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Early Intervention in Mathematics

What does a child need to know to understand number concepts? This article is an account of a research study which aimed to assess the effectiveness of an early year's intervention in relation to the number element of the revised mathematics curriculum. It considers the main differences between traditional approaches to teaching number and an approach which uses counting, matching and discussion, where numbers are not taught individually, but learned in the context of other numbers, on number lines and in games. The results point to positive learning outcomes in number concept development and in social skills for children who took part in the intervention.

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INTRODUCTION

In Ireland, the discrepancy between the achievement in mathematics of pupils in schools designated as disadvantaged and in non-disadvantaged schools has been a concern for many years (Greaney and Close, 1989; Shiel and Kelly, 2001; Weir 2003; Department of Education and Science (DES), 2005; Shiel, Surgenor, Close and Millar, 2006). The *National Assessment of Mathematical Achievement* in 2004 reported that 26% of pupils in fourth class in schools designated as disadvantaged had achievements levels under the 10th percentile on a standardised mathematics test compared to 8% in non-designated contexts (Shiel et al.). Internationally, there is evidence to suggest that there can be a three year differential in achievement levels between children in early mathematics knowledge as they begin school (Griffin, Case and Siegler, 1994; Mullan and Travers, 2007). The Cockcroft report (Cockcroft, 1982) found that in a class of eleven-year-olds there is generally likely to be a seven-year range in arithmetical ability. In this context the importance of early intervention is highlighted.

Early Intervention

Early intervention is a key element of inclusion policy. The low levels of early intervention are a cause for concern. As part of a wider study on learning support

in mathematics Travers (2007) surveyed teachers and found that only 20% reported having an early mathematics intervention programme in place. One of the issues influencing this may be attitudes to early assessment. Travers found that over 27% of the teachers either agreed or strongly agreed that Junior Infant pupils should not be assessed, with a further 28% being undecided on the issue. Identifying which pupils are at risk of future difficulties in mathematics must involve assessment that is child friendly, sensitive and a positive experience for the pupil. The success of schools implementing early intervention projects utilising such assessment needs to be further promulgated. Since the introduction of the general allocation model in Irish primary schools in September 2005, 92% of schools now provide some support in mathematics with 77% of learning support/resource teachers providing both literacy and mathematics support (Travers). Thus, the opportunities for early intervention in mathematics have increased in recent years.

Number Worlds Intervention and Central Conceptual Structure

What does a child need to know about a number in order to understand the concept of that number? Many prominent researchers have addressed this question, the most influential being Piaget (1952). According to Piaget, the development of number was closely linked to the development of logic and conservation and this led to an emphasis on developing the skills of ordering, classifying and matching. Griffin, Case and Siegler (1994) proposed the Central Conceptual Structure to encapsulate all that a child needs to know in order to understand number concepts.

Griffin et al. proposed that children need to have a representation of number that is akin to a mental counting line and that children must:

- **be able to generate the verbal label for each number**
- **understand 1-1 correspondence**
- **understand that each verbal label has a set size associated with it which has a certain canonical perceptual form**
- **understand that movement from one of these set sizes to the next involves the addition or subtraction of one unit**
- **recognise the written numerals 1-10.**

In a pilot study which preceded this research and which dealt with the issue of early mathematical intervention, teachers found that this knowledge was easily turned into teaching objectives (Mullan and Travers, 2007) by using the *Number Worlds* Kindergarten mathematics' intervention games (Griffin and Case, 1997).

Griffin et al. argue that this knowledge is essential to performance on a broad array of mathematical tasks and that the absence of this knowledge constitutes the main barrier to learning arithmetic. If there has not been a heavy emphasis on counting or quantity in early home environments then according to Griffin et al. counting and quantity *should be* the core focus of the school mathematics curriculum. Counting is one of the strands of the revised mathematics curriculum (DES, 1999) but it is not included in the early mathematical activities of the curriculum.

The purpose of the research study undertaken by the authors was to assess the effectiveness of early intervention in mathematics teaching in relation to the number element of the revised mathematics curriculum. The potential of the programme to facilitate a team approach to in-class support in mathematics and involve parents was also a key focus of the study.

METHODOLOGY

The intervention used in this study was the *Number Worlds* programme (Griffin and Case, 1997). The study set out to assess academic and social outcomes of the programme in designated disadvantaged schools, and to assess the *Number Worlds* programme's potential to facilitate more in-class support work from learning support/resource teachers and parents. This necessitated a multi-method study. To assess the academic outcomes a quasi-experimental design was used. Quantitative and qualitative data were used to ascertain the key elements across different contexts that defined the effectiveness, or otherwise, of the programme. The sample of schools involved in the study was purposive. Seventeen classes in eight schools (Schools 1-8) were assessed on the *Number Knowledge Test* (Griffin et al., 1994), a validated test of early number ability (Clarke and Shinn, 2004). Schools 7 and 8 were not designated as disadvantaged. Schools 1-6 were designated as disadvantaged and nine classes in Schools 1-6 (Classes 1, 2, S2, 3, 3a, 4, 5, 5a and 6) were taught number concepts using the *Number Worlds* programme while five control classes in these schools (Classes 2a, S2a, 4a, 6a, and 6b) and three control classes in Schools 7 and 8 (Classes 7, 7a and 8) were taught number concepts as advised in the primary school mathematics curriculum. Class size and mean age of children in each class can be seen in Tables 1 and 2 respectively.

Table 1: Class sizes

Class	1	2	2a	S2	S2a	3	3a	4	4a	5	5a	6	6a	6b	7	7a	8
Class Size	23	25	22	20	22	17	15	20	18	18	17	20	19	19	31	31	27

Table 2: Mean age of children in each class

Group	1	2	2a	S2	S2a	3	3a	4	4a	5	5a	6	6a	6b	7	7a	8
Mean Age	4.5	4.6	4.7	5.9	5.9	4.6	4.9	4.8	4.7	4.5	4.4	4.9	4.4	4.6	4.9	4.9	4.9

To assess the impact of the intervention, quantitative data were analysed using ANOVA tests on the pre and post test scores from the *Number Knowledge Test* (Griffin et al., 1994). The percentage increase in the mean score of each class was also tabulated. Group and individual interviews were held with all class teachers and learning support/resources teachers implementing the programme along with a sample of parents. A video analysis of one complete lesson was conducted. Interview data and observations from video analysis were coded and categorised into themes. All teachers received professional development input on the aims of the programme, the psychology of early number development and a video demonstration of a lesson.

In evaluating any intervention, fidelity is a major issue. There is a balance between following a programme exactly as intended by the authors and exercising professional judgment in terms of adapting the programme to the differing complex classroom contexts. Ideally *Number Worlds* lessons should have three parts: the first ten minutes should be spent on whole-class games; the next fifteen minutes should be spent on small group games and the final ten minutes of each lesson should involve the whole class listening while one child from each small group gives an account of what happened during small-group games. Table 3 is a summary of the number of times per week that groups spent on aspects of *Number Worlds* lessons.

Table 3: Aspects of programme covered in each class per week

Class	**1**	**2**	**S2**	**3**	**3a**	**4**	**5**	**5a**	**6**
Whole Class Games	2	2	0	4	4	3	5	5	5
Small Group Games	3	4	3	4	4	3	4	4	5
Language Round Up	0	2	0	0	0	3	2	2	5

There are a myriad of intermingling individual and environmental influences on children's learning. In assessing an intervention in a real-world context it was recognised that not all variables can be controlled. Every effort was made to build

up an accurate picture of the organisation of the teaching of number in all of the classes involved. In this way we hoped to describe the different circumstances in which the programme was implemented and the resulting outcomes.

FINDINGS AND DISCUSSION

Significant Differences

At post-test, the mean percentage increase in *Number Knowledge Test* scores in the intervention groups was higher (74%) than that of control groups (38%). There continued to be differences between the mean scores of children in disadvantage and non-disadvantage status schools. However, significant differences in mean scores that had existed before the intervention had been reduced and were no longer significant.

This was not the case for three of the four control classes in disadvantage status schools whose mean post-test scores continued to be significantly lower than those of the control classes in non-disadvantaged schools. The mean post-test score of one class (2a) was not just significantly lower than those of the classes in non-disadvantaged schools but was also significantly lower than mean post-test scores of intervention classes 3, 4, 5 and 6 in the designated disadvantaged schools.

It is difficult to disentangle the reasons for differences in percentage increases in mean post-test scores. There are many possible influences on children's learning including teacher influences, children's language ability, cognitive ability, illness, parental support and cultural differences. However, it is possible that the higher increase in mean scores of most intervention groups was due to the intervention and specifically to the differences in the ways in which children experienced number in the intervention classes. These differences in children's experiences are outlined in the following sections.

Teaching Methods

The most striking difference between both groups was the way in which numbers were introduced to children. The emphasis in intervention classes was on counting, matching and discussion. Numbers were not taught individually. Children were required to count and sometimes to match sounds, objects, counters and pictures. They learned about numbers in the one to ten range in the context of other numbers on number lines and in games. In contrast, numbers were introduced individually in the control classes. At least one week was spent on teaching the concept of each number. Teachers involved the whole class or groups

of children in clapping, jumping or performing a physical activity a certain number of times. Children sang songs and number rhymes using counters/cubes or a physical activity to reinforce number concepts. After at least one week of making and recording sets of a particular number, children learned to decompose individual numbers into number stories. Thus the emphasis in the control classes was on individual numbers and composition/decomposition of numbers, while the emphasis in *Number Worlds* groups was on numbers in context and in relation to other numbers.

Written Work

A second striking difference between intervention groups and control groups was the amount of written work that took place during mathematics classes. The intervention lessons did not include written work. Children in some intervention classes did written work on days when they did not do *Number Worlds* (Table 3). Control classes did written work almost every day during mathematics lessons. Children drew sets to match numerals and illustrated stories of numbers in copies and workbooks. One teacher (Class7) reported that she followed the workbook page by page because children in junior infants have difficulty finding pages. Teachers of intervention groups commented that when children began to write in workbooks after (and some during) the project, they did not seem to need to be taught how to do workbook tasks:

> *It made any kind of written work kind of a lot easier because they covered all the topics beforehand and…they recognised them (numbers) in a different format (Class S2).*

The ease with which children using the *Number Worlds* programme undertook symbolic work in workbooks may be explained by the fact that children had first learned about numbers enactively as Bruner (1966) suggests should be the case. Our observations in classrooms suggest that there continues to be a heavy reliance on workbook activity in junior infant classrooms, despite the fact that children's use of workbooks has been found to dissipate rather than to intensify the quality of teaching and to reduce opportunities for children to learn (Reynolds and Muijs, 1999). One teacher commented:

> *I think the practical was so important for early maths because so much of commercial schemes, there is so much emphasis on the written and it's the practical that is needed for junior infants (Class 6).*

Group Work and Communication

A third striking difference between intervention and control groups was the amount of group work that took place. Intervention groups spent approximately 50% of each class playing games with four or five other children within a group. During small group games children played together and learned social, communication and game skills from one another. They argued and watched each other to see if anyone was cheating. Their conversation was always about number, about going too far or not far enough, about the number of dots on the dice or the number of jumps to take with counters. Even better, when groups were supervised or "scaffolded" by an adult, all four or five children in the group heard questions such as, "How many more do you need?" or "Do you have enough?". They also heard correct and incorrect answers or sometimes suggested answers themselves because they had a vested interest in correct responses.

Interactive group work was not a feature of control classes. Most teacher-child and child-child communication tended to be in one-to-one settings. When children were working on activities, copies or workbooks, there were opportunities for children to speak to children who were sitting close-by and for teachers to support individuals. However, time constraints and pupil-teacher ratio meant that only a minority of children could benefit from this type of teacher-child interaction.

Adult Support

There was more adult support in most intervention classes than in control classes. Each small group in Classes 4, 5 and 5a was supervised by an adult and the increases in mean scores of these groups were amongst the highest. In other classes (1, 2, 3, 3a and 6) adult support was divided between groups. *Number Worlds* provided a structured way for parents to be involved and adult support facilitated learning about number and about social skills:

> *I think it was brilliant too to involve the parents 'cause sometimes you have some parents who want to be involved but they don't know what to do…it was a way of involving them and it gave those (parents) a structure (Class 4).*

> *Now they obviously, some of the children would get distracted or stop playing or fight…and I found it worked quite well in my class anyway with just two adults (Class S2).*

Unusual Outcomes

The percentage increase in mean scores of two classes (1 and 4a) stand out as unusual. The following points are of interest as they may have influenced scores in these groups.

Class 1, whose percentage increase in mean score (24%) was lower than all other intervention classes, covered fewer aspects of the intervention than any of the other intervention classes (Table 3). The teacher reported that she omitted the language round-up section at the end of the class as she felt that there was a lot of language learning during group work. However, Groups 3 and 3a also omitted this language round-up and their increases in mean scores were 96% and 55% respectively. The teacher also reported that she could have done with more adult help:

> *It was great to have her (special needs assistant)…but I probably could have done with more help. I found it very hard to supervise the other groups – if you were teaching a new game to one group…the others…they'd be fighting about whose turn it was or losing the dice or whatever, you know (Class 1).*

Class 4a, whose percentage increase in mean score (70%) was higher than all control classes was taught by a teacher with a Montessori degree whose teaching methods included lots of play and sensorial materials. One of the principles governing Montessori methods is that concepts should be conveyed to children "not so much through the eyes and ears, but through the child's hands…cognition is born from manual movement" (Lillard, 2005, p. 57). The teacher in Class 4a also borrowed the *Number Worlds* idea of having a number line on her classroom floor from her colleague in Class 4 so that children could jump and count at the same time.

CONCLUSION

This research focused on a mathematics intervention, *Number Worlds*, which taught number concepts in a way that differed from conventional approaches. It is difficult to disentangle the reasons behind the success of the *Number Worlds* intervention. However, we believe there is sufficient evidence to suggest that teachers' emphasis on counting, small group structured play and the deployment of in-class support in a purposeful manner were the key elements which helped to improve children's understanding of early number concepts.

In addition to the main benefit of enhancing children's understanding of number concepts, the programme provided a way for class, learning support and resource teachers, special needs assistants and parents to work in partnership in classrooms. These adults worked unobtrusively with class teachers during the short but central component of the programme, small-group work. The benefit of parental involvement in interventions can be far-reaching because parents who become involved in intervention programmes become better socialisers of all their children and because parents can carry on with the goals of a programme long after it is over (Seitz and Apfel, 1994).

In the years since this research took place (2005/2006) *Number Worlds* has been commercially packaged. It is expensive to buy and the manual has become rather unwieldy. Our intention has not been to promote *Number Worlds* as an exclusive method of intervention but rather to promote the underlying principle of Central Conceptual Structure theory (Griffin et al., 1994) and the methodologies required to teach Central Conceptual Structure. In order to implement these methodologies counting games for small-group work have to be bought or made, adult in-class support is needed and junior infant children need to spend more of their mathematics class-time counting.

The methods we have been using to teach mathematics have been failing many students in designated disadvantaged schools (Greaney and Close, 1989; Shiel and Kelly, 2001; Weir 2003; DES, 2005; Shiel, Surgenor, Close and Millar, 2006). We believe that early intervention and parental involvement will secure better longer term outcomes for children. However, early intervention ought to mean *early* intervention. Glaring differences in children's knowledge of number should be addressed in children's first year in primary school. The value of the programme described in this research is that it involved parents, it was whole-class based and most importantly, it addressed differences at the earliest possible opportunity for the children involved.

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