Chapter One: Background to the Project

Introduction

Changes to the National Administration Guidelines, which took effect from July 2000, seek to ensure that schools give priority to achievement in literacy and numeracy, especially in the early years of schooling.

> *Each Board, through the principal and staff, is required to … develop and implement teaching and learning programmes … giving priority to student achievement in literacy and numeracy, especially in years 1–4.* (National Administration Guideline 1 i (b))

This priority followed from the 1998 announcement by the New Zealand Government of a national goal for literacy and mathematics:

> *By 2005, every child turning nine will be able to read, write, and do maths for success.*

The United Kingdom and Australia have given similar priority to literacy and numeracy. In Australia, the target is that "every child commencing school from 1998 will achieve a minimum acceptable literacy and numeracy standard within four years" (DEETYA, 1998). One of the first acts of the Labour Government in the United Kingdom in 1997 was to announce national standards for literacy and numeracy. These were:

- *for 80% of 11 year olds, by 2002, to achieve the standards expected for their age in English, i.e., Level 4 in the National Curriculum tests; and*
- *for 75% of 11 year olds, by 2002, to achieve the standards expected for their age in mathematics.* (Reynolds, 1998, p. 4)

The New Zealand goal followed a decade of reports that highlighted concerns over the achievement of New Zealand students in mathematics. The reports of both the Second (SIMSS) and the Third (TIMSS) International Mathematics and Science Studies showed that the overall levels of mathematics achievement of students aged nine and 11 were lower than in almost every other western country surveyed. At the equivalent of year 5, students in 16 countries achieved at significantly higher levels in mathematics than in New Zealand, five countries showed no significant difference to New Zealand, and students in four countries achieved at significantly lower levels. Of particular relevance to the current project is the fact that year 4 and year 8 students did poorly on the sub-tests involving number skills.

The responsibility for the poor international standing of our students has been widely attributed to the lack of quality in our mathematics teaching (Garden, 1997; the New Zealand Ministry of Education, 1997a; the New Zealand Ministry of Education, 1997b; and the Education Review Office, 2000).

The following sections in this chapter seek to set the scene for the implementation of the CMIT pilot project in New Zealand. There is little doubt that one major impetus of the project was to improve the number learning of New Zealand children through a professional development programme, in which teachers were expected to reflect critically on their own mathematical pedagogy and content knowledge.

The Acquisition of Number Concepts

> *Teachers need to understand the interconnectedness of mathematics concepts and possess a good "mental map" of pupils' lines of development in order to teach numeracy effectively.* (Askew, 1997, p. 115)

Over the last twenty years, we have learned a great deal about young children's understanding of basic number concepts and how they come to develop these ideas. Based on the research of Carpenter, Wright, Young-Loveridge, Steffe, and others, we have been able to map out in some detail how basic number concepts develop in young children. This section reviews this research and, in particular, the development of learning frameworks or models that identify the key constructs of number understanding.

Since the late 1980s, there has been compelling evidence to suggest that many New Zealand children are under-challenged in mathematics in the first year of school, particularly in the area of number. The Young-Loveridge (1989) study in New Zealand involved an interview-based assessment of 81 children who were beginning school and, one year later, asking their teachers whether they had taught particular concepts during the preceding year. Young-Loveridge observed that:

> *The fact that large numbers of children were taught certain concepts (e.g., rote counting, enumeration, pattern recognition, ordinal numbers, numeral recognition) even though they already knew them, but were not taught addition and subtraction, which they could also do, is a finding which is consistent with the ideas that the curriculum is not well matched to the skills of the children.* (p. 60)

Young-Loveridge's research also highlighted a distinction between what children learn and what children are taught, stating that "certain skills were learned over the first year of school by considerable numbers of children even though they had not been taught these skills by their teachers" (p. 56).

Research reports from Wright (1994) and Aubrey (1993) similarly suggest that the mathematics taught in school-entry classes in Australia and the United Kingdom is below where many of the children are operating.

> *The demonstration of such early competencies poses challenges to the conventional reception class curriculum which follows a sequence of sorting, matching and classifying, joining and separating sets, counting and ordering, recognising and writing numbers 0–10, where simple mathematical relationships may be demonstrated through the use of concrete material. … [R]eception-age children clearly enter school having acquired already much of this mathematical content.* (Aubrey, 1993, p. 39)

At least part of the reason for this mismatch between classroom programmes and children's knowledge is a limited understanding of the development of number concepts in young children.

A number of researchers (Fuson, 1992; Carpenter, 1999; Jones et al, 1996; Wright, 1998; and Young-Loveridge, 1999) have identified a range of key concepts in their attempts to identify frameworks or models of early number development. As Fuson states, there are many similarities and interrelationships in the frameworks developed by these researchers:

> *The work on counting and cardinal conceptual units …, cardinal conceptual operations …, and cardinal conceptual structures … was stimulated by Steffe and is a summary of his work and my own related work.* (p. 250)

In Steffe's (1992) framework, descriptions of children's strategies are used to explain the stages of number development, as illustrated in the following quotation, in which Steffe describes figurative counting as:

> *… quite distinct from a child simultaneously putting up four fingers and then three fingers as replacements for the hidden items, and then taking the fingers as a collection of perceptual unit items for counting. This latter coordination of finger patterns and the counting scheme is within the province of children with perceptual counting schemes.* (p. 89)

The research of Jones et al (1996) provides a framework for the development of children's numerical thinking that spans the period from pre-place value and initial counting to the understanding of three digit numbers. The framework, which consists of five levels across the four key constructs of counting, partitioning, grouping, and number relationships, draws on Steffe's notions of numerical composites and abstract composites. As this framework spans a longer period of children's learning, it has fewer levels or stages than the Learning Framework for Number that underpins CMIT.

An important outcome of the constructivist teaching experiments conducted by Steffe and colleagues (1992b) was the development of psychological models to explain children's numerical thinking and its construction and development over time. Wright (1998) has adopted many of the notions within these psychological models in his development of the Learning Framework for Number. For example, the stages described as perceptual and figurative counting are drawn directly from the work of Steffe. In addition, the diagnostic interview and the use of videotaping in the CMIT project are derived from Steffe's research.

As previously mentioned, the CMIT project is underpinned by the Learning Framework for Number and an interview-based assessment called the Schedule for Early Number Assessment (SENA). These were both developed by Wright (1996a) in the Mathematics Recovery Project. They were then adapted for classroom-based teaching in the CMIT project. The project is discussed in greater depth in the final sections of this chapter.

The work of Cobb et al (1997) is useful in understanding what are called "collections-based" (or grouping-based) and "counting-based" approaches to teaching addition and subtraction with one digit and two digit numbers. The collections-based approach is closely related to the partitioning or part/whole notions which underpin the Learning Framework for Number of the CMIT project.

Young-Loveridge's (1999) developmental framework of numeracy is underpinned by the work of Fuson (1997) and Resnick (1983). Young-Loveridge's framework is structured into four stages: a unitary concept of numbers, a ten-structured concept of numbers, a multi-unit (tens and ones) concept, and an extended multi-unit (hundreds, tens, and ones) concept.

While most of the models or frameworks discussed in this section address the key concepts of counting, number sequencing, numeral identification, place value, grouping, and partitioning, the links between these constructs are less clear. Furthermore, as Higgins (2000) states, it is unclear exactly what features of instruction facilitate the conceptual understanding of these constructs.

The questions of how best to help children acquire number understanding and how the teaching of number understanding links most effectively with the teaching of other mathematical ideas are still being debated. Many educators suggest a broad approach, taking account of children's strategies and providing opportunity for children to develop meaning through reflection, rather than a narrow, lock-step approach that emphasises learning specific skills (Denvir, 1986; Wright, 1996b).

The Professional Knowledge of Teachers

> *The professional development of teachers is accepted almost universally as critical to the advancement of educational effectiveness.* (Bobis, 2000, p. 3)

Bobis' view is based on the rationale that professional development will improve the quality of teaching and, ultimately, lead to better outcomes for students. The adequacy of pre-service training and professional development to prepare teachers to teach mathematics effectively has received considerable attention since the publication of the Third International Mathematics and Science Study. Many commentators have laid the blame for the poor performance of New Zealand children firmly at the feet of teachers (Garden, 1997; the New Zealand Ministry of Education, 1997a, 1997b; and the Education Review Office, 2000).

There is little debate that what a teacher knows is one of the most important influences on what happens in classrooms and, ultimately, on what students learn. What teachers know about mathematics and about students affects all the core teaching tasks. Teachers' knowledge shapes how they select activities and resources, how they present material in class, how they interact with students, and how they assess students' progress. Research confirms that teachers' knowledge of subject matter, student learning and development, and teaching methods is important and critical to teacher effectiveness (Greenwald, Hedges, & Laine, 1996; Hammond & Ball, 1997; and Maher, Davis, & Alston, 1992). While there is reasonable consensus on these components of teacher knowledge, there is little agreement on exactly what comprises each component and on whether they are all equally influential (Fennema, 1992; Ball, 1996; and Higgins, 1999).

In a series of studies, Carpenter and Fennema (1992) found that learning to understand the development of children's mathematical thinking could lead to fundamental changes in teachers' beliefs and practices and that these changes were reflected in student learning. Carpenter et al (1999) found that although teachers had a great deal of intuitive knowledge about children's mathematical thinking, it was fragmented and, as a consequence, did not generally play an important role in most teachers' decision making. To address this problem, Carpenter and Fennema developed Cognitively Guided Instruction (CGI) to help teachers construct conceptual maps of children's mathematical thinking in specific content domains. The emphasis in CGI is on helping teachers to identify the range of strategies used by students to solve number problems and to ensure that their teaching programme builds on what children know.

The term "effective" is used throughout the literature on professional development and, as mentioned earlier, it is widely accepted that the key to improved learning outcomes is teacher effectiveness. An important research project, which was conducted by King's College London (Askew, 1997), aimed to investigate the distinctive characteristics of effective teachers of numeracy. It is one of a small number of projects where effectiveness was defined on the basis of learning gain, that is, teachers were identified as highly effective if the students in their classes achieved a high average gain during the year in comparison with other classes from the same year group. The project involved a sample of 90 teachers who were selected from 11 primary schools in three different localities, and it incorporated data from over 2000 students. The project explored the knowledge and the beliefs that underpinned the practices of the "effective" teachers. The researchers found that what distinguished highly effective teachers from other teachers was a set of beliefs that underpinned a particular series of classroom practices. These beliefs concerned what it means to be numerate, the relationship between teaching and students' learning of numeracy, and which presentation and intervention strategies are effective.

In addition to a well-developed set of beliefs that underpinned their classroom practices, the "highly effective teachers of numeracy themselves had knowledge and awareness of conceptual connections between the areas which they taught in the primary mathematics curriculum" (Askew, 1997, p. 3).

Teachers need to understand the connectedness of mathematics concepts and possess a "good mental map of pupils' lines of development" (Askew, 1997, p. 115). Bobis (2000) elaborates on the notion of a mental map:

> *By mental map, it is meant that teachers understand certain stages of development that children progress through, say, in regard to their strategy use … Knowledge of such strategy development allows a teacher to identify where a child is "at" and to know where a child may need assistance to progress to the next stage of development. Thus, a teacher possessed a type of "map" for each child's mathematical development.* (p. 8)

The findings of Askew et al (1997) indicate the importance of:

- a positive attitude towards mathematics;
- a coherent set of beliefs that underpin certain classroom practices; and
- a well-developed understanding of the interconnectedness of numeracy.

The evaluation of Count Me In (Bobis, 1996) in New South Wales focused on the impact of the project on the professional development of teachers. Data from questionnaires and interviews revealed that teachers considered that they had gained knowledge relating to mathematical content, teaching strategies, and how children learn mathematics. Many teachers reported that they changed their classroom practice as a result of their involvement in the project. They also reported that they asked more challenging questions of their children and allowed them more opportunities to explore, discuss, and reflect on their mathematics.

Origins and Aims of Count Me In Too

CMIT is a major, school-based and systemic initiative of the New South Wales Department of Education and Training that focuses on improving the mathematical competencies of children in the first three years of schooling. The project provides "first wave" support for early numeracy by assisting teachers to understand the "relative sophistication of students' solution strategies for relatively simple number problems" (Stephens, 2000, p. 6). The development of CMIT drew substantially on the theory and approaches of the Mathematics Recovery Program (Wright, 1996a). The key parts of CMIT that were taken from Mathematics Recovery are the Learning Framework for Number (in New South Wales this was called the Learning Framework in Number) and the SENA. These are described in more detail below.

In 1996, the New South Wales Department of Education and Training trialled an early number project, at that time named Count Me In (CMI), in 13 schools throughout the state. The basic goal of the project was to develop the knowledge of junior class teachers to better understand children's mathematical strategies and their stages of development from using less sophisticated to using more sophisticated strategies. It was hoped that this improvement in teacher knowledge would lead to the improvement in the mathematical achievement of young children.

The project adopted a school-based model of professional development, with mathematics consultants (facilitators) working alongside classroom teachers. The role of the consultants was to assist teachers with the implementation of the Learning Framework in Number that underpinned the CMI project. Teachers needed to be able to assess the mathematical development of children and then select developmentally appropriate learning experiences.

The evaluation of CMI showed that the programme was a success (Bobis, 1996). Open-ended questionnaires and semi-structured interviews revealed that the teachers considered that they had increased their knowledge and understanding of mathematical content, of children's thinking strategies, and of how children learn mathematics. They reported that they had changed their classroom practices by allowing their students to take more responsibility for their own learning and by encouraging the children to be more reflective. The report found that 90% of the students had progressed in their numerical development, as indicated on the SENA. While almost all children made progress in the project, it was generally the more academically able who made the most progress.

In 1997, the project was renamed Count Me In Too (CMIT) and extended to include 53 schools and 40 consultants. The 1997 evaluation of CMIT focused on the degree of agreement between teachers when judging the arithmetical ability of children on the SENA (Bobis, 1997). Results showed that, while there was some degree of inter-rater variability on the Forward Number Word Sequence (FNWS), the Backward Number Word Sequence (BNWS), and Numeral Identification (NID) aspects of the SENA, it was not significant. While teachers were found to be competent in interpreting behavioural indicators that were easily detected, such as finger counting, the majority did not engage in detailed searches for less overt clues. Bobis (1997) suggested that teachers needed training to take account of less overt behavioural indicators.

The third evaluation of CMIT in 1998 examined the impact of the project on the mathematical achievement and self-concept development of kindergarten and year 1 children. The children who took part in the project performed significantly better than the control group on all aspects of the SENA post-test, except for the BNWS. There were no obvious relationships between the children's self-concepts and their achievement on the SENA.

CMIT was first introduced in New Zealand as part of a centrally funded professional development contract that was delivered by the Auckland College of Education. The contract incorporated frameworks of number understanding drawn from Wright's Mathematics Recovery Programme and CMIT. The success of the Auckland contract and the response to CMIT presentations at a hui for mathematics advisers (Wellington, April 1999) and a series of half-day teacher seminars held subsequently led to the year 2000 pilot implementation.

Description of the Learning Framework

The initial Learning Framework in Number was developed for the CMI project in 1996 by Bob Wright. It drew widely on the work of Les Steffe and colleagues from the University of Georgia, USA; Paul Cobb and colleagues from Vanderbilt University, USA; and Bob Wright's colleagues from the Southern Cross University, Australia (New South Wales Department of Education and Training, 1999). In 1997, the Learning Framework in Number was expanded to include sections on concepts of early multiplication and division.

The Learning Framework for Number adopted by the New Zealand CMIT pilot project includes developmental progressions in five aspects of early arithmetical knowledge. These five aspects relate to a child's:

- level of sophistication in counting and in other strategies to solve relatively simple addition and subtraction problems – the Stages of Early Arithmetic Learning (SEAL);
- facility with forward number word sequences (FNWS);
- facility with backward number word sequences (BNWS);
- ability to identify numerals (NID); and
- understanding of tens and ones (Base 10).

Appendix A contains an overview of the Learning Framework for Number that was used in the New Zealand CMIT pilot project.

Description of the Schedule for Early Number Assessment (SENA)

The SENA, which has been refined over a number of years, has been used extensively by teachers and researchers to assess the early arithmetical development of young children (Wright, 1996a). It was used by teachers in New South Wales to monitor the arithmetical development of their students throughout CMI and CMIT. In the New Zealand pilot project, the SENA involves presenting 49 tasks in an individual interview with the child. The role of the teacher is to elicit a child's most sophisticated strategy and then determine where each response is categorised within the Learning Framework for Number. Having teachers assess and monitor the development of children through the SENA interviews is an integral component of CMIT. The teachers use the initial and the subsequent assessment to make decisions regarding which learning experiences are necessary to help individual children and groups of children to advance through the stages and levels of the Learning Framework for Number.

A copy of the SENA interview used in the New Zealand CMIT pilot project is contained in Appendix B.