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Early Mathematics Development and Later Achievement: Further Evidence

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There is a growing international recognition of the importance of the early years of schooling as well as an interest being shown in the relationship of early education to later achievement. This article focuses on a cohort of English pupils who have been tracked through primary school during the first five years of the new National Numeracy Strategy. It reports a limited longitudinal study of young children's early mathematical development, initially within three testing cycles: at the mid-point and towards the end of their reception year (at five years-of-age) and again at the mid-point of Year 1 (at six years-of-age). These cycles were located within the broader context of progress through to the end of Key Stage 1 (at seven years) and Key Stage 2 (at eleven years) on the basis of national standardised assessment tests (SATs). Results showed that children who bring into school early mathematical knowledge do appear to be advantaged in terms of their mathematical progress through primary school. Numerical attainment increases in importance across the primary years and practical problem solving remains an important element of this. This finding is significant given the current emphasis on numerical calculation in the English curriculum. It is concluded that without active intervention, it is likely that children with little mathematical knowledge at the beginning of formal schooling will remain low achievers throughout their primary years and, probably, beyond.

Introduction

Given the growing international recognition of the importance of the early years of schooling and, in particular, the interest shown in the relationship of early education to later achievement, it is surprising to note, as Tymms (1999) observed, that relative to reading research, there appear to have been few studies that have focused on mathematics in the English context at least. This situation, however, may be rapidly changing as numeracy and literacy policies within both England and Australia are directed towards strengthening the educational achievements of all school children (see Department of Education, Training and Youth Affairs [DETYA], 2000).

At the outset, however, it is essential to recognise that *mathematics, school mathematics, mathematical literacy and numeracy*, may be defined differently according to social and cultural contexts. Numeracy, in the sense of quantitative literacy, has been regarded as a priority for mathematics education since Cockcroft (1982). Indeed, the recent report Numeracy, a

Priority for All: Challenges for Australian Schools (DETYA, 2000) suggested: "current Australian approaches in the early and middle of years of schooling broadly include the development of students' mathematical knowledge, skills and understandings, and the fostering of students' capabilities and dispositions to make effective use of this learning" (p. 4). That said, even early years mathematics researchers may use the term numeracy in broad and not altogether consistent ways. Moreover, in the context of early childhood education (see Organisation for Economic Co-operation and Development [OECD], 2001) it is probable that notions of school readiness as much as school achievement will be invoked, and broad, holistic learning, rather than 'narrow literacy and numeracy objectives', emphasised.

Perry (1999), for instance, has identified key principles underlying young children's development as well as their own and others' expectations of their capabilities. Early learning is seen as both important in its own right and in terms of future learning. It is recognised that children develop at varying rates yet in a relatively orderly manner, with later learning building on existing understanding, skills, and knowledge. These principles indicate that all children are active and competent learners who need to see themselves, and be seen, in this way. Furthermore, they need to be challenged to learn just beyond current independent mastery, as well as have opportunities to practise recently acquired skills in a range of social and cultural contexts.

Context

Research by Stevenson and Stigler (1992) and Young-Loveridge, Peters, and Carr (1997) has suggested that the range and quality of early mathematical experiences are the main determinants of later achievement. Given that many young children enter school with highly developed numerical skills (Aubrey, 1993, 1997; Young-Loveridge et al., 1997), this finding is all the more important. In this context, researchers have often focused specifically on numeracy (see Ewing-Rogers & Cowan, 1996; Hughes, 1966; Munn & Shaffer, 1993) although more recently, this is less likely to be the case (see de Lemos & Doig, 1999, who included geometrical shapes in assessment; Smith, 2001, who regarded spatial sense, measuring, and time as important to investigate; and van Tuill et al., 2001, who included logico-mathematical skills in assessment).

The evidence for the existence of such early skills and understandings indicates that the early childhood mathematical curriculum, be it in school or preschool, must cater for a wide range of interests and competences, and that these comprise more than mere number skills. Indeed, children have been demonstrated to make great progress in terms of curriculum content once in their first year of formal schooling (Suggate, Aubrey, & Pettitt 1997; Tymms, Merrell, & Henderson, 1997), and Doig and de Lemos (2000) have shown that this progress continues in the second and third years of schooling. However, Mulligan, Mitchelmore, Outhred, and Russell (1997) have also indicated that some children do *not* deal effectively with mathematical situations or move from concrete to more abstract thinking.

The importance, then, of building upon children's prior knowledge is not in question, and whilst preschool programmes are more likely to emphasise holistic and contextualised learning, once in school, children will probably encounter a formal mathematics curriculum that carries with it broad expected levels of achievement. Suffice it is to say, at this point, that a focus on numerical and/or mathematical objectives is likely to have an influence on early childhood pedagogical strategies and professional practice, as well as children's learning. Furthermore, in order to make use of the rich informal knowledge young children bring into school, early assessment of what they already know and can do must be carried out and may lead to the involvement of parents, as Meaney (2001) has explored with Maori parents, or Merttens and Vass (1990) through home tutoring of mathematics in the English context.

If, indeed, children's early experiences constitute the main determinants of later achievement, then a better understanding of numeracy learning and teaching may assist in the improvement of classroom practices. Research on teachers' classroom practices on the one hand, and the development of teaching based on research findings on the other, is leading us to a deeper understanding of effective practice. For example, the Effective Teachers of Numeracy Study (Askew, Brown, Rhodes, Johnson, & Wiliam, 1997) considered classroom organisation of effective teachers as well as teachers' beliefs about teaching and mathematics. Whilst finding no common classroom strategy was associated with effective teachers, the researchers were able to link particular teaching orientations to effective practice with all but one of the so-called *connectionist* teachers who valued children's methods and understandings, and who emphasised making connection within mathematics. By contrast, teachers holding a *transmission* orientation, who viewed mathematics as a collection of discrete skills, conventions and procedures to be taught and practised, and teachers holding a *discovery* orientation, who viewed mathematics as being developed by students through interactions with concrete materials, were only moderately successful.

The finding that effective teachers used no common form of classroom organisation is particularly interesting given the current English context of a *back to basics* National Numeracy Strategy (1999) daily numeracy lesson with its structured oral and mental calculation using whole class teaching, main lesson for new topics and consolidating previous work, and plenary to draw together what has been learned. Indeed, the more recent Leverhume Research Programme (Brown et al., 1998, 2000, 2003) that focused attention on nine-year-olds has suggested a rise in average performance of 3% over the period in which the National Numeracy Strategy has been operating but variation, with gains in mental addition and subtraction and with a slight fall in word problems. Moreover, average attainers appeared to have increased their scores slightly at the expense of low attainers.

The Effective Teachers of Numeracy study supports the view that teachers' beliefs about what mathematics is and how it should be taught is important to effective practice, and the Cognitively Guided Instruction (CGI) model of mathematics teaching rests on the principle that pedagogical decisions should be based upon a cognitive science understanding of the way children learn particular content (Carpenter, Fennema, Peterson & Carey 1988; Fennema, Carpenter, & Peterson, 1989). As teachers' decisions are understood to be influenced by their knowledge of mathematics and children's mathematical development, enhancing knowledge of the way children learn mathematical content is seen as a means of raising the quality of practice.

The Victorian Early Numeracy Research Project (Clarke, 2000), one of ten strategic research projects undertaken by State and Territory education authorities across Australia, has also attempted a detailed analysis of characteristics of early numeracy learning, beliefs, and practices of effective numeracy teachers. The project aimed at researching numeracy teaching practice through the identification of effective classroom teaching approaches in mathematics for students in the early (preparation to Year 4) as well as the middle years (Years 5 and 6) in a range of Victorian schools. It also aimed at determining the potential of these approaches for improving student outcomes. The major outcome from this research has been the identification, description, and elaboration of twelve scaffolding practices that contribute to improved student learning outcomes. These practices describe a range of communicative practices that teachers use to support students' mathematical learning. They can be selected and used, for example, to "explore/make explicit what is known, challenge/extend or to assist students arrive at a key generalisation" (Commonwealth of Australia, 2004, pp. 3–6). Specifically, they support teachers to make more informed decisions about how they will meet the learning needs of all students as appropriately as possible.

Doig, McCrae, and Rowe (2003) have identified a number of key elements that have emerged from recent research studies on effective numeracy practice: "a clear focus on concepts and thinking, an emphasis on valuing children's strategies, and encouraging children to share their strategies and solutions" (p. 24). The review of such studies provided here has been of necessity brief and excluded the wider range of recent early intervention strategies and approaches that have been devised for special groups of children but, nevertheless, it serves to highlight the vital importance of learning in the early childhood years in laying the foundations for later achievement. It also demonstrates that a better understanding of children's early mathematical learning may assist us in providing more effective teaching practice.

Indeed, the study to be reported here focuses on the mathematical performance of a cohort of three hundred children just completing their primary education who have experienced the first five years of the English National Numeracy Strategy [NNS]. These children were tracked in depth from age five to six years with follow-up, national standardised assessment [SATs] at seven years and more recently, reassessed at eleven years, again through SATs. (The National Curriculum sets standards of achievement ranging from levels 1 to 8 that provide information on how pupils are progressing. At seven years they will be expected to reach level 2 and at eleven years level 4.)

The following questions have provided a structure for the methodology of the final phase of this work to be reported here:

- Is early achievement likely to be a major determinant of subsequent success?
- Is this the case for all children or are there particular areas of gain (or loss) for particular groups of children?
- Is it likely that performance can be related in any way to the NNS teaching received?

Background

In our earlier paper (Aubrey & Godfrey, 2003), we reported a limited longitudinal study of 300 young English children's early mathematical development within three testing cycles, at the mid-point and towards the end of their reception year (at five years-of-age), and again at the mid-point of Year 1 (at six years-of-age), located within the broader context of progress through the first phase of formal schooling (described as Key Stage 1) to standardised assessment tests [SATs] carried out at seven years.

Assessment was carried out using the Utrecht Early Mathematical Competence Test [UEMCT] (van Luit et al., 1994). This comprised eight sub-tests with five items in each, including comparison, classification, correspondence, seriation, counting, calculation, and practical problem solving. Broadly, one set of sub-tests related to the understanding of relations in shape, size, quantity, and order, whilst a second set of sub-tests related to counting and basic arithmetic.

Three hundred pupils were selected from twenty-one schools, large and small, from rural and urban areas, with high and low concentrations of children eligible for free school meals and / or with special educational needs, as well as representing a broad range of achievement levels based on the schools' previous SAT results. Whilst our earlier paper focused upon the performance of the English pupils, reference was also made to the larger sample from our wider European project which involved children from Flemish-speaking Belgium, Germany, Greece, Slovenia, and the Netherlands (van de Rijt et al., 2003).

Results showed that children's total scores at around the mid-point of reception year were indeed predictive of later achievement at the end of Key

Stage 1 (KS1), although the combined scores over three testing cycles which extended to the mid-point of Year 1 were more so. Discriminant analysis determined that a combination of a counting sub-test (one seemed sufficient) and a sub-test focusing on understanding of relations in shape, size, order or quantity (a different one at each testing cycle), together with the general number knowledge sub-test, was the best predictor of final SAT levels.

Comparison with the international data set suggested a trajectory for English pupils different from that found elsewhere in Europe, with more of a bias towards arithmetic sub-tests than their European counterparts who start school later and, thus, experience a broad, holist preschool program. Moreover, the pattern of dependence of scores on age in which no advantage was found in including any national differences was especially interesting, given the early English school starting age. Findings suggested the need for young English pupils to have a broad and balanced early mathematics curriculum with appropriate emphasis being placed on practical problem solving, in line with Perry's principles discussed earlier.

Aims

Aims for the current and final phase of our research were thus to:

- build on the existing longitudinal study by tracking our original cohort of pupils from their KS1 SATs in 2000 to the end of their primary years and their KS2 SATs in the Summer of 2004;
- examine these results in the light of our earlier findings, where early achievement did appear to be a major determinant of later success;
- consider the results in the light of the NNS curriculum that pupils had received.

Methods

Participants

More than three hundred schools in the south-east of England were informed about the initial project and invited to take part. Since most were willing to participate it was possible to select schools carefully to include east, west and the centre of the region, urban and rural areas, large and small schools, with high and low concentrations of children eligible for free school meals [FSM] and special educational needs [SEN], as well as a broad band of achievement levels based on schools' SATs results. The SATs results for the schools selected ranged from the twentieth to the ninety-fourth percentile. Eventually twenty-one schools took part. As far as possible, groups of ten children (five boys and five girls) were nominated from each reception class selected, based on the teacher's judgment of the range of ability in the class. Ages at the first cycle of testing are shown in Table 1.

Table 1
Ages at the First Cycle of Testing

	Mean age (months)	SD	N
Boys	60.1	3.56	163
Girls	59.8	3.57	156
Total	60.0	3.56	319

Materials

Three forms (A, B and C) of the Utrecht Early Mathematical Competence Test (van Luit et al., 1994) were used. Each form comprised eight sub-tests, providing forty items in total. These were as follows:

1. Concepts of comparison (between two, non-equivalent cardinal, ordinal, or measure situations)
2. Classification (grouping of objects in a class on the basis of one or more features)
3. One-to-one correspondence (counting and pointing to objects at the same time to make a one-to-one relation)
4. Seriation (dealing with discrete and ordered entities)
5. Using number words (flexibly and in sequence, in this case, backwards and forwards)
6. Structured counting (counting objects in a variety of arrangements)
7. *Resultative* counting (responding to “how many” questions or otherwise determining an amount without the need to point and count)
8. Applying general knowledge of numbers in real-life situations (solving practical word problems).

For ease of reporting, the first four sub-tests that assessed understanding of relations in space, size, quantity, and order will be described hereafter as *relational* tasks. The second four tests, comprising counting forwards and backwards, ordering numbers within 20, and simple problems solving which required manipulation of numbers within 10, will be described simply as *numerical* tasks.

Reliability coefficients for each form of the test when used in England as well as the different countries have been reported elsewhere (see van de Rijt et al., 2003). Analysis of the scores of the English sample, with a view to finding dependence on time of day or day of the week, discovered no evidence that the test was not robust in such respects.

Procedure

Approximately one hundred children took each form of the test, on each of three testing cycles. Details are provided in Table 2.

Table 2
Children Taking Each Form of the Test on Each Testing Cycle

	N	Form A	Form B	Form C
T1	319	119	100	100
T2	299	113	93	93
T3	290	107	88	95

Tests were individually administered with each form taking approximately twenty minutes to complete. Most items were orally presented with children responding mainly to pictorial material or, in the case of some of the counting and number tasks, manipulating unifix blocks. A few items required children to match two objects in a picture using a pencil to link them.

A limited longitudinal design was employed within three testing cycles, at the mid-point and towards the end of children's reception year (at five years of age), and again at the mid-point of Year 1 (at six years of age). The same tester was used for the three testing cycles, with the exception of one or two rural schools that were not accessible by public transport.

SAT results at KS1 (seven years) and KS2 (eleven years) were also included in the analysis, though the focus of this report is the assessment at the end of primary schooling. These national standardised tests, taken at seven and eleven years, sample pupils' National Curriculum mathematical performance on number and calculation, solving problems, measures, shape and space, and data handling and, hence, teaching of NNS.

Preliminary analysis

The multilevel analysis used for the study provided an extension of multiple regression to incorporate the hierarchical structure of the data, with groups of ten pupils (five girls and five boys), nested within classes, within schools, with different areas of the authority. Preliminary analysis (Aubrey & Godfrey, 1999) revealed that different areas of the authority and different classes of pupils showed no significant variation. Moreover, no difference was found between mean scores of boys and girls, though there was some indication that boys' results were more variable and less predictable. All these factors are thus ignored in subsequent analysis.

The basis multilevel regression model allowed scores to be plotted against age in order to analyse differences between scores in the different testing cycles. Sub-test scores showed little difference between cycles 1 and 2 (around five years of age) and a larger difference between cycles 2 and 3 (at five and a half to six years). The profile of different topics varied, some relational tasks declining over time.

Between 1998 and 2004, there was considerable sample attrition illustrated in Table 3. This arose partly from family mobility, partly from pupil absence and partly from transfer to junior (seven to eleven years) from infant schools (up to seven years), although many of the schools involved were combined infant and junior schools. Only 82.4% of the original sample was included in the KS1 SATs results and only 59.4% in the KS2 SATS results. Nevertheless, just over 50% of the sample appeared in all five sets of results[1].

The gender balance was maintained fairly steadily throughout and is ignored in the following analysis. Sample sizes are shown in Table 3.

Table 3
Sample Size in Each Round of Testing

Tests	Boys	Girls	Total	Percentage of original sample
First Cycle UEMCT	162	156	318	100%
Second Cycle UEMCT	152	145	297	93.4%
Third Cycle UEMCT	150	140	290	91.2%
KS1 SATs	134	128	262	82.4%
KS2 SATs	94	95	189	59.4%
All the above	83	84	167	52.5%

Before analysing the results of the KS1 SATs, Aubrey and Godfrey (2003) applied optimal scaling (with OVERALS [1] in SPSS) to determine a score to be attributed to each of the levels attainable by the children that would be suitable for regression with UEMCT results. This approach was motivated by the absence of raw score data from some schools, and the use of fine grading in recording levels. The results were very close to counting levels W (working towards), 1, 2C, 2B, 2A, 3 and 4 as worth 1, 2, 3, 4, 5, 6 and 7 respectively. This simplified quantification was used for analysis.

In the case of KS2 results, all schools that provided data did provide raw scores, and there was very little use of fine grading. Although the scores were not normally distributed (Kolmogorov-Smirnov $Z = 1.46$, $p = 0.03$), they ranged from 9 to 100 and offered an adequate quantification of performance.

Table 4 shows the Pearson correlations between KS2 SATs scores and total or partial (numerical and relational) scores in each cycle of the UEMCT testing, and with the quantified levels attained at KS1.

Table 4
Pearson Correlations Between KS2 SAT Scores and Scores in UEMCT for KS1 SAT

	Total Scores	Numerical Scores	Relational Scores
UEMCT 1	.57	.50	.52
UEMCT 2	.66	.60	.63
UEMCT 3	.63	.66	.58
UEMCT average	.70	.68	.65
KS1 SATs	.78		

As four years passed between KS1 SATs and KS2 SATs, it might be expected that UEMCT scores would be less successful predictors at KS2 (at eleven years) than at KS1 (at seven years) but, indeed, they were only slightly less so. The biggest drop from KS1 to KS2 was the correlation with the total score in the third cycle of UEMCT testing. This cycle of testing was closest in time to the KS1 SATs, and had by far the highest correlation (0.72) and the furthest to drop (to 0.63).

For both KS1 and KS2 SATs, the correlation with total UEMCT scores gradually increased from one cycle to the next. For KS1, total UEMCT scores were more highly correlated than either partial score with SATs levels. At KS2 this held only for the first and second cycles of UEMCT testing. In the third cycle the numerical score was more closely associated than total score with KS2 SATs performance. This seems to suggest that either relational performance was in some sense a less useful indicator of the type of mathematical ability measured in SATs at the time of the third cycle of testing than it was earlier. It also suggests that in the schools concerned not much happens between the ages of seven and eleven that disturbs the predictive value of mathematics tests taken at around the ages of five and six years.

At KS1, the data were consistent with the view that the final UEMCT score was a reasonably good predictor of performance in SATs and that taking the second UEMCT score into account improved the prediction, but the first UEMCT score added no further information about later performance.

Table 5 shows the proportion of variance explained when total, numerical, and relational UEMCT scores were used as predictors of KS2 SATs scores in simple regression models, starting with cycle 3, then adding cycle 2, and finally cycle 1. Very similar results were found at KS1. The first UECMT score added no useful predictive information to what was contained in the second and third scores.

Table 5
Variance Explained by Variables in Sequential Regressions of KS2 SATs Scores on Scores in UEMCT Cycles 1, 2 and 3

	Total Scores	Numerical Scores	Relational Scores	Numerical and Relational Scores
Cycle 3	45.1%	43.8%	33.0%	46.1%
Adding Cycle 2	5.7%	5.6%	11.0%	5.9%
Adding Cycle 1	0.0%	0.1%	0.2%	0.0%

The best simple regression equation was:

KS2 SAT score = 3.37 + 1.37 x Third UEMCT Score + 1.15 x Second UEMCT score.

In this equation, the third UECMT score seems to be about 1.2 times as important as the second. At KS1, the third score was 1.7 times as important. This higher figure can be explained in terms of recency. At age seven years, the time of third testing was much more recent than the second. At age eleven years, the difference was less notable.

Changes in the predictive value of UECMT scores from KS1 to KS2 are slight and subtle. It does seem clear, however, that for both Key Stages relational scores are rather less important than numerical scores, and that these are less effective than total scores. Cycle 3 alone is less effective in predicting KS2 than KS1, but by adding information from cycle 2, this difference is partially eliminated. After a longer time lapse, the most recent UECMT results are less dominant and evidence of sustained high performance is relatively more important. This suggests, although other interpretations are possible, that there is in general some underlying consistency in children's performance in mathematics, measured with some variability by UECMT at various ages and by KS2 SATs. It also suggests that children are making some real progress through time in terms of mathematical development, and that slower progress during the early years is unlikely to be compensated for by faster progress later.

Aubrey and Godfrey (2003) distinguished between the actual raw scores gained by children in the various test and residual scores after adjustment for age. A series of regression models was compared. This led to the conclusion that raw scores in UECMT were an effective predictor of both raw and age-related scores in KS1 SATs. However, age-related performance measured in UECMT was an effective predictor only of age-adjusted performance, but not of raw scores measured in KS1 SATs. This pattern is rather complicated and difficult to interpret.

For the KS2 analysis the approach was more straightforward. UEMCT and SATs scores were regressed on age and residuals were used as age-adjusted scores. This means that age-adjusted scores were calculated independently for each round of testing, and the relationship between age and adjusted scores was also independently calculated. The resulting pattern for KS2 SATs shown in Table 6 is rather simpler than the one for KS1 reported in Aubrey and Godfrey (2003).

At KS2, with both cycles used as predictors, making age adjustments to UEMCT scores only very slightly reduced the predictive value for raw KS2 SATs scores. Whereas 50.8% of variance was accounted for by raw scores, 50.1% was by age-adjusted scores. The best predictive value was that of age-adjusted UEMCT scores for age-adjusted KS2 SATs scores, but it was only best by a negligible amount. Predictive value was lost only when raw scores in UEMCT were used to predict age-related scores at KS2. The proportion of variance accounted for was 46%.

The differences between the patterns at KS1 and KS2 are quite small and, if generalised to other schools, would scarcely give individual schools any cause for concern. They therefore deserve careful consideration. The suggestion arising from Table 6 is that raw and age-adjusted performance in the earliest years of schooling were equally important for predicting raw scores at KS2, whereas early age-adjusted scores are a rather poorer predictor of raw scores at KS1.

Table 6
Proportion of Variance Explained in Sequential Regressions of KS2 SATs Scores on Scores in Total UEMCT Scores in Cycles 1, 2 and 3, With and Without Adjustments for Age

	No Age Adjustments	Age Adjustments for UEMCT	Age Adjustments for KS2 SATS	Age Adjustments for both
Cycle 3	45.1%	44.4%	40.7%	45.0%
Adding Cycle 2	5.7%	5.7%	5.3%	6.5%
Adding Cycle 1	0.0%	0.0%	0.0%	0.0%

As suggested by the relative high correlation between KS2 SATs and KS1 SATs (see Table 4), a far more successful predictive model can be calculated employing KS1 SATs results alongside UECMT scores. Once these are taken into account, the first UECMT score had no predictive value at all. The best simple regression model is:

KS2 SAT score = 2.26 + 9.84 x KS1 SATs level + 0.92 x Second UEMCT score.

However, taking the difference of scale into account, the KS1 SATs levels were still 1.6 times as important as UEMCT scores from eighteen months earlier. The KS1 SATs were clearly better predictors of KS2 SAT performance than UEMCT scores a year and a half earlier. This may be at least in part because there is some similarity of format and content between SATs at different Key Stages. It may be because during the 18 months the future mathematical progress of the child becomes more settled. It is interesting that the second UEMCT score, rather than the third, was the best representative of continued high performance.

Table 7 suggests that making age adjustments to KS1 SATs made an almost imperceptible improvement in prediction of raw KS2 scores and age-adjusted scores, and that age-adjusted KS2 scores were less predictable than raw scores with or without the use of age adjustment for earlier tests.

Table 7
Proportion of Variance Explained in Sequential Regressions of KS2 SATs Scores on Scores in Total UEMCT Scores in Cycles 1, 2 and 3, and on KS1 SATs Levels With and Without Adjustments for Age

	No Age Adjustments	Age Adjustments for UEMCT	Age Adjustments for KS2 SATS	Age Adjustments for both
KS1 SATs	60.1%	60.8%	56.4%	57.6%
Adding Cycle 2	4.4%	4.7%	3.0%	5.7%
Adding Cycle 3	0.2%	0.3%	0.2%	0.4%
Adding Cycle 1	0.0%	0.0%	0.0%	0.0%

At KS2, SATs pupils are grouped by level on the basis of their score. The national target level for pupils of this age is 4. Anything less than that is regarded in some way indicative of a problem of some kind. Table 8 charts the progress of an average member of each of these groups through the three cycles. The picture is very similar to that found by Aubrey and Godfrey (2003) at KS1.

Boxplots in Figures 1 to 4 show graphically the progress of these groups in terms of relational scores, numerical scores, total scores, and age-adjusted total scores in UEMCT. The boxes labelled “missing” represent children who were not included in the KS2 SATs data. They indicated that sample attrition affected a broad range of children, and probably did not have much biasing effect upon the results.

In Figure 1, the relational scores for pupils assigned to level 4 appear to lag one cycle behind those of pupils assigned to level 5. Similarly those at level 3 lag behind those at level 4. This is not true of the same extent of the numerical scores shown in Figure 2, and not true at all of total scores shown in Figure 3, where the final UEMCT score for each group is superior to the second scores for the next highest group.

Table 8
Mean Total, Relational and Numerical UEMCT Scores for Each Cycle of Testing and KS1 SATs Levels for Children Grouped by KS2 SATs Level

		UEMCT Mean Scores			
KS2 SATs Level	Cycle	Total	Number	Relational	KS1 SATs Mean Level
N	1	10.6	4.0	6.6	
	2	8.0	3.0	5.0	
	3	11.2	4.2	7.0	
					1.8
3	1	12.7	5.0	7.7	
	2	15.2	6.4	8.9	
	3	23.6	11.4	12.3	
					3.3
4	1	15.8	6.9	8.9	
	2	19.0	8.7	10.4	
	3	27.9	13.8	14.1	
					4.5
5	1	20.7	9.4	11.4	
	2	25.6	12.0	13.6	
	3	32.3	16.2	16.1	
					5.5

NB. Only one pupil appeared at Level 1 and one at Level 2. These are omitted from the table.

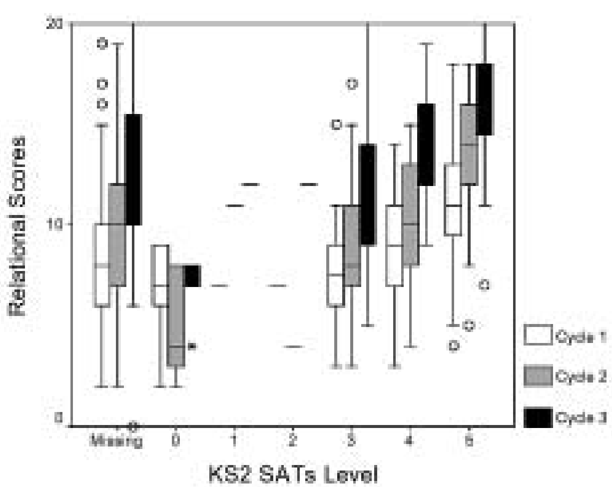

Figure 1. Boxplots of Relational Scores in each UEMCT cycle of testing for children grouped by KS2 SATs level

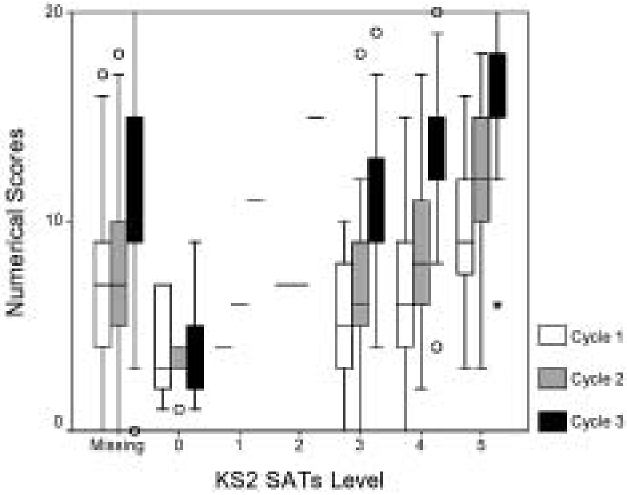

Figure 2. Boxplots of Numerical Scores in each UEMCT cycle of testing for children grouped by KS2 SATs level

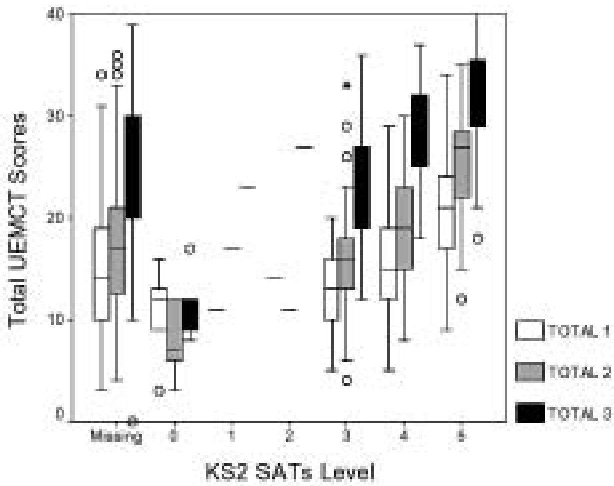

Figure 3. Boxplots of Total Scores in each UEMCT cycle of testing for children grouped by KS2 SATs level

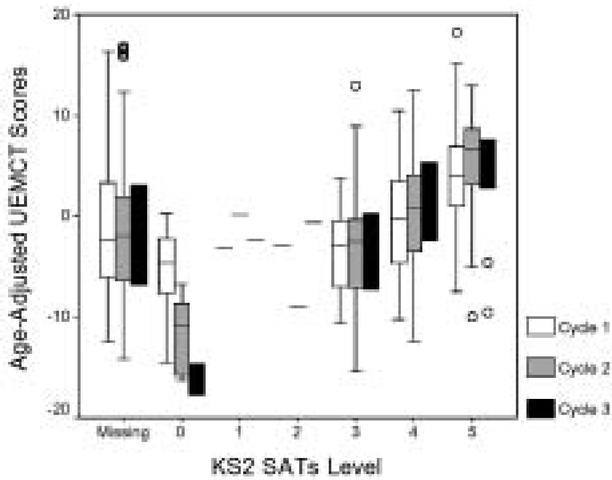

Figure 4. Boxplots of Age-adjusted Total Scores in each UEMCT cycle of testing for children grouped by KS2 SATs level

The age-adjusted scores shown in Figure 4 suggest that children who just failed to reach the KS2 target of level 4 (the national norm) and were assigned to level 3 had, on average, proceeded steadily through the three UEMCT tests attaining just below average for their ages. Those who achieved the target on average started off at the appropriate score for their age and made slight progress. Those who reached level 5 (above the national norm) at KS2 on average started high and made more progress, presumably hitting a ceiling in the final round of testing. The most remarkable thing is that children making virtually no progress up to the age of eleven, and classified in KS2 SATs as 'N' (not classified), are distinguished not so much by low scores initially, but by their swift decline during the earliest years of schooling.

It is also notable that the maximum and minimum scores shown for each type of score for each group in each cycle of testing are quite widely separated. Individual children could be very far from the average score for their group.

Finally, Aubrey and Godfrey (2003) took a finer grained look at how UEMCT scores might predict KS1 SATs performance by applying discriminant analysis to the eight individual topic scores in each cycle of testing. The results were that for each set of tests, the best prediction of KS1 SATs levels was achieved by a combination of a relational topic score with a numerical topic score, together with the General Number Knowledge topic score. The two most predictive topics, in addition to General Number Knowledge varied from cycle to cycle. General Number Knowledge, as defined in UEMCT, appeared to be genuinely an important predictor. The other topics appeared to be best representatives of what predictive value there was in the relational topics as a whole, and the numerical topics as a whole. In fact, at KS2 General Number Knowledge remained important, but otherwise the topics involved were different. Classification was no longer important in cycle 1 but became so at cycle 3. Structured Counting disappeared at cycle 2 and Seriation appeared. Resultative Counting was replaced by Structured Counting at cycle 2.

Discussion

These results reinforce and extend those reported in Aubrey and Godfrey (2003). We showed then that children with higher mathematical knowledge at six years tended to have higher scores on SATs at seven years. Changes in the predictive value of UEMCT scores from KS1 to KS2 were small and subtle. For the schools and pupils concerned, nothing much happened to disturb the predictive value of mathematics tests taken at around the ages of five and six years. By the third cycle of UEMCT, the numerical score was more closely associated than total score with KS2 SATs performance. Furthermore, at both KS1 and KS2, correlation with relational scores was slightly higher than with numerical scores in cycles 1 and 2, but rather lower in cycle 3, suggesting that relational performance was rather less useful as an indicator of the type of mathematical ability measured in SATs at the time of the third cycle of testing than earlier. Overall, at KS1 the data were consistent with the view that the final UEMCT score was a reasonably good predictor of performance in SATs and that taking the second UEMCT score into account improved the prediction, but the first UEMCT score added no further information about performance.

In general, there appeared to be some consistency in children's performance in mathematics, measured with some variability by UEMCT at various ages and by KS2 SATs. Children were making some real progress through time in terms of mathematical development, and that slower progress during the early years is unlikely to be compensated for by faster progress later. Sample attrition of more than one third affected a broad range of children and probably did not bias the results obtained.

Adjusting UEMCT and/or SAT scores for age did not perceptively improve prediction. The age-adjusted scores suggested that children who just failed to reach the national KS2 target of level 4 and were assigned to level 3 had, on average, proceeded steadily through the three UEMCT tests, attaining just below average for their ages. Those who achieved the target on average started off at the appropriate score for their age and made slight progress. Those who reached level 5 at KS2 on average started high and made more progress. Children making almost no progress up to the age of seven years and classified in KS2 SATs as 'N', were distinguished less by low initial scores, than by their swift decline during the earliest years of schooling.

Applying a discriminant analysis to each of the eight individual test scores in each cycle of testing at KS1 indicated that the best prediction of KS1 SATs levels was achieved by a combination of a relational topic score with a numerical score, together with the General Number Knowledge topic score. The results for a similar discriminant analysis at KS2 indicate that General Number Knowledge remains important, but otherwise the topics involved were different.

Conclusions

The results of the second phase of primary schooling confirm and reinforce our earlier results for the first phase of schooling. Children who bring into their reception year numerical and relational knowledge do appear to be advantaged in terms of their mathematical progress through primary school. Numerical attainment increases in importance across the primary years. Though it is beyond the scope of this article to speculate too wildly on the relationship of this finding to the current emphases in the English curriculum, that General Number Knowledge, involving practical problem solving, remains important across primary schooling is worthy of note, given the Brown et al. (2003) finding that English children's scores for word problem solving may have declined with the introduction of the NNS and its emphasis on numerical calculation. As Press and Hayes (2000) have argued for the Australian context, an emphasis on numeracy outcomes, however defined and whichever are emphasised, inevitably has implications for curriculum and pedagogical practice in the early childhood years.

Indirectly these findings may argue for the importance of pre-school education between three and five years. Reception class teachers (for five year olds) who systematically monitor their pupils from the beginning of the year, and identify and coach those without these mathematical skills, may well help to reduce inequality. Without active intervention, it seems likely that children with little mathematical knowledge at the beginning of formal schooling will remain low achievers throughout their primary years and, probably, beyond.

Endnote

1. Readers who look very precisely at the figures in the tables presented may find slight discrepancies caused by the use of the slightly different samples of children involved in the different tests. Estimating each figure using the full quota of children who have the necessary data was done in preference to having less full data for each figure and a consistent set of results.

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