RESEARCHING PRIMARY NUMERACY

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Abstract: I describe a major research programme on primary mathematics in the UK, the Leverhulme Numeracy Research Programme, and give a sample of some of the preliminary results. The Programme combines large-scale longitudinal survey and case studies, quantitative and qualitative data, and observation and intervention studies in order to try to ascertain how and in what way different factors affect pupils' progress. The case-studies have focused on factors relating to home cultures, pupil behaviours, curriculum and teaching styles, teacher subject knowledge, and school policies/leadership. The results quoted relate to these areas and also to effects of the implementation of a national reform which occurred during the research programme.

BACKGROUND

As in other countries, there has been continual concern over the standards of calculation in primary schools (ages 4-11) in the UK (Brown, 1999). This has become more urgent and more political with the publication of international comparisons first at secondary and more recently at primary level (e.g. Lapointe, Mead & Askew, 1992; Mullis *et al.*, 1997), and the realisation that countries in the developed world will need a highly skilled workforce to maintain their economic competitiveness.

In English-speaking countries this has led to an increasing desire by governments to control primary mathematics. In England this first led from complete freedom for teachers over both curriculum and teaching methods in the 1970s to a legally imposed broadly defined national curriculum in 1989/90 (Johnson & Millett (Eds.) 1996) together with related national tests to be at the end of each stage (2 to 4 years). More recently continuing political concern over standards of basic skills in primary schools led to a National Numeracy Strategy, introduced in 1999/2000, which has incorporated a much tighter prescription of content, teaching sequence and teaching methods.

The key features of this National Strategy are:

- *an increased emphasis on number and on calculation, especially mental calculation,* including estimation, and selection from a repertoire of strategies;
- *a three-part template for daily mathematics lessons,* starting with 10-15 minutes of oral/mental arithmetic practice, then direct interactive teaching of whole classes and groups, and finally 10 minutes of plenary review;

- *detailed planning using a suggested week-by-week framework of objectives,* specified for each year group, which introduces many skills at an earlier stage than previously, and covers areas of mathematics other than number;
- *a systematic standardised national training programme,* run by consultants locally and by school mathematics co-ordinators in all schools, using videos to demonstrate 'best practice', with in-school support for low-performing schools.

Although not legally imposed, the Numeracy Strategy has been almost universally implemented, and is being extended in a slightly modified form to secondary schools.

The meaning of *numeracy* reflects the social context of its use (Brown et al., 1998). It was accepted by educational policymakers in the UK that numeracy was to be defined broadly, as in other countries, as the competence and inclination to use number concepts and skills to solve problems in everyday life and employment. Nevertheless it was felt necessary, for political and educational reasons, that the aspects of numeracy to be newly emphasised at primary level should focus on proficiency (DfEE, 1998), regarding numeracy as a culturally neutral and value-free set of autonomous skills, underpinned by visual models (e.g. the number line). In contrast to 1980s developments, there are few references to problem-solving and those which occur are mainly traditional 'word-problems', with artificial contexts. In the remainder of this paper 'numeracy' is to be interpreted in this narrow way, although I would espouse a much broader interpretation relating to social practices (Baker & Street, 1993).

The national concern about numeracy also led the Trustees of the Leverhulme Trust, a charity, to fund a £1 million 5-year study, the *Leverhulme Numeracy Research Programme*, to run from 1997 to 2002. The aim of this programme is

- *to take forward understanding of the nature and causes of low achievement in numeracy and provide insight into effective strategies for remedying the situation.*

The design of the research programme is reported in the next section. We wanted to examine the contribution of many different factors to low attainment, in individual children, classes, schools or population groups, by studying, on both a large and small-scale, cases in which these factors varied. Intervention studies were also planned.

When the proposal was written it could not have been anticipated that a new government would quickly implement the National Numeracy Strategy. Clearly this has affected the Leverhulme Programme as the implementation occurred in the middle year (1999/2000) of the 5-year programme. For example it has meant that curriculum objectives, teaching sequence and aspects of teaching methods no longer vary between classes, and thus the effects of differences in these can only be perceived in data from the early years of the project. An intervention project concerning teacher professional

development has also had to be modified to fit with the Strategy training courses. The Leverhulme work addresses fundamental issues in primary numeracy and will not merely act as an evaluation of the implementation of the Numeracy Strategy, which is being done, with the parallel Literacy Strategy, by a Canadian team (Earl *et al.*, 2000, 2001). But inevitably our data can be used to inform some aspects of the evaluation.

RESEARCH DESIGN

The Leverhulme Numeracy Research Programme is a longitudinal study that combines large-scale survey in a 'core project' with case-study data in five 'focus projects'. Two of the focus projects take the form of intervention projects.

The Core Project: Tracking numeracy *(Margaret Brown, Mike Askew, Valerie Rhodes, Hazel Denvir, Esther Ranson, Helen Lucey, & Dylan Wiliam; 1997-2002)*

Aim: To obtain large-scale longitudinal value-added data on numeracy to:

- inform knowledge about the progression in pupils' learning of numeracy throughout the primary years, and
- to assess relative contributions to gains in numeracy of the different factors to be investigated in the programme.

Methods: Data on pupil attainment has been gathered twice a year for 4 years, on two longitudinal cohorts of about 1600 pupils, one moving from Year 1 (age 5/6) to Year 4 (age 8/9) and the other from Year 4 to Year 7. Each cohort includes all children of the appropriate age in 10 primary schools in each of 4 varied local education authorities (about 75 classes). Detailed data is collected on pupils, teachers and schools including lesson observations, teacher interviews and questionnaires. Many instruments are modifications of those designed for our 'Effective Teachers of Numeracy' project (Askew *et al.*, 1997). This data forms the basis for both statistical and qualitative analysis to investigate the relative contributions of different factors. (The methodology of the testing in this project is discussed in a paper (Brown *et al.*, 2002) in the PME 26 Research Forum: Measuring Mathematics Learning and Goals for Systemic Reform.)

The core study provides a base for the case-study investigations in the focus projects, and has both generated hypotheses to be explored in the focus projects and allowed hypotheses arising from those to be checked on a larger sample.

Focus 1) Case-studies of pupil progress *(Mike Askew, Valerie Rhodes, Hazel Denvir, Margaret Brown & Helen Lucey; 1997-2002)*

Aim: To obtain a clear and detailed longitudinal picture of the numeracy development of a range of pupils taught in a varied set of schools and to examine this in the light of their classroom experiences, to ascertain what works, what goes wrong, and why.

Methods: This project is exploring the classroom practice factors influencing pupil attainment, including school, teacher, teaching, curriculum and individual pupil factors. From the longitudinal core sample we selected 5 schools which presented interesting contrasts. In each of these schools we selected children of varied attainment, six from a Reception (age 4/5) and six from a Year 4 class to provide longitudinal case study data, plotting progression in learning over 4 or 5 years. Children are observed and informally interviewed in two blocks of five lessons each year, and their written work collected. Longer interviews concerning perceptions of progress, attitudes and home support, and involving assessment questions, occurred at the end of Years 3 & 6.

Focus 2) Teachers' conceptions and practices and pupils' learning *(Mike Askew, Alison Millett & Shirley Simon; 1999-2002)*

Aim: To investigate the relationships between teachers' beliefs about, knowledge of and practices in teaching numeracy and whether changes in beliefs, knowledge and/or practices raise standards.

Methods: The project is following twelve teachers before, during and after their experience of a short course of professional development as part of the National Numeracy Strategy. We are adapting the methods of eliciting teachers' subject knowledge and beliefs from our earlier work (Askew *et al.*, 1997) in order to construct teacher profiles. Changes in teachers' practices are monitored using video recording of lessons, and changes in pupils' attainment by using the tests developed for the core project. The teachers' profiles, their classroom practices and their pupils' attainment will be monitored over three years.

Focus 3) Whole school action on numeracy *(Alison Millett & David Johnson; 1997-2001)*

Aim: To identify whole-school and teacher factors which appear to facilitate or inhibit the development of strategies for raising attainment in numeracy.

Methods: This research focuses on six schools as they each experienced an inspection and then implemented the National Numeracy Strategy. Each school had identified the need for improvements in their teaching of numeracy and we have collected data both on the strategies schools used to develop the teaching of numeracy and the effect of these strategies on pupils' attainment. The research is investigating the complex interplay of school factors (policies, leadership) and teacher factors involved in the implementation of change over four years. The research uses documentary analysis, observation in classrooms and at meetings, and interviews with a range of informants (headteachers, maths co-ordinators, classroom teachers, governors and parents).

Focus 4) School and community numeracies *(Brian Street, Alison Tomlin & Dave Baker; 1998 - 2002)*

Aim: To refine and establish the meanings and uses of numeracy in home and school contexts; to establish differences between practices in the two environments and to draw inferences for pedagogy.

Methods: This project is investigating the influence of social factors on attainment, in particular differences between numeracy practices, and the linguistic practices associated with them, in the pupils' home and school contexts. Three schools were selected to provide a range of home cultures. Case-study pupils were then chosen from Reception classes (age 4/5) and followed through Year 1 and into Year 2. We have been using ethnographic methods including participant observation of classrooms and of informal situations in and out of school, and interviews with teachers, parents and pupils. The study extends previous work on literacy practices (Street, 1996) into numeracy, but retains a comparative element between the two.

Focus 5) Primary CAME (Cognitive Acceleration in Mathematics Education) *(David Johnson, Mundher Adhami, Michael Shayer, Rosemary Hafeez, Sally Dubben, Ann Longfield & Jeremy Hodgen; 1997-2000)*

Aim: To investigate the effect on the development of numeracy of managed cognitive challenge/conflict designed to encourage verbal interactions and metacognitive activity in whole-class and various small group arrangements of children in Year 5 and Year 6

Methods: An experimental design is used to investigate whether intervention in classroom practices aimed at promoting intellectual development can be effective. It extends our earlier work on CAME (Cognitive Acceleration in Mathematics Education) in secondary schools (Adhami *et al.*, 1998) which uses Piagetian and Vygotskian paradigms. The research team, including teacher-researchers in each of two laboratory schools, first devised and trialled a sequence of mathematical problem situations designed to challenge children, and promote teacher-child and child-child discussion in cooperative small group work and whole-class discussion. This led to the main fieldwork involving research with teachers in a further 8 schools, with the teacher-researchers as tutors. We have used systematic observation of lessons and professional development sessions, and pre- and post- intervention pupil assessments of cognitive development and mathematical attainment. A linked study is demonstrating how this intervention acts as a basis for teachers' continuous professional development.

Coherence of themes

Although the structure of the Leverhulme Programme has been described as six projects, there has been great added benefit in the projects being part of the larger

programme. The results of the programme will be published under a sequence of four common linked themes, to each of which several projects contribute.

- children's learning and progression
- teachers and teaching
- home, culture and school
- professional development of teachers.

In the next sections it is not possible to report the complete findings of the programme under each theme, but I will provide some sample results. This not only for lack of space (we are contracted to write a series of four books for Kluwer), but because at the time of writing we have not analysed all the data (we have another six months which will be devoted to data analysis). The results presented here must be regarded as provisional since neither all the data nor all the analysis has been finally checked.

SOME RESULTS: CHILDREN'S LEARNING AND PROGRESSION

1a) Lessons aimed at accelerating the cognitive level of children's mathematical thinking appear to show some generic results, but the results in terms of national assessment levels are more ambivalent.

The fifth focus project *Primary CAME* generated a series of 'Thinking Maths' lessons which teachers could use occasionally alongside the National Numeracy Strategy. The results in the group of experimental schools showed a significant difference compared with control schools in the rises in children's generic cognitive level as measured on a well-validated test. There was a problem administering a final mathematical problem-solving test because it was close in time to national tests at the end of primary school, so the raw national test scores were used instead as a post-test. Although there was some indication of a higher performance for experimental schools, there was no significant overall effect because of unexplained unexpectedly high results in the national tests from two control schools. This raises questions about using high stakes test results as a research measure as they may not be sufficiently reliable.

1b) The proportion of pupils who can answer a specific question increases with age approximately following a cumulative normal distribution with variations from this relating to the curriculum and testing regime. Changes in the curriculum as a result of the National Numeracy Strategy have had a significant effect on attainment in some areas.

Where children are exposed at an early stage to a fact, skill or idea the improvement in facility (the proportion of pupils who are successful) follows roughly a cumulative normal curve, as one might expect. The items that occur over several years in our tests which most closely match this model are those relating to multiplication facts shown in Table 1.

Item	*Year 1*		*Year 2*		*Year 3*		Year 4		Year 5		Year 6	
	Oct	*Jun*	*Oct*	*Jun*	*Oct*	*Jun*	Oct	Jun	Oct	Jun	Oct	Jun
4x5	*10*	*38*	*37*	*65*	*72*	*87*	85	91				
7x8			*3*	*14*	*12*	*32*	31	47	56	74	77	83
9x9					*15*	*41*	49	65	75	86	89	92

Table 1: Facilities of multiplication items: younger cohort results in italic from October 1998 to June 2001; older cohort results from October 1997 to June 2000 (n>1600)

Interestingly there is no evidence of significant improvement on multiplication facts between the earlier results for the start of Year 4 in 1997 for the older cohort and the end of Year 3 in 2001 for the younger cohort; yet improvement of knowledge of multiplication facts was what the Education Minister promised the public as the effect of the Numeracy Strategy.

However there is evidence of the effect of the Strategy on other items. (This can be seen also in Table 1 in the other paper on the Programme in the PME26 Proceedings (Brown *et al.*, 2002)). On average, performance at the end of Year 3 is 10% higher than expected for the younger cohort who have experienced the National Numeracy Strategy; this is the equivalent of about 4 months' learning.

This effect seems to reflect a curriculum which is both more ambitious in that pupils are taught some material earlier than previously, and more focused on mental strategies which are a focus of the tests we use. (This comparison before and after the Numeracy Strategy will become clearer when we have the 2001/2002 results analysed for the younger cohort in Year 4 to compare with the previous cohort 4 years earlier.)

It might be claimed that the improved performance was due to changes in generic pedagogy rather than curriculum content but an examination of differences in performance on individual items shows that this is unlikely.

We found that for six items out of 65, the younger cohort at the end of Year 3 in 2001 had percentage success rate greater than 10% higher than that for the older cohort at the start of Year 4 in 1997 (and for only one item was the facility more than 10% higher at the start of Year 4). In the case of all these items improvements can be explained by references to curriculum change, in particular to increased early emphasis on the number line, inverse operations and horizontal recording. This seems to provide evidence of effectiveness of curriculum change in enhancing achievement, but early introduction may not necessarily result in long term benefit.

These results depend on data from the large-scale survey, although they can be understood by reference to case-studies. For example it was clear that at the start of the

project in 1997/8 most schools were following broadly similar curricula related to one or more published schemes. However St. Luke's, a case-study school in the second focus project *Case-studies of pupil progress,* was following a significantly more ambitious curriculum than all the others. Most children in the class right from Reception year (age 4-5 years) were using textbooks intended for children one year older. The results from that school in both our tests and the national tests were exceptionally high. (The school had a somewhat above average intake, sufficient to make this policy viable but not to fully account for the results.) By the end of the project the school had purchased a new set of texts which were matched to the National Numeracy Framework, but this time most children were following the books intended for the correct year group, as the school was satisfied that the Numeracy Strategy curriculum was sufficiently ambitious. Correspondingly the results of the school although still above average are now somewhat lower than previously in relation to those of other schools.

Strong curriculum effects have been suggested by international studies at secondary level such as SIMS (the IEA Second International Mathematics Study) (Burstein, 1992). Nevertheless the between-countries, within-topic correlations between coverage and attainment across countries in SIMS were quite low (Robitaille & Garden, 1989). It is also true that when curriculum variation was taken into account in TIMSS - the Third International Mathematics and Science Study, only very small changes in the international rankings resulted at both primary and secondary levels (Mullis *et al.*, 1997, Beaton *et al.*, 1996). Other TIMSS studies suggest more subtle relations between curriculum and attainment (Schmidt *et al.*, 1996; Stigler & Hiebert, 1997).

1c) Over several years most children remain at roughly the same percentile of attainment, although with some oscillation. A few however gradually change their relative positions. The progress of some children appears to be held up because of some fundamental conceptual gaps.

We have been observing classroom behaviour in mathematics lessons of 30 children in each cohort (6 from each of 5 classes in different schools) over 4/5 years, and related these to their test results. For most pupils their percentile in the sample remains roughly constant with minor oscillations; however in some cases there seem to be longer-term trends.

Debbie, in the older cohort at Pinedene school, is a child whose test results oscillate considerably around the median, with no obvious long term trend. She started at about the median in Year 4, moving up to the 65th percentile at the end of the year but her performance dropped gradually through Year 5 to about the 35th percentile at the start of Year 6. By the end of Year 6 and again at the end of Year 7 she was back at about the 60th percentile. When we talked to Debbie she felt that she had learned a lot in Year 4

but had found the teacher and the work in Year 5 difficult to understand, and had recovered in Year 6 with a more supportive and more relaxed teacher. Her perceptions of the quality of the teaching and of her reaction to it correspond to our classroom observation data. This, and the fact that the changes in her performance are similar to, but more extreme than, the changes in the class performance suggests that in her case the quality of teaching is a key factor and that Debbie was particularly sensitive to it. (Some case-study children in the class did not follow the trend of class performance.) It also seems likely that her parents splitting up in Year 5 might have exacerbated the problems that year.

However it is also instructive to look at Debbie's mathematical profile. Although we saw her working with her friend excitedly learning about equivalent fractions in a pictorial context in Year 4, more abstract fractions, and more especially decimal fractions, remained a problem; in our tests she made no progress in this area between the end of Year 4 and the start of Year 6. Debbie volunteered to us in Year 5 that she did not understand these ideas and always got wrong answers in tests. The teaching we observed in that year was not addressing her problems. However during Year 6 the ideas fell into place and she scored quite well on those items at the end of that year and in Year 7.

Another child whose progress was held up by fundamental conceptual problems was Joseph. Joseph, at St. Luke's School and like Debbie in the older cohort, had a performance which gradually declined from near the 80th percentile at the start of Year 4 to about the 60th at the end of Year 6 and Year 7. Our classroom observation suggests that Joseph tried hard to remember standard algorithms but he often became confused and had a fragile understanding of place value to fall back on (his parents had arranged for a private tutor the previous year but Joseph said he did not find this useful). This apparent gap in understanding led to some continuing quite basic errors in place value, although at the end of Year 6 in some areas like fractions he showed quite sophisticated understanding. After a year in a high set at a prestigious school, Joseph's performance in the test deteriorated, both on fractions and on place value. It is interesting to speculate whether, in contrast to many successful children in his class, Joseph's poor progress was part of the 'collateral damage' of the decision by St. Luke's referred to earlier to accelerate the curriculum by a year.

Thus the progress of individual children shows many variations and appears to depend on many factors, relating to the child's ability, personality and inclinations, the home circumstances, and especially to whether the teaching addresses the mathematical ideas causing problems. For different children the balance of importance of these factors also changes. In spite of general trends, it is impossible to predict the future progress of any specific child from one or two test results.

SOME RESULTS: HOME, CULTURE AND SCHOOL

In this area we probably have as yet fewer conclusions than elsewhere since we are still writing up case studies and are awaiting the full data set on the tests before doing the analysis for gender, ethnicity, postcode, parental pattern, etc.. However we still have a few results, both on a micro and a micro-level, which suggest the likely final pattern.

2a) While the numeracy attainment of a school is quite closely related to a 'poverty indicator' of its intake, the gains made in numeracy are independent of this indicator.

In the UK as in some other countries the only readily available indicator of the background of the children in a school is the proportion of children claiming an entitlement to free school meals. As is generally the case with educational data (Levin, 1999) we found a negative correlation between this and average attainment for the school. For example in Year 5 the correlation was -0.63.

However when we looked at the relation between the gains children made over a year and the proportion of children claiming free school meals this correlation was reduced to almost zero (-0.06 for Year 5). This suggests that it is the fact that children from less advantaged homes start behind others which causes continued weak performance; there is no evidence that they make slower progress (see also Burstein, 1992). This is however an average result and the case studies point to many individual variations.

2b) The relationship between numeracy attainment and home circumstances for any individual child is very complex.

In the fourth focus project *School and community numeracies*, we have been studying social factors which may affect children's progress, with case study children moving from Reception to Year 2 in three schools, one an inner city multi-racial school, one a school in a prosperous suburb, and one on a long-established social housing estate with many social problems but with mainly white pupils.

This has thrown up some counter-examples to the general relationships referred to above. For example one of the most materially deprived families is that of Aaysha, whose parents are recent immigrants from Pakistan, as yet unemployed, speak little English (although her father attends classes) and live in temporary accommodation where facilities are basic and shared with many other families. Some of their home numeracy practices (e.g. methods of finger counting) differ from those taught at school. Nevertheless Aaysha is doing very well at school, becoming fluent in English and good at mathematics. An explanation for this is that both parents are well-educated and numerate, and worked in the insurance business in Pakistan; indeed her father has an

MA in statistics. Thus they have intellectual and educational, if not economic, capital, and a determination to succeed which is associated with recent immigrants.

On the other hand some second generation immigrants are less well placed. For example Kim lives with his mother and grandmother. His mother works long hours in a reasonably well-paid full-time administrative job which involves some numeracy, and he spends a lot of time with his grandmother, a nurse working shifts who many years previously had run a small 'home school' in Jamaica. Like many other children, Kim is expected to practise his numeracy skills at home. The problem in the Reception class (age 4/5) was that the pedagogy and underlying epistemology used by Kim's grandmother seemed to be out of line with those of the school. She expected Kim to be able to recall quite sophisticated number facts which he could not do, while asserting that the homework set by the school was too difficult. Kim therefore refused to engage with much of the numeracy work either at home or at school, and his frequent condoned absences led the school to believe that he was overindulged. There was improvement in home-school understanding and in Kim's attainment in Year 1 when his mother arranged for a discussion with his male teacher, also of Jamaican origin.

The experiences of Kim illustrate a general point that many families of our case-study children expect children to regularly do school mathematics at home, in addition to the homework set (normally an hour per week). Thus the predominant numeracy practices at home may not be domestic but those the parents perceive as 'school practices'. Some parents say they do this to support the work at school; for others it is to compensate for what they see as a lack of challenging numeracy teaching in the school. These practices occur across all social groups.

Yet in some cases, like Aaysha, this additional home support seems to be informal, sensitive and successful and in other cases, like Kim, to be limited to recall of facts with an unproductive outcome that adds to the child's sense of failure and discourages them from engaging further. It may be that families with greater intellectual and social capital can be more supportive as they are more sensitive both to the child's needs and to the nature of school numeracy practices (Galbraith & Chant,1990).

SOME RESULTS: TEACHERS AND TEACHING

3a) It is difficult when comparing across many classes of the same age to find a clear relationship between factors relating to teachers or teaching and the learning which occurs.

We looked in two different ways for relationships between different factors and the average gains for each class in a particular year group between October and June. First we correlated against the gains in attainment for Years 4 and 5 all our data from teacher

questionnaires (at least 60 were returned from the 75 classes in each year group; many of the omissions were due to changes of teachers) which related to personal qualifications and experience and also to self-reported practices and beliefs. Several items were, with permission, taken from TIMSS (Mullis et al., 1997).

There were no factors which had significant effect sizes for both year groups, and only a very small number which were significant even for one year group. The factors included the age, length of teaching experience, training and qualifications of teachers, as well as frequency of whole class teaching, type and frequency of homework, and use of calculators and computers. These results are consistent with those for TIMSS both internationally (Beaton *et al.*, 1996; Mullis *et al.*, 1997) and when the English results were analysed independently for the Numeracy Strategy Task group.

In a previous study (Askew *et al.*, 1997) we found that teachers who were effective in teaching numeracy, defining effectiveness in terms of gains achieved by their classes over the year, tended to have a particular orientation to the teaching of numeracy which we characterised as 'connectionist'. In the Leverhulme study we wondered whether in the same way we could characterise 'teaching' as more or less effective. There have recently been several 'evidence-based' claims in the UK for effective styles of teaching (e.g. DfEE, 1998; Hay McBer, 2000; Muijs & Reynolds, 2001) and it seemed useful to see whether we arrived at similar results.

Having analysed what seemed to differentiate the lessons observed of Year 4 teachers whose classes made high and low average gains in 1997/8, we compiled a list of characteristics which were organised using an adapted version of a framework from Saxe (1991). We used this to devise a scale and rated the lessons of teachers in Years 1 and 5 the following year and Years 2 and 6 in 1999/2000. However the correlations with average gains were very low ($r<0.2$, except in Year 6, where $r= 0.39$). (It is not clear why the correlation was higher in Year 6 but it might be that the curriculum variation is reduced that year because of the high-stakes national tests). We tried another way of rating the lessons in terms of the connections between the mathematics, the teacher and the children. However again the correlations were low ($r<0.2$).

This suggests either that our observations, our ranking systems or our tests are unreliable, or that compared with pupil factors, teaching and teachers have a rather small effect on pupils' gains. Again this would not be out of line with other findings (e.g. Mortimore *et al.*, 1988; Creemers, 1997; Burstein, 1992), which suggest that even after the effect of the pupil variables have been removed the teaching accounts for at most 10% of the variance in attainment.

3b) For a particular class across different years, the relationship between teaching and learning seems clearer than across different classes.

We have not yet analysed the data from the full sample in terms of progress made in different years by the same class, but examination of case study data suggest that controlling the pupil factors more closely in this way means that the factors relating to teaching become more salient. Classes appear to make slower progress in years where the teaching ranking is low on our adapted Saxe scale. Those case study children who can review their progress over different years are generally able to identify accurately the years when least and most progress was made, and attribute this to the teaching.

SOME RESULTS: PROFESSIONAL DEVELOPMENT OF TEACHERS

4a) A short programme of professional development supported by in-school action can be almost universally effective in implementing change in curriculum and in aspects of teaching.

Teachers and headteachers in our sample have universally welcomed the National Numeracy Strategy and the support it has given them. They report improved grasp of the priorities for teaching and have changed their methods and curriculum to meet these (see also Earl *et al.*, 2001, 2002). They have praise for the training delivered in local centres, and in schools by the mathematics co-ordinators who are fellow-teachers. It is clear from our interviews and observations that all teachers have changed their practices and their curriculum. In some cases we have observed the same teacher with a Year 4 class in 1997/8 and 2001/2, and found a noticeable change in confidence.

Data from the six case study schools in the third focus project, *Whole school action on numeracy,* suggested that there were six factors relating to the effectiveness of the co-ordinator in improving the standards in the school:

- clarity of vision about priorities of action and ways of working;
- enthusiasm about the role;
- balance between headteacher and co-ordinator, each valuing each others' role;
- high priority to resourcing the co-ordination role, for example to enable co-ordinators to work with other teachers in their classrooms;
- coherence and consistency within the school community;
- regular external support available and used.

In the three schools where most of these factors were not present, a change of co-ordinator occurred during the implementation of the Numeracy Strategy. By the end of that year all three schools had improved their position with respect to these factors and the results in national tests correspondingly improved (Millett & Johnson, 2000).

4b) Professional development which changes and links together teachers' subject knowledge, beliefs, and practice is a much longer term and more difficult enterprise.

In the second focus project *Teachers' conceptions and practices and pupils' learning* we have been examining the changes taking place in relation to a 5-day Numeracy Strategy training course focusing on teacher subject knowledge. Although some of the teachers reported that it had increased their confidence, and some superficial changes in practice and curriculum occurred due to new aspects of pedagogical subject knowledge (e.g. the teaching of different methods of calculation), the course did not appear to have been sufficiently sustained or to have involved enough informed collaborative reflection (Cobb *et al.*, 1997) to have had a strong effect in terms of subject knowledge, beliefs or practices.

In contrast the professional development practices developed in the fifth focus project *Primary CAME* involved teacher researchers modelling lessons in which teachers acted as pupils, then teachers trying lessons out in their own schools and finally meeting to discuss the outcomes. The cycle has similarities to the Japanese model (Stigler & Stevenson, 1991). These meetings continued over two years which was judged to be generally necessary for teachers to develop their beliefs, teaching practices and subject knowledge. The essential ingredients were *cycles of practice and (collective) reflection*, informed *by clear theoretical perspectives*.

CONCLUSION

The opportunity to view primary numeracy from many different perspectives, using different research methods, has allowed a holistic view of teaching and learning and avoided simplistic conclusions. Factors relating to individual pupils have strong effects. Curriculum seems a more salient factor than generic pedagogy. Both these can be changed quite rapidly at a systemic level, but development in teachers' deeper understanding is a long term process.

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