National Teacher Research Panel
engaging teacher expertise

This summary was commissioned by the National Teacher Research Panel for the Teacher Research Conference 2004, which explored and celebrated teacher engagement in and with research. All conference materials are available at www.standards.dfes.gov.uk/ntrp

A multi-sensory approach to teaching mental arithmetic

Aims of the project

The focus of this teacher-led action research was to construct a programme of multi-sensory teaching activities to develop mental arithmetic capability in children from Nursery through KS1.

Context

The study took place in an Infant School on the South Coast of England, serving a mixed catchment area with one in three pupils on the special needs register.

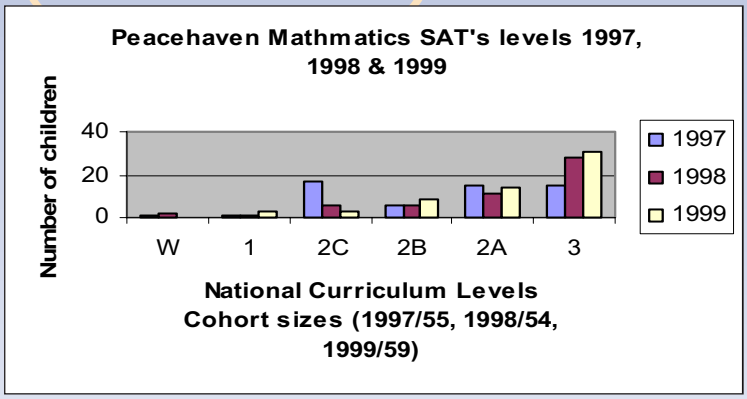
Teachers in the school in collaboration with the University Of Brighton School Of Education carried out a Teacher Training Agency (TTA) Teacher Research Project during 1996-7 to begin to construct in Reception and Year 1 an effective programme of multi-sensory arithmetic activities. An extension of the project in 1997-8 enabled the activity programme to be extended from Nursery to Year 2.

Since the original study there have been further research developments carried out by Brighton EAZ, Bristol Learning Support Service and Downs Educational Trust, investigating the effectiveness of the teaching activities for children with various special needs including Down Syndrome.

Summary of main findings

- Children whose arithmetic had been supported using visual structured imagery during the research project showed a dramatic improvement in attainment in KS1 SATs 1998 in comparison with the results of the previous cohort (1997) whose learning had not been supported by visual structured imagery. Since the study similar levels of attainment have been sustained year on year at the school.

Figure 1



- The programme of teaching activities helps to meet the early learning goals of the Foundation Stage and the KS1 objectives of the National Numeracy Framework.
- Children were drawn to the apparatus and used its structured patterns to show their understanding of number and arithmetic.
- Teachers found the programme of activities easy to follow and found it easy to assess c hildren's understanding by observing and listening to children's explanations as they used the structured apparatus.

Background

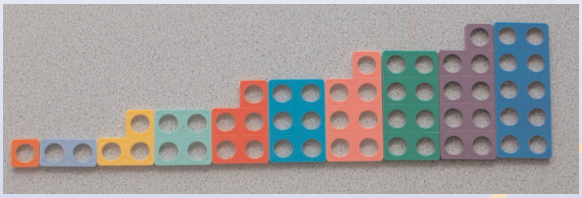
Peacehaven Infant School has a two form entry with 180 pupils on roll plus 25fte nursery class, one third of its pupils is on the special needs register and just over 20% of children qualify for free school meals. Baseline assessment results show many children enter the school with poor language skills.

Prior to 1997 in teaching successive classes we had been aware that many children had not substantially mastered arithmetic. We had used various published mathematics schemes all of which relied on counting as the basis for arithmetic and moved children very quickly from counting towards formal symbols in mathematics. Some children were able to arrive at correct answers without necessarily knowing why. We had felt schemes put an artificially low ceiling on teacher expectations for some children.

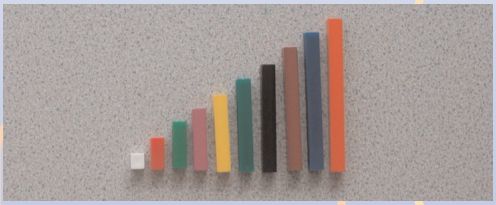
The serendipitous discovery of a copy of Catherine Stern's book Children Discover Arithmetic led us to challenge our pedagogy and explore the use of the visual images originally used by Stern within a structured programme of teaching activities we developed during the project. The activities used shapes and rods and encouraged children to develop a systematic mental imagery of number, to develop mathematical language and to apply their arithmetic to real life problems.

The structured images which we used are shown below:

Shapes



Rods



We wanted children to develop an understanding of number that relates numbers to each other (relational understanding) which could be generalised to solve new problems. Previous methods of solving arithmetic problems by applying learnt procedures and falling back on counting when they met a new problem did not seem effective.

Our research coincided with the publication of the National Numeracy Framework which emphasised mental arithmetic strategies and set high expectations of children's achievement. Paradoxically the Framework did not give specific emphasis to direct teaching of relational understanding and avoided the use of visual structured apparatus, although it expected children to employ relational understanding in mental arithmetic

Throughout the project the research was led by the maths co-ordinator and the headteacher in collaboration with Tony Wing from Brighton University. In the first phase of the research the children were taught by the maths co-ordinator, who was teaching in Year 1, and one Reception teacher. In the extension phase of the research we wanted to see whether the Programme of Activities could be taught successfully throughout the school by non-specialist teachers so all seven class teachers used the programme of activities as the basis for their arithmetic teaching.

Teaching and Learning with the Programme of Activities

Creating a 'mathematics environment'

All classrooms and the Nursery created a visually rich mathematics environment giving number a high profile so that children could see number being used. For example drawers were numbered as well as labelled, storage pots were marked to show how many pencils etc. they should contain, teachers were encouraged to take opportunities to use clocks and calendars and to show numbers in daily use in data handling situations like 'how many children are having a school dinner today? And how many are having a packed lunch?'

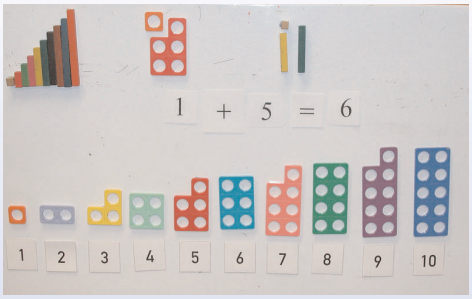
Displayed prominently in every classroom was a large display 'number line', a line with numbers from 0-20 marked at regular intervals, each interval marked by the numeral, the corresponding visual structured image and the number word. (see figure 3). There was also a smaller 'number line' showing numerals from 0-100.

Each classroom also had a mathematics area which included an interactive display offering a variety of independent activities including: counting, numeral recognition games, pattern making, problem solving in terms of puzzles and construction apparatus. Here children could practise what they had learned and make new discoveries.

Teaching Activities

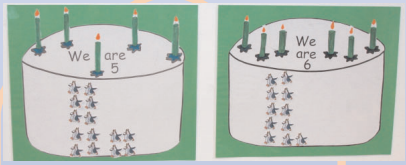
The programme of teaching activities using visual structured apparatus was taught throughout the school in the daily mathematics lesson. The activities were predominantly practical and multi-sensory because they involved the children seeing and feeling the structured images, whilst they were hearing and saying connected mathematical language. The tendency to move too quickly into formal symbols was resisted. The early activities in the programme focused on teaching children the patterns and how each related to other patterns before the numerals were named. Children were not required to record their arithmetic on paper until they had shown understanding in a practical context.

In whole class or focus teaching the structured apparatus was used either on a table top or on a magnetic white board to illustrate teaching points, and children used it independently either individually or in group work



Making connections to real life mathematics

Teachers were encouraged to make connections between classroom teaching activity using the structured apparatus and the 'real world'. For example, if the children were working on addition, they would be invited to make up their own addition story to apply the number bonds they had learnt. When learning about '1 less' in subtraction links might be made with number songs which involve decrease like 'Five little firemen'. When handling data, for example how many children were having school meals and how many were having a packed lunch, counters would be arranged into the Stern patterns to show how many in each data set.



The programme of activities was carefully designed to scaffold children's learning so they were not expected to take on too many new ideas at a time. Each activity built on and extended previous learning. Sometimes familiar activities were revisited with a deeper teaching focus. Inbuilt was the opportunity for children to practise and rehearse what they had learnt. The activities were very simple, for example to practise addition children might throw a number die and then feel in a 'feely bag' for two shapes that made that number. Alternatively they might build a model with the apparatus to represent number bonds of ten. Using rods children might be asked to arrange 1-10 rods in a 'staircase' pattern and then fill spaces with more rods to show all combinations of two rods which make 10.

Findings

The evidence of pre and post testing and observation notes indicated the following findings in terms of learning outcomes:

- The Year Two children's scores in the National Tests at the end of KS2 showed dramatic improvement over previous cohorts' scores (see figure 1). They had developed a range of strategies to solve arithmetic problems, seeing numbers as related 'wholes' and generally did not solve arithmetic problems by counting. Many were able to apply their arithmetic to solve problems.
- With very few exceptions children had developed confident and positive attitudes to maths. Children were drawn to the images and enjoyed working with them.
- Children benefited from frequent opportunities to count ever larger sets of objects. This gave them experience of higher numbers and understanding of the structure of the number system. Teachers found this a useful assessment tool.
- Frequent reminders to use mental imagery - phrases such as 'let your fingers be your eyes' if they were feeling for shapes in a feely bag and 'try to see the shapes in your mind's eye' when they were doing mental arithmetic, were found to be helpful.
- Children were able to write arithmetic quickly and accurately when they had not been asked to record arithmetic until they had understood arithmetic symbols and knew addition and subtraction facts to ten in practical activities. It was found that it was also important that children developed pencil control before recording their number work so the writing process was not laborious for them.

Teachers found the activities were straightforward once they were familiar with the approach. They benefited from time to read and understand the rationale behind the approach. They found the programme of activities and assessment sheet useful in planning and assessment and that they supported appropriate grouping of children for focus teaching and independent work. Teachers found that the imagery also provoked ideas for the pupils on position, action, pattern, colour, shape, odd and even, more and less as well as the value of numbers. In this supportive mathematical context children were helped to understand much mathematical language. Parents recognised their children's success and began to see evidence of their children's understanding of arithmetic at home.

Research methods

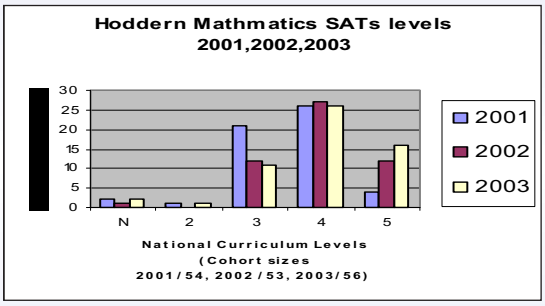
In each class a sample of six children was chosen. To give a balance of age and gender, in each group of six there were three boys and three girls who were autumn, spring and summer born, otherwise the children were randomly chosen resulting in a spread of ability. At the start of each phase of the research we established the starting point for each child on a record of progress that we had devised after looking at several published baseline assessments. During the research period we extended this record of progress to cover the entire Key Stage One curriculum for number and arithmetic.

The record of progress was matched to the programme of teaching activities. The children's progress was recorded throughout the research period. The Nursery staff made regular observations of children as they worked independently with the visual structured apparatus. At the end of the research period we were able to see the progress that had been made by each of the chosen children. We compared the results of the whole Year 2 cohort who did KS1 SATS in May 1998 who had used visual structured apparatus throughout Years 1 and 2 with the results of the previous cohort who took their KS1 Tests in May 1997 who had been taught largely without the visual structured apparatus. We also looked carefully at the strategies used by both cohorts of children to answer the number questions in their KS1 SATs.

Further development since the research project

In 1998 at the end of our research project we wrote "We expect it is highly likely that it is the strategies children use when answering arithmetic questions at the end of Key Stage One SATs which are the significant performance indicator for potential success at Key Stage Two SATs, and not the overall level. The arithmetic questions at Key Stage One SATs are simple and many can be solved purely by counting; children can achieve level 2C having answered very few number questions. However at the end of Key Stage Two children will not be able answer the arithmetic questions if counting is their only strategy; relational understanding and strategic arithmetic are essential for success. Our children's impressive success in the end of Key Stage One SATs raised the question of how high our expectations should be of their achievement at the end of Key Stage Two".

Four years later our first research cohort of children (who had taken KS1 SATs in 1998) took their KS2 SATs in 2002. Their results showed a marked improvement over the results of the previous cohort. The KS2 results for 2003 show that the improvement has been sustained.



Since our original study further research has been carried out by Wiltshire County Council Psychological Service in conjunction with the Downs Educational Trust. Their findings suggest that the approach is particularly relevant to children with Down syndrome who tend to be good visual learners, and are good with patterns but tend to have poor auditory memory. The Wiltshire Project was a pilot for a much larger scale study which is currently underway led by the Down Syndrome Educational Trust in Portsmouth.

Interest in our work has been shown by the Dyslexia Institute which suggests the present extent of research indicates that support for pupils with some specific difficulties in mathematics should be structured, cumulative and multi-sensory.

Further development work in Key Stage 2 has been carried out through a DfES Best Practice Research Scholarship at Moulscombe School in Brighton, supported by Brighton EAZ and the University of Brighton.

Ways forward

Our findings show striking evidence of children (from all ability groups) responding positively to visual structured images and the related programme of activities. Colleagues in other schools who have adopted the approach since dissemination of the findings report similar responses, as do ITT students using the approach. We feel this justifies much larger scale development work to further test the findings, especially since the approach enables achievement of the National Numeracy Framework's objectives.

Other research into arithmetic teaching suggests that current approaches in many schools, and in many published mathematics materials, continue to both underplay confident, relational mental arithmetic and to allow children to build their arithmetic laboriously upon limiting counting procedures. Unfortunately the models and images for number recently published by the National Numeracy Strategy do not include any references to structural apparatus. We find this disappointing in the light of the many children's successes with Catherine Stern's images and approaches we have seen but perhaps classroom teachers will continue to choose for themselves approaches and equipment that they know works.

Further reading

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