections. Stage 2 marks the beginning of counting for the purpose of finding out "how many" when collections are joined or separated, and the counting depends on having materials available to count, starting from one.

This is similar to “perceptual counting” (see Bobis et al., 2005), and “direct modelling” (Carpenter, Fennema, Franke, Levi, & Empson, 1999). Stage 3 is marked by a shift to counting mentally, starting from one (or “figurative counting”; see Bobis et al., 2005). Stage 4 is the highest counting stage, and is characterised by the ability to count on or back from one of the collections. Stage 5 is an important landmark for children because it marks the replacement of counting strategies by the use of number properties and relationships to solve problems (part-whole strategies). Children at Stage 5 are able to break numbers apart and recombine them in ways that make a problem easier to solve, or can find answers to new problems by deriving them from known answers to related problems. Part-whole strategies are similar to “thinking strategies” (Lampert & Cobb, 2003) or “derived-fact strategies” (Carpenter et al., 1999). Stage 6 involves elaboration and consolidation of part-whole strategies in a range of addition and subtraction contexts. Stage 7 marks a shift from additive thinking to multiplicative reasoning for multiplication and division problems. Stage 8 marks a move away from multiplicative thinking to proportional reasoning for problems involving proportion and ratio.

The number framework is supported by research showing identifiable progressions in the development of number concepts (e.g., Carpenter et al., 1999; Cobb, Gravemeijer, Yackel, McClain, & Whitenack, 1997; Young-Loveridge & Wright, 2002). Although the number framework focuses on number and arithmetic, as students move through the framework stages, they learn how to reason algebraically as they acquire methods for manipulating numbers and come to understand number properties. There is now recognition that early algebraic reasoning within the context of arithmetic provides an important foundation for later algebra (Carragher, Schliemann, Brizuela, & Earnest, 2006; Department for Education & Employment, 1999; Irwin & Britt, 2005; Perry & Dockett, 2002).

Stage	Description
0	<u>Emergent</u> Cannot count
1	<u>One-to-One Counting</u> Can count a small collection up to 10, but cannot use counting to add or subtract collections.
2	<u>Counting from One on Materials</u> Can add two collections by counting, but counts all the objects in both collections
3	<u>Counting from One by Imaging</u> Adds two collections by counting all, but counts mentally by imaging objects
4	<u>Advanced Counting</u> Recognizes that the last number in a counting sequence stands for all the objects in the collection, so counts on for the second collection
5	<u>Early Additive Part-Whole Strategies</u> Recognizes that numbers are abstract units that can be partitioned (broken up) & recombined (part-whole thinking). Uses known number facts to derive answers
6	<u>Advanced Additive Part-Whole Strategies</u> Chooses from a range of different part-whole strategies to find answers to addition and subtraction problems
7	<u>Advanced Multiplicative Part-Whole Strategies</u> Chooses from a range of different part-whole strategies to find answers to multiplication and division problems
8	<u>Advanced Proportional Part-Whole Strategies</u> Chooses from a range of different part-whole strategies to find answers to problems involving fractions, proportions, and ratios

Figure 1. New Zealand's number framework

Individual Task-based Assessment Interview

Another key aspect of the numeracy initiative is the individual diagnostic assessment interview, aligned with the framework and designed to provide information about students' knowledge and mental strategies (Bobis et al., 2005). Although these assessments take longer than pencil-and-paper tests, there are considerable benefits in terms of improved validity and reliability. Unlike written mathematics tests, which

focus on the number of correct answers given by a student using any method, an individual interview provides a comprehensive picture of a student's thinking and reasoning for different types of mathematical problems.

Emphasis on Mathematical Thinking and Reasoning

A key message coming through in the PD programs with teachers has been the importance of focusing on students' mathematical thinking and reasoning, not just within the assessment process, but also as part of classroom instruction. One of the earliest programs to do this was Cognitively Guided Instruction (CGI), a program developed in the United States that helped teachers to identify key aspects of students' thinking, which could then be used in planning classroom mathematics instruction (Carpenter et al., 1999; Carpenter, Franke, & Levi, 2003). *Understanding* mathematics (instead of the mindless application of rote procedures) is a key aspect of the New Zealand initiative. An explicit statement has been made, urging teachers not to teach standard written methods (i.e., vertical written algorithms) until their students have a good understanding of part-whole relationships and can use mental calculation strategies (Book 1: New Zealand Ministry of Education, n.d.). Research evidence supports the idea that students should be encouraged from the beginning to make sense of mathematics and actively engage in finding ways to solve problems, rather than passively accepting a single "right" way of working out answers (see Kamii, 1994; Pesek & Kirshner, 2000).

The emphasis in the New Zealand initiative on students' thinking and reasoning is consistent with literature on the importance of mathematical reasoning for mathematics learning (e.g., National Council of Teachers of Mathematics, 2000; Russell, 1999; Tang & Ginsburg, 1999). According to Russell, mathematical reasoning is about developing, justifying, and using mathematical generalizations. It leads to interconnections between aspects of mathematical knowledge, and this web of mathematical understanding is the foundation that provides insight into mathematical problems. By emphasizing mathematical reasoning in the classroom, teachers can capitalize on flawed or incorrect reasoning as a means of assisting students towards a deeper understanding of mathematics.

Theoretical Orientation to the Teaching and Learning of Mathematics

The constructivist/socioconstructivist approach has been an important influence on the development of numeracy reforms (Hufferd-Ackles, Fuson, & Sherin, 2004; Mulligan & Vergnaud, 2006). Such an approach views students as actively constructing their knowledge and understanding. The developmental perspective evident in the number framework reflects a view that there are general patterns of progression in the way that new understanding builds on prior competencies and understanding, reminiscent of Piaget's theory of cognitive development.

A socioconstructivist approach to mathematics learning, according to Hufferd-Ackles et al. (2004), combines radical constructivism (learning as self-organization) and sociocultural perspectives (Mulligan & Vergnaud, 2006). A key aspect of the sociocultural approach is the recognition that an individual's learning is affected by participation in the wider culture, including the classroom, the family, and the outside world (Forman, 2003; Lampert & Cobb, 2003; Sfard, 2003; Yackel & Cobb, 1996). Discourse is also important to the socio-cultural perspective, because "taken-as-shared mathematical meanings are constructed through a process of interacting in a community" (Hufferd-Ackles et al., 2004, p. 83). Sfard (1998) argues that both "acquisitionist" (individualistic) and "participationist" (social) metaphors of learning offer valuable perspectives, and hence it is dangerous to "choose just one" of these. Many writers have discussed the value to students' mathematics learning of working collaboratively with peers, and the importance of productive discourse, argumentation, and justification of solution strategies (e.g., White, 2003; Wood, 1999). Related to the sociocultural approach is Yackel and Cobb's (1996) distinction between "sociomathematical norms" which to refer normative understandings of what is acceptable or valuable with respect to mathematics (e.g., what is mathematically sophisticated, or what is an acceptable mathematical explanation), and more general "social norms" which refer to what is acceptable or valuable, whatever the subject (e.g., challenging others' thinking, or justifying one's own interpretation). Both general classroom social norms and sociomathematical norms are important components of a classroom culture and have enormous implications for students' mathematics learning. The socio-constructivist approach (Hufferd-Ackles et al., 2004) includes aspects of both socio-

cultural and radical constructivist views, and can be seen in the materials provided for teachers who participate in a numeracy initiative (e.g., Book 3: New Zealand Ministry of Education, n.d.).

Impact of the NZ Initiative on Teachers and Students

The Impact on Teachers' Professional Practice

The PD program has been positively received by participating teachers, principals and facilitators. Teachers have reported developments in their professional knowledge as a result of their involvement in the project (in particular their pedagogical content knowledge), and have noted changes in their classroom practices to accommodate their new knowledge and understandings (Thomas & Ward, 2001, 2002). Teachers made comments such as:

“I am much more aware now of how students reach their conclusions. I am taking more notice of their use of strategy.”

“There are many ways to a correct answer, and as a class we have explored that more thoroughly than before.”

Teachers also noted increases in confidence and enthusiasm for mathematics teaching (Thomas & Ward, 2001, 2002). One teacher commented that:

“This project has been the most worthwhile [professional] development I have been involved in... far more effective than a two-day course.”

Another commented on how s/he was “*amazed at how students could be extended.*”

No matter how positive teachers are about their experiences of the numeracy initiative, ultimately the measure of its success lies with improvements in students' mathematics learning.

The Impact on Students' Mathematics Learning

In the New Zealand numeracy initiative, data from diagnostic interviews with students at the beginning and end of the project is sent by teachers to a secure website

where it can be later analysed. This extensive data set provides valuable information, not just about what constitutes reasonable expectations for student achievement and progress at particular year levels, but also about how the initiative impacts on students, and the extent to which this varies as function of their age, gender, ethnicity, SES, or some combination of these (see Young-Loveridge, 2005a, 2006, 2008). Table 1 provides an example of one kind of analysis, presenting the percentages of Year 0 to 3 students (110,000 in total) at each stage on the strategy section of the number framework, at the initial and final interviews.

Table 1. *Percentages of Students at Each Stage on the Number Framework as a Function of Project Status (Initial or Final) and Year Level 2002-2005*

Year Level	0-1		2		3	
Number of students	32	737	38	680	42	143
Project Status	Initial	Final	Initial	Final	Initial	Final
0 Emergent	18.5	3.3	4.1	1.0	1.7	0.4
1 One-to-one Counting	29.7	10.6	13.3	2.7	5.0	1.0
2 Counting All with materials	41.4	43.9	42.6	20.0	19.9	6.3
3 Counting All with imaging	7.4	22.2	17.0	19.0	12.6	8.1
4 Counting On	2.8	18.0	20.4	43.6	46.1	44.0
5 Early Additive Part-Whole	0.1	2.0	2.5	13.1	13.8	35.6
6 Advanced Additive Part-Whole	0.0	0.0	0.1	0.7	0.8	4.6

A comparison of the initial and final data for each year level shows substantial improvement. For example, the percentage of Year 2 students at stage 4 (counting on) or higher, increased from 23% to 57%. The percentage of Year 3 students at stage 5 (early additive part-whole) or higher, increased from 15% to 40%.

Other findings related to the student achievement data include:

- All students benefited from participation in the initiative, regardless of ethnicity, gender, or socio-economic status.
- Asian and European students began the project at higher stages on the number framework, and benefited more from participation in the initiative, than did

students of Maori or Pacific Islands descent.

- Gender differences were small, with slightly more boys progressing to higher framework stages than girls.
- Students at schools in high socio-economic areas started the project at higher framework stages, and made larger gains over the course of the project, than did students at schools in low and medium socio-economic areas.
- Analysis of the patterns of progress showed that even when starting point was taken into account, progress varied as a function of ethnicity, and the patterns of differential progress varied according to whether the starting point was high or low on the framework (Young-Loveridge, 2005a, 2006). At middle and higher framework stages, European and Asian students made greater progress on the number framework over the course of the project than did Maori or Pacific Island students. At lower framework stages, the pattern was reversed, with Pacific Island students tending to outperform other groups in terms of progress. Overall, however, the “achievement gap” was not narrowed appreciably by the project.

The Magnitude of Effects

It was not immediately obvious from the analysis of their performance whether the students in the numeracy initiative made progress because they had been part of the project, or simply as a result of “normal” aging. In a traditional experimental design, comparisons are made of the progress (the difference between pre-test and post-test scores) of a “treatment” group with a “control” group that did not experience the intervention. An important feature of New Zealand’s numeracy initiative was the assessment of students by their own teachers, as part of the “treatment”. Because this was an essential component of the intervention itself, it was not possible to have a control group in the traditional sense. However, to get around the lack of a control group, data from students at the beginning of the program was compared with data gathered at the end of the program. Young-Loveridge (2005a, 2005b) used adjacent age groups to explore the differences between younger students after the project and older students before the project (e.g., 5-year-olds after the project with 6-year-olds

before the project, 6-year-olds after the project with 7-year-olds before the project, and so on). Because the PD program took place over about nine months of the school year, by the end of the program, the younger students were, on average, still about three months younger than the older students had been at the beginning of the program initially. This meant that the younger students at the end of the program were slightly disadvantaged developmentally, compared with their (one-year) older peers at the beginning of the program. Hence this younger-older comparison provides a fairly conservative (stringent) measure of progress, so statistically significant differences favouring younger students at the end of the program reflect sizeable benefits from participating in the project. Analysis of initial framework stages for adjacent age groups was done to ascertain the pattern of “normal” development before intervention, and this showed that adjacent age groups differed by half to three-quarters of a standard deviation of a (framework) stage (Young-Loveridge, 2005a).

Effect sizes (based on the standardised mean difference between groups) were calculated for adjacent ages and the median effect worked out for each of the three domains (see Table 2). The average (across three domains in 2003 & 2004) of the median effect sizes for children in the first four years of school was 0.41, close to the value considered to be “medium” in magnitude (Fan, 2001), and substantially greater than the 0.18 effect size reported for the National Numeracy Strategy in England (Brown, Askew, Millet, & Rhodes, 2003). Figure 2 presents the percentage of students at stage 5 or higher on the framework for the three Strategy domains, and selected Knowledge domains (Fractions, Place Value, Basic Facts) for the adjacent-years comparison. It is clear that in most cases, more of the younger students (whose teachers had participated in PD) than older students (before their teachers began PD) were at upper stages on the framework. In the early years of school, the most noticeable progress seemed to be on the Knowledge domains of Basic Facts, Place Value, and Fractions. The advantages of the PD were greatest for children at middle and upper levels of the primary school, perhaps because the majority of students in the first year or so of school were not assessed on the Multiplicative or Proportional (strategy) domains.

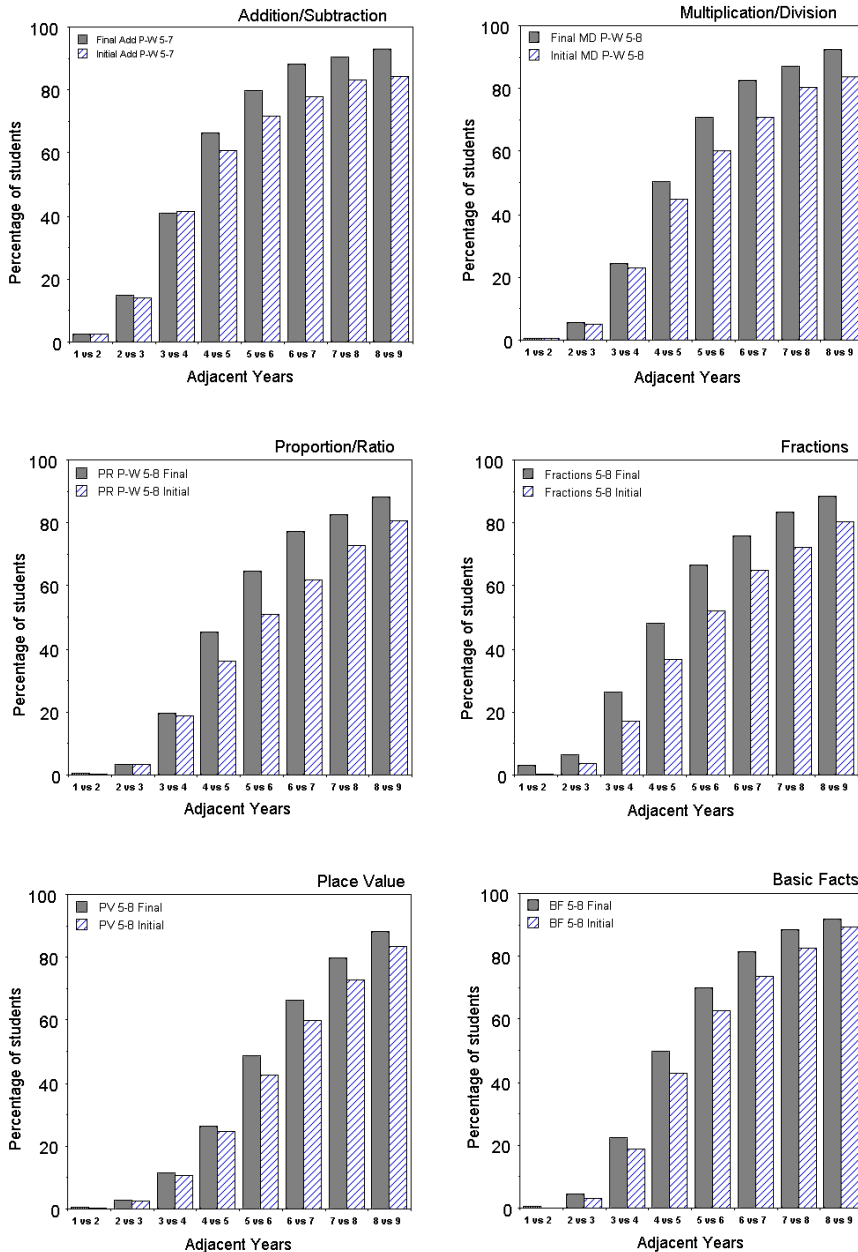


Figure 2. Percentages of students at stage 5 or higher on the number framework for strategy domains and selected knowledge domains for adjacent years comparisons (Younger students' Final data vs. Older students' Initial data)

Ethnicity Differences

Effect sizes for ethnicity differences were substantially smaller for individual interviews (as in New Zealand's Numeracy Development Project [NDP]) than for written tests, such as used for TIMSS (0.2 & 0.7 for European vs. Maori on NDP & TIMSS, respectively; 0.3 & 1.0 for European vs. Pacific Islands, on NDP & TIMSS, respectively; see Young-Loveridge, 2006). These findings indicate that using individual interviews may be a fairer way to assess the mathematical thinking of students from minority groups. Written tests have the disadvantage that literacy difficulties may prevent some students from engaging with the mathematics itself. Interviews have obvious advantages for early years students who tend to have limited literacy skills.

The focus of the diagnostic interview is typically on the nature of the students' mathematical thinking relative to the framework. Information gathered from diagnostic interviews is used to inform classroom planning. Teachers participating in the New Zealand numeracy initiative are expected to use the diagnostic interview to assess their students at the beginning of the project (after the PD workshop on diagnostic interviews), and at the end (after 15-20 weeks of PD) (see Book 2: New Zealand Ministry of Education, n.d.).

Table 2. *Summary of Effect Sizes for Comparisons between Framework Stages of Younger Children after the Project with Those of Older Children before the Project of Children in Adjacent Age Groups*

2003			2004		
Age Groups Compared	No. of Younger Children	Effect Size	Age Groups Compared	No. of Younger Children	Effect Size
Addition/Subtraction					
4&5	3562	0.45	4&5	2614	0.34
5&6	14009	0.24	5&6	8008	0.06
6&7	18324	0.10	6&7	8211	0.05
7&8	17849	0.11	7&8	9033	0.18
8&9	16976	0.17	8&9	9863	0.27
<i>Median</i>		<i>0.17</i>	<i>Median</i>		<i>0.18</i>

2003			2004		
Age Groups Comparand	No. of Younger Children	Effect Size	Age Groups Comparand	No. of Younger Children	Effect Size
Multiplication/Division					
5&6	471	0.60	5&6	389	0.75
6&7	3473	0.62	6&7	2317	0.48
7&8	8276	0.49	7&8	5938	0.35
8&9	12178	0.39	8&9	8449	0.36
<i>Median</i>		<i>0.55</i>	<i>Median</i>		<i>0.42</i>
Proportion/Ratio					
5&6	472	0.73	5&6	380	0.83
6&7	3412	0.68	6&7	2303	0.56
7&8	8164	0.58	7&8	5901	0.41
8&9	12082	0.46	8&9	8376	0.41
<i>Median</i>		<i>0.63</i>	<i>Median</i>		<i>0.49</i>

Evaluation of New Zealand's Numeracy Initiative

When an education system invests a lot of money on implementing a new initiative, it is important to ensure that the money is well spent. An ongoing process of evaluation has continued to monitor the impact of the New Zealand numeracy initiative. Although data on students' mathematics achievement gains and teachers' positive responses to the initiative provide strong evidence of its effectiveness, anecdotal evidence from teachers and facilitators/consultants suggests that the project has not been not equally effective for all teachers or all students. Now that the implementation process is coming to an end for teachers working at the early years level, the focus for facilitators is shifting to issues of sustainability and the need to provide support for particular groups of teachers (e.g., beginning teachers or those returning to the profession after an absence). Evaluation research continues to explore ways to increase the effectiveness of the initiative by gaining insights into the ways that facilitators and teachers have responded to it.

Time seems to be an important factor, not just in terms of the amount of time spent participating in the project, but also how early or late in the implementation process teachers participated in the PD program. Numeracy facilitators/consultants

have commented informally on how their advice and support to teachers has improved substantially over the years since the project began, as they have acquired more experience and a deeper understanding of students' mathematics learning. Hence teachers who participated in the earlier years of the initiative may not have benefited to the same extent as teachers who participated more recently. Unfortunately many of the schools in the initial years of implementation were those serving low SES communities schools that needed the most support.

Evidence suggests that while some teachers have embraced the initiative enthusiastically and changed their mathematics teaching substantially to focus on conceptual understanding, others have gone back to previous teaching approaches. Because each year, facilitators have been given a new cohort of teachers to support, there has been little time to offer ongoing support to the teachers from previous years. There are questions about whether one year is really sufficient to enable early years teachers to fully appreciate all major aspects of the initiative. The decision to make the PD program for early years teachers one year was an attempt to balance the time needed to understand and implement a different way of teaching mathematics with the need to ensure that all teachers working with students at this level would eventually get the opportunity to be involved in the initiative. It was decided that teachers at higher grades would be given additional time in the PD program, in order to understand the complexities of multiplicative and proportional reasoning as well as additive thinking. Decisions about the length of time for the PD program took no account of the individual learning needs of the teachers, which varied considerably, as one might expect. Informal feedback suggests that some teachers began with quite low levels of pedagogical content knowledge. For example, the idea that numbers could be partitioned in order to make operations easier, was for some teachers a revolutionary idea. It later transpired that some of these teachers had, up until the project, been relying on counting strategies to solve their own problems.

Efforts to examine differences in the impact of reform on teachers show just how complex the process is. For example, Higgins (2005) identified two very different orientations adopted by New Zealand teachers towards the numeracy initiative, a "design adherence orientation" and a "contextually responsive orientation". The

design adherence orientation emphasises material-based activities for children and adherence to program design, as reflected in the books providing examples of ways various materials and activities could be used to strengthen children's mathematical thinking (see New Zealand Ministry of Education, n.d.). In contrast, the "contextually responsive orientation" emphasises structural components of the program designed to give teachers a deeper understanding of these components for flexible use as part of classroom practice. Whereas the "design adherence orientation" involves slavish following of a "program" (not the intent of the initiative), the "contextually responsive orientation" involves using and adapting tools provided to extend children's concepts and understanding to a higher level. Higgins provides examples of teachers' comments that reflect each of these two orientations. This area of investigation provides a fruitful direction for exploring individual differences in the ways that the reforms have impacted on teachers, and their students.

The issue of sustainability of the initiative over the longer term is a major concern. Data from diagnostic interviews at the end of the PD program provide information about improvements in framework stages reflecting teachers' very recent exposure to the numeracy initiative. An obvious question to ask is about what happens once the novelty has worn off, facilitators are no longer providing regular support, and the content of the PD program becomes just a distant memory. In an effort to find out what happens over the longer term, Thomas and Tagg (2006) used data from a representative group of schools that participated in the PD program in previous years (the Longitudinal Study). They found that teachers continued to use tasks from the diagnostic interview to assess their students' strategies stages on the number framework, and even better performance by students on the number framework compared to same-aged peers whose teachers had only just completed the PD program. This has been taken as evidence that sustained commitment to the numeracy initiative over several years can produce even greater benefits to students' mathematics learning than are evident at the end of the PD program. However, a possible problem with this interpretation is that not all schools that agreed to submit data actually did so. If only schools that were happy with their data submitted it (successful schools), then this may have inflated the results for the Longitudinal Study.

It seems likely that some teachers need more time to work with different approaches to teaching mathematics, having acquired a rather superficial knowledge of the program that did not empower them to respond appropriately to the learning needs of their students. The challenge for the future is to find ways to identify teachers who need additional support in coming to understand how they can address the mathematics learning needs of their students. Certain factors have probably exacerbated this problem, including high levels of staff turnover, particularly in schools serving low SES communities. A case study of a school in a medium SES area has provided evidence of what is possible when teachers are fully committed to the reform process and involve their children in decisions about learning, including setting personal learning goals and taking responsibility for helping peers learn about different ways of solving mathematics problems (Young-Loveridge, 2005b). The children at this school showed strong evidence of an ability and inclination to communicate mathematically with their peers, whereas this was much less evident for the children from lower SES schools (Young-Loveridge, Taylor, & Hawera, 2005).

The importance of establishing classroom norms, both social and sociomathematical norms, has been discussed extensively by Yackel and Cobb (1996). However, shifting classroom discourse away from a traditional teaching approach towards a greater focus on students' communicating their mathematical reasoning, justification and argumentation, is no easy matter. Anecdotal evidence suggests that only a small minority of teachers have been able to make such a shift towards establishing a community of mathematical learners who participate in collective problem-solving. Hunter (2006) has documented the experiences of one New Zealand teacher in a low SES school who managed to shift her classroom discourse away from teacher questioning and student explaining, towards building a community of learners who were able to challenge each other and justify their mathematical reasoning. It was a lengthy process for the teacher to change children's expectations about appropriate ways of engaging with mathematical reasoning and debate within the classroom. She had to teach her students how to disagree with each other honestly but respectfully. Hunter's findings are consistent with those of other researchers who have explored argumentation in classrooms (e.g., Hufferd-Ackles et al., 2004; White, 2003; Wood, 1999).

The findings presented and the issues raised here are consistent with a huge body of literature on the difficulties of bringing about large-scale reform in education (e.g., Coburn, 2003; Earl, Watson, & Torrance, 2002; Elmore, 1996; Fullan & Earl, 2002). However, New Zealand has the advantage of being a relatively small country and that has probably made the implementation of the reform process somewhat easier. There have been many benefits to mathematics education, quite apart from improvements in students' mathematics learning. The numeracy initiative has provided the impetus for building and strengthening the mathematics education community. The needs of the PD program have led to the development of an infrastructure to disseminate information out to teachers, schools, and teacher educators. Regular conferences with presentations by well-known international researchers bring the New Zealand mathematics community together and encourage debate and discussion. The evaluation process associated with the initiative has grown as researchers have been able to pursue some of their own research interests as well as investigating the questions they are required to by the system that provides the funding.

Conclusion

The numeracy initiative in New Zealand, developed as a consequence of mathematics reforms, has played an important part in improving the mathematics learning of students and teachers. However, there is still a great deal of work to be done to help teachers gain a better appreciation of the social dimension of mathematics learning, and the value of involving more-skilled others (peers, older children, and adults) in supporting and facilitating children's mathematics learning. The importance of helping children learn to communicate their thinking and reasoning mathematically cannot be underestimated. More research is needed to monitor the impact of numeracy initiatives on teachers and students, particularly over the longer term. There are some important questions to consider such as whether or not counting should continue to be emphasized so heavily in the early years, or whether students would benefit from more experiences with comparison of quantities and other measurement activities (see Sophian, 1987, 2004, 2007, 2008). Evidence suggests that the chal-

lenges of sustaining the benefits of the numeracy initiatives are many. The reform process is a long and difficult one. It will take time and commitment to bring about the kind of deep and lasting change that mathematics educators envisage for the future.

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