Intervention in Young Children's Arithmetical Learning: The Development of a Research-based Mathematics Recovery Program.

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An applied research project in the area of intervention in young children's arithmetical learning is described. The project draws upon current research into young children's mathematics learning, in developing an intervention program which, in organisational terms, has much in common with the Reading Recovery program. The project is collaborative with school systems and its outcomes will include specialised professional development courses for teachers. This paper includes a discussion of the Reading Recovery program, puts the case in favour of early intervention in mathematics, and gives an overview of the theoretical bases of the intervention program.

Both within Australia and overseas, school education systems are increasingly seeking ways to improve children's learning of mathematics in order to provide children with more opportunities for success in mathematics and to improve children's attitudes to the learning of mathematics (A National statement on mathematics in Australian schools, 1989; Curriculum and evaluation standards for school mathematics, 1989; Cockcroft Report, 1983). At the same time, governments are increasingly looking to education in mathematical, scientific and technical fields to provide a basis for economic recovery and renewal.

Early intervention in literacy learning. In the area of literacy education many school systems have established programs of early intervention. Reading Recovery (e.g. Clay, 1979), arguably the most successful of these programs (Pinnell, 1989; Pinnell, Fried & Estice, 1990; Pinnell, Lyons, DeFord, Bryk & Seltzer, 1991; Gaffney & Anderson, 1991), originated in New Zealand in the late 1970s (Clay, 1987) and has been adopted nationally in that country. In the last four years Reading Recovery has been adopted by schools in Australia's three eastern states and in the ACT, and was recently the focus of a front-page article in the national press (Bita, 1991, Sept. 3, p. 1). In 1991 the Australian federal government allocated $5.5 million to "the national development of a range of Early Intervention strategies for use by teachers in helping junior primary school students with learning difficulties in literacy" (Australia's language– policy information paper, 1991, p. 6). Most recently, Reading Recovery has spread to the US, Canada and Britain. In the US and Canada, Reading Recovery programs have been established in over 500 school districts across 34 states and two provinces, and in the UK, three million pounds has been allocated to the introduction of Reading Recovery in inner-city schools (The Running Record, 1992). In contrast, an extensive literature search and discussions with leading mathematics education specialists both within Australia and overseas indicate that there are virtually no early intervention programs focusing on mathematics.

Some features of the Reading Recovery program. According to Clay, "Reading Recovery is a prevention strategy designed to reduce dramatically the number of children with reading and writing difficulties in an education system" (1987, p. 36). Children in the Reading Recovery program are taught in a one-to-one withdrawal situation for a half-hour per day, five days per week, by a specialist Reading Recovery teacher. Children participate in the program for up to 20 weeks. Reading Recovery teachers undergo a year-long professional development course which includes theoretical and practical training. Children eligible for the Reading Recovery program are those who, on reaching six years of age, are identified as being in the lowest range of ability level (typically lowest 15%) for their grade level. A child exits the program when he or she "shows evidence of an independent, or self-extending system for reading and can read material typical for his [or her] class, … making room for another student" (Pinnell et al., 1991, p. 3).

Evaluations of Reading Recovery Programs

An evaluation in New Zealand. Glynn and others (Glynn, Crooks, Bethune,

Ballard, & Smith, 1989) completed a government-commissioned evaluation of the implementation and impact of the Reading Recovery program in New Zealand schools. Glynn's report seems particularly useful for the insights it provides into the many facets of New Zealand's Reading Recovery program, rather than specific findings. Included in their recommendations is
that further research be conducted on the effectiveness of individual aspects of the Reading Recovery programme, and on the benefits of some of the modifications to existing practices which are suggested in this report. The Reading Recovery program has very laudable and almost universally supported goals, and improvements in the achievement of those goals are well worth further effort (1989, p. 134).

This support for the goals of Reading Recovery can be taken as support for research into similar approaches in early childhood mathematics.

A U.S. evaluation of the effectiveness of early intervention in reading. A recent large-scale evaluation conducted in Ohio, investigated the significance of two important features of the Reading Recovery program, viz, the year-long training program for teachers, and individualised instruction for students. The study involved 40 schools, 403 students, and extended over a 70-day teaching period. Four instructional approaches were evaluated: (i) Reading Recovery; (ii) a modified version of Reading Recovery in which teachers underwent a two-week training session rather than the year-long training program; (iii) a program which used direct instruction to teach reading skills; and (iv) a program also taught by fully-trained Reading Recovery teachers, but which was distinctive because it involved small-group tutorials rather than individualised teaching. The study found that Reading Recovery was significantly more successful than the other three intervention programs, and that its success is attributable to four separate and necessary features. With respect to early intervention in reading, three of these are distinctive to Reading Recovery, viz, the framework of instructional activities, the nature of the teacher-student interactions, and the teacher-training program, and the fourth is individualised instruction. This study established the importance of the distinctive teaching methods of Reading Recovery as well as its organisational features. There are important similarities between the current Maths Recovery program and Reading Recovery, not only in organisational terms, but also in theoretical orientation. For these reasons the positive results of the Ohio study can be taken as an important indicator of the potential for success of the Maths Recovery program.

The Case for Early Intervention in Mathematics

Factors in support of early intervention in children's mathematics learning include: (a) the wide variation in the arithmetical knowledge of young children of similar ages or in the same class (discussed below); and (b) the groundswell of support for endeavours to improve children's learning of mathematics, to provide children with more opportunities of success in mathematics and to improve children's attitudes to the learning of mathematics. Considering the support by education systems for early intervention in literacy learning and the absence, both within Australia and overseas, of attempts to establish early intervention programs in mathematics, the development of a research-based mathematics recovery

program seems warranted. Early intervention in reading is justified because "what children at risk really need is to immerse themselves in … functional, meaningful experiences … as early as possible. … Our recent experience … confirms the power of providing holistic experiences to children early in their school careers" (Pinnell et al., 1989, p. 182-3). Pinnell's arguments for Reading Recovery seems to apply equally well in the case of mathematics.

Variation in children's arithmetical knowledge. Wright used the label "three-year difference" for the observation that, within a given Kindergarten class, "one child, before the age of four, has acquired arithmetical knowledge that the other child will not acquire before the age of seven" (1991c, p. 1). In classrooms where there is a particularly wide range of abilities it is very difficult for the teacher to give the necessary teaching time to the least advanced, and also to cater for the average and more advanced children.

Why Year One as the level for intervention? It seems reasonable to suggest that intervention in arithmetical learning should occur as early as possible. The children who do benefit significantly from an intervention program should be given the chance to do so sooner rather than later because one or two more years of unproductive participation in the regular class program is likely to increase their experience of failure in mathematics and there will be a much greater gap to overcome. Consequently the most appropriate intervention years are Kindergarten or Year One. I do not favour intervention in the Kindergarten year because it is the transition year from home to school during which children are gradually inducted into the culture of schooling. Kindergarten children are much less likely to be accustomed to being "taught", particularly in a one-to-one situation. Additionally it is conceivable that, during the Kindergarten year, some children who have acquired little of the more formal mathematical language and related arithmetical knowledge at the beginning of the school year nevertheless are, able to make substantial gains in their mathematical knowledge and learn successfully during their first year of school and beyond.

Theoretical Bases of the Maths Recovery Program

The theoretical bases of the Maths Recovery program are grounded in Steffe's extensive investigations of young children's arithmetical learning (e.g. Steffe, von Glasersfeld, Richards, & Cobb, 1983; Steffe & Cobb, 1988) and related work by Wright (e.g. 1989; 1991a; 1991b; 1991c). An extensive overview of major features of the theoretical models of Steffe et al. is readily available (Wright, 1991a; 1991b; 1992; in press). Steffe's methodological approach – the constructivist teaching experiment (e.g. Steffe, 1991), features (a) selecting children who were regarded as the least advanced at their class level; (b) withdrawing these children from their regular class several times per week, for individual teaching sessions; (c) teaching children in such settings for extended periods – one or two school years. Videotaping of interviews and teaching sessions is a key investigative tool of this methodology.

The major goal of Steffe's investigations is to better understand the

learning processes that children use in problem-centred contexts, rather than intervention. Nevertheless, the models and procedures which resulted from those teaching experiments are highly appropriate as a basis for the Maths Recovery program. This is particularly so because the children who participated in the teaching experiments were selected because their arithmetical knowledge was significantly less advanced than that of their classmates. Available from the work of Steffe et al. are research-based models of the development of young children's arithmetical knowledge, associated learning activities for children and associated teaching strategies which are particularly appropriate for use with an individual child. Emphasised in the work of Steffe et al. are: (a) coming to understand the meanings and strategies that a child generates and uses in problem-centred arithmetical contexts; and (b) using such understandings to determine teaching situations and related learning activities that are likely to result in the child creating more sophisticated meanings and strategies, and associated advances in arithmetical knowledge.

Application to early intervention. The application of the results of the work described above to early intervention was inspired by the Reading Recovery program. There are three organisational features of Reading Recovery which have obvious parallels in the Maths Recovery program: the focus on the second year of school (i.e. children around 6 years of age); the extensive training program for teachers; and individualised teaching of children over an extended part of the school year. Beyond this, there is significant common ground in the theoretical underpinnings of Reading Recovery (e.g. Clay, 1979; Pinnell, 1989) and Steffe's pioneering investigations of young children's arithmetical learning. Thus, important in the work of both Clay and Steffe, is an emphasis on understanding children's meanings and strategies, and the explicit rejection of approaches which focus on "teaching skills in isolation" (Pinnell, 1989, p. 180). Together, the work of Clay and Steffe signals a shift from generalist theories of success or failure in learning, to more powerful, subject-specific theories (see also Cambourne, 1990).

The Pilot project. A pilot Maths Recovery project was completed by the author during 1991. This involved one teacher, who taught four children individually, for approximately 30 minutes per day, for four weeks. The four children were selected from a total of 15 who were nominated by their class teachers, and individually interviewed by the author. The pilot project was judged to be highly successful in terms of the gains made by the children, the project teacher's development as documented in her journal, and the class teachers' perceptions of the progressions of children who participated in the program. The pilot project represents a very important first step in the establishment of an early intervention program in arithmetical learning. Nevertheless, it is likely that, for many children, a teaching cycle longer than the four weeks of the pilot program is required. In the case of Reading Recovery teaching cycles are of up to 20 weeks' duration. Additionally, the theoretical models of young children's arithmetical learning which will be applied in the intervention program predict that teaching cycles of up to 20 weeks may be required.

Overview of the Maths Recovery Project

Maths Recovery is a three-year project which commenced in July 1992 and will involve at least 20 schools. The project staff includes a researcher, a research associate seconded from a regional school system, a research assistant, and a teacher in each of the 20 schools.

Aims of the project. The major aim of the Maths Recovery project is: (a) to establish an accredited, year-long, professional development course for teachers; (b) which has as its focus a program of early intervention in arithmetical learning; (c) through which selected children at the Year One level are placed in a long-term, individualised teaching program; (d) and the purpose of which is to advance their arithmetical knowledge to a level at which they are likely to learn successfully in a regular class. Other aims are: (a) to develop accredited units of study at the Masters level, which serve to prepare specialists to deliver the professional development course to teachers; (b) to develop a series of three 50-hour accredited professional development modules aimed at classroom teachers, and which focus on effective classroom teaching strategies for addressing learning difficulties in mathematics in the K-3 range; and (c) to prepare a range of educational resources (e.g. booklets, teachers' guides, journal articles), which focus on addressing learning difficulties in mathematics in the K-3 range, and which are aimed at audiences such as: parents, classroom teachers, school administrators, consultants, and researchers.

First Year of the Project

In its first year the project involves six teachers, one in each of six schools working half-time on the project for the second half of the year. One of the major objectives of the first year is to provide detailed information about the necessary contents of the proposed professional development course for Maths Recovery teachers. Additionally, the progress of children who participate in the project will be documented and compared with non-participating counterparts.

During the third term of the school year the six participating teachers were introduced to the theoretical bases referred to earlier and were taught interview and analysis methods which have the purpose of assessing young children's numerical knowledge. In each school 15 Year One children were selected in consultation with Year One class teachers for interview by the Maths Recovery teacher. From eight to twelve of these – depending on the school, are regarded as being among the least advanced of the Year One cohort, in their arithmetical knowledge. Of interest in this study are the advancements in arithmetical knowledge of Year One children of all ability levels and, for this reason, children other than those regarded as being among the least advanced were included in the group of non-participating counterparts. On the basis of analyses of interviews, four of the children in each school were selected for an eight week teaching cycle during the fourth term. For each child, the interview process results in an arithmetical profile which includes a counting stage and levels of numerical development (Wright, 1991c; in press), and related descriptions of children's arithmetical procedures (Steffe & Cobb, 1988). A key factor in the selection of participants was variety across the group of 24 participating children in numerical profiles.

During the eight-week teaching cycle, the participating children will be

withdrawn from their regular class for 30 minutes per day, for four days

per week. On the fifth day the project teachers and project staff will meet to learn more about the underlying theoretical models, confer on individual cases, plan specific teaching activities, review the progress of the program, and collaborate on future directions. At the end of the teaching cycle all 90 children will be interviewed again and the progress of the 24 participating children will be compared with that of their 66 counterparts. Children's progress is described in terms of qualitative advancements in their arithmetical knowledge. These advancements are determined by a comparison of the child's arithmetical profiles at the beginning and end of the teaching cycle and, in some cases, by a consideration of reorganisations of arithmetical knowledge (e.g. Steffe & Cobb, 1988) observed during the teaching cycle. Throughout the project each of the participating teachers and project staff will document their perceptions of the project and significant events in a professional journal.

Videotaping of interviews and teaching sessions. All of the initial and final interviews and approximately 50% of the teaching sessions are being videotaped. The reasons for this include: the videotapes will be reviewed in order to plan the future teaching sessions; they provide a basis for collaboration among the members of the project team; they serve to document the progress of the children and provide data for project evaluation, and they provide material which can be incorporated into professional development packages for teachers.

Second and third years of the project. The first half of the second year will focus on data analysis and reporting, and the development of a prototype professional development course which will be undertaken by a new group of six teachers in the second half of the year. The third and final year of the project will involve a teacher in each of 10 schools working half-time on the project for the whole school year. Because in this year the program will be operating for a full school year, the question of children's discontinuation will be more significant than in the first two years where teaching cycles will be considerably shorter than 20 weeks. In general terms children will be discontinued in the program when it is judged that they are able to learn successfully in their regular class.

Research Questions

During the course of the project the following research questions will be addressed.

1. What advancements in arithmetical knowledge are made by the participating children and how do these compare with those of their non-participating counterparts?
2. How useful are the theoretical models of young children's arithmetical learning for specialist teachers involved in a mathematics recovery program?
3. What changes occur in the beliefs and practices of the participating teachers during their participation in the professional development program?
4. What implications or benefits does the program have for current

classroom practices associated with teaching and learning mathematics in the K-2 range?

5. What influences does the project have on the beliefs and practices of colleagues of participating teachers?

6. What implications does the program have for early childhood mathematics curricula?

Conclusion

Ultimately, the usefulness of a Maths Recovery program will be judged by a consideration of its costs and benefits. The program described in this paper has received substantial resource commitment from regional government and Catholic school systems and the Australian Research Council as a collaborative research project. This collaboration embraces planning and conducting of the research project, as well as funding. The project can be regarded as an expansion to research, of an extensive and successful program of collaboration over recent years which to date, has focussed primarily on teacher professional development and also pre-service teacher education (e.g. Johnson, 1988; Directions and strategies for teacher education. 1990; Treyvaud & Davies, 1991).

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BITS CUT OUT

Recent research in early childhood mathematics has documented a wide range in the ability levels in mathematics of children in the first two years of school. Additionally, in the first two years of school, amongst teachers there is, to some extent at least, a lack of awareness of the differences

in ability levels in mathematics, and associated with this, insufficient assessment of children's mathematical abilities.

has recently been established in government and Catholic school systems of the North Coast Region of NSW

Reading Recovery is the name of an early intervention program in reading that originated in New Zealand through the work of Dr. Marie Clay (e.g. Clay, 1979) and was widely adopted by the Department of Education in that country. The program has been used in Victoria and Queensland, as well as in some states in the U.S. (Pinnell, Fried & Estice, 1990) and is being considered for introduction into government and non-government schools in the North Coast Region.

In this program children who, when they reach six years of age, are identified as being in the lowest range of ability level (e.g. lowest 15%), are withdrawn daily for 30 minutes of individual instruction, for between 12 and 20 weeks. Children exit the program when they reach the average level of reading ability for their class.

Part C – Theoretical Basis of the
Teaching Framework

The teaching framework which is proposed draws on the work of the research group headed by Professor Les Steffe at the University of Georgia, and related work undertaken in the North Coast Region by the project leader. Steffe's group has published extensively in the area of children's early number learning (e.g. Steffe, von Glasersfeld, Richards, & Cobb, 1983; Steffe & Cobb, 1988). Nevertheless, their theoretical models and approaches, while being generally applicable, have not been applied in an early intervention program.

The project leader completed his doctoral work under the supervision of Professor Steffe and has published extensively in the area of early childhood mathematics (see the list of relevant publications). His recent contributions include a 30-page research report commissioned by the Victorian Ministry of Education on the development of young children's counting.

Second, there are vast differences in the amount and nature of mathematical experiences that children have in their preschool years. Some children, at the beginning of Kindergarten year, have acquired little of the more formal mathematical language and related number knowledge. There is some evidence from the investigation described above (Wright, 1990b, p. 8) that at least some of the children who have had significantly fewer mathematical learning experiences, and therefore are less advanced when they begin the Kindergarten year, will nevertheless catch up during the Kindergarten year. Thus it seems that, during the Kindergarten year there may well be a reasonable amount of reordering among the children. A second and related factor contributing to this apparent reordering could be associated with

the nature of the typical mathematics program in the Kindergarten year. The program, particularly in the first three to six months, may well be more suited to the less advanced children.

Goal

To develop an early intervention program in number learning through which selected children at the Year One level are withdrawn from their regular classroom to undertake an individual learning program.

The children would be selected because they have not developed the necessary knowledge to learn the number topics typically taught in Year One, e.g. two and three digit numeration, addition and subtraction. The purpose of the program is to bring about significant advances in their knowledge of the number topics typically taught at the Kindergarten and Year One levels. This will be undertaken in the belief that, if the children are returned to their regular class when they have achieved the number knowledge typical of their classmates at that time of the school year, there is a much greater likelihood that they will continue to learn successfully in a regular class.

Objective

The program will result in the development and implementation of an exemplary program of intervention in the number learning of Year One children whose development of number concepts is identified as significantly less than that typical of children beginning Year One, to the extent that the children are unlikely to experience a reasonable amount of successful learning in their regular class.

Guiding Principles

The early intervention program will:

(1) be based on a specific teaching framework (see Part B);

(2) take account of established and sound teaching practices, as well as current research-based knowledge of young children's mathematics learning;

(3) use the teaching framework as a basis to develop procedures for assessing the number knowledge of children at Year One level;

(4) use the teaching framework to generate teaching procedures which are likely to result in significant advances in the number knowledge of Year One children selected for a program of intervention.

Overview of the Teaching Framework

A more detailed description of the framework is provided in Part C and in Wright (in press b), a copy of which is available on request from the Project Leader.

he Chief Investigator has recently completed a critical review of current curricula in early childhood mathematics (1992, in-press-b), a study of the beginning knowledge of children in the first year of school (1991c), and has documented the development of numerical knowledge in the first two years of school (1992, in-press-a).

In a study of the gains during the first year of school, in number knowledge by 81 New Zealand children, Young-Loveridge (1989) found that

"high scorers made smaller gains than … middle or low scorers" (p. 59) and concluded that "the relationship was due in part to the match between the school mathematics programme and the existing skills of less knowledgeable children being better than that for children who came to school already knowing a great deal about numbers" (p. 60). By way of contrast Wright's (in press) study did not find evidence to support the notion that the less advanced make greater gains than the more advanced.

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