Introduction and background

Low attainment is widely considered to be one of the most serious problems in education in England. Low attainment in mathematics is a particular problem because of the subject’s importance to the economy and to individuals – it has been a key concern of government policy for over 2 decades. However, the problem appears to have got worse rather than better. Nationally representative data from an ESRC funded project (ICCAMS: Increasing Competence and Confidence in Algebra and Multiplicative Structures), indicates that in England the proportion of very low attaining pupils at the end of Key Stage 3 has roughly doubled since the 1970s. During Key Stage 3, the gap between the lowest and highest attaining pupils in mathematics increases and the low attaining pupils fall further behind other pupils. A substantial proportion of pupils have difficulty with the basic concepts in secondary mathematics: approximately 40 per cent in algebra and 65 per cent in ratio.

This research was funded by the Nuffield Foundation and carried out by a team from the University of Durham, King's College London, University College London and the University of Loughborough. It sought to gain a better understanding of low attainment in mathematics in lower secondary. It focussed on the lowest attaining 40 per cent of the Year 9 cohort who are unlikely to achieve the new grade 4 at GCSE by age 16.

Key findings

Methodology

- Researchers developed a 50-minute computer delivered test to ascertain what low attaining pupils in Year 9 already know. The test was named the Investigating Mathematical Attainment and Progress Test (IMAP). It was designed to assess knowledge of number, multiplicative reasoning, and algebra. A separate arithmetical fact retrieval test was also completed. It consisted of 30 items with pupils completing as many as they could in 2 minutes.
- The tests were delivered to 2,841 Year 9 pupils in 4 secondary schools – those who took the test were in the lowest 40 per cent for attainment. These pupils were further subdivided into quintiles according to ability.
- The tests were also taken by 1,050 high and middle ability pupils in Year 5. This was done so that researchers could assess whether low attainers' understanding of maths is qualitatively different from that of middle and higher attainers. In addition to the test, 195 pupils and 12 teachers took part in interviews.

Comparisons between Y9 and Y5 samples

- On average, pupils in the Y9 matched sample got just less than half the items on the IMAP test correct (46%). Relative to other topics, the hardest were the percentage items (23% correct). Aside from quintile 5 (the most able), which is likely to be subject to ceiling effects, the profile for each quintile was broadly similar.
- The Y9 sample performed better than the Y5 sample on arrays and area, percentages and arithmetic recall, whereas the Y5 sample was stronger on derived facts and selecting a calculation, although these differences were all small. Scores were not significantly different for estimation, fractions, integer calculation, number lines, place value or ratio. An inspection of the 6 Area and arrays items indicated that the Y9 superiority resulted from the 2 numeric (dimensionless) area items. However, the matched Y5 sample performed better on the remaining 4 array items, which are related also to derived facts.
- There was no further evidence of substantive differences in the relative strengths of the two groups in their responses to the mathematical topic areas and skills within the test.
- There was no evidence that performance in any particular topic had a special place in explaining performance in other areas of mathematics. This was also the case when each of the 2 year groups were analysed separately. The researchers' hypothesis was that weaknesses in certain key threshold concepts might explain why low attainers had failed to progress. If such differences had been discovered, they could have led to clear recommendations for curriculum and teaching. However, the research has not identified evidence for such threshold concepts.

Factors associated with low attainment

- This part of the research explored 3 questions. What factors determine success in GCSE mathematics? Are some areas of mathematics particularly crucial? Can low attainment be overcome?
- To answer these questions, researchers drew on data from a large nationally representative survey data carried out as
part of the Increasing Competence and Confidence in Algebra and Multiplicative Structures (ICCAMS) study and linking this to demographic, prior attainment and further attainment data held in the National Pupil Database. The sample analysed comprises 10,913 pupils who took one or more ICCAMS tests in Y7, 8 or 9 in 2008 or 2009 as part of the ICCAMS study along with an attitude questionnaire. The attitude questionnaire explored self-efficacy, intrinsic enjoyment and performance goals (the extent to which a person is motivated by manifest achievement, particularly in comparison to others).

- Analysis of the data found that the strongest single predictors of attainment in GCSE mathematics are KS3 mathematics teacher assessment level, ICCAMS test scores and KS2 mathematics level. Other prior attainment measures (KS3 and KS2 levels in science and English, KS1 average level) are also strong predictors, but less so.
- The following had moderate predictive power: the number of recorded absences, self-efficacy, number of half-days excluded from school, number of terms eligible for free school meals, performance goal orientation and IDACI (an index of deprivation based on pupils' home postcode). On average, one additional day of exclusion from school, or nine additional days of absence over a school career, were each associated with a reduction of one grade in GCSE mathematics. This was after taking into account other factors, such as prior attainment, SES and gender.
- Other variables, including intrinsic motivation, the number of schools attended, the amount of variation in recorded IDACI (income deprivation affecting children index) scores and gender, had no correlation with GCSE mathematics grade. There was no evidence that threshold concepts (i.e., particular subsets of mathematical knowledge or skill that unlock future progression) were a predictor.
- Many previous studies find socio-economic status (SES) variables to be a predictor of academic outcomes. The findings of this research confirm this. However, once the data was controlled for prior achievement using regression analysis, the additional predictive power of SES dropped to close to zero. This suggests that the additional progress made from KS2 to GCSE is typically not related to socio-economic status. Similarly, gender was found to be only very weakly related to either outcomes or progress to GCSE.
- On average, one additional day of exclusion from school, or 9 additional days of absence over a school career, were each associated with a reduction of one grade in GCSE mathematics. This was after taking into account other factors, such as prior attainment, SES and gender. However, it is important to stress that there is no evidence that these are causal relationships: factors which have not been measured could have caused both poorer GCSE performance and a tendency towards exclusion or absence. Nevertheless, these findings warrant further research.
- Smaller relationships were found with self-efficacy and intrinsic motivation, and the number of schools attended.
- The analysis explored the relationship between each individual question in the ICCAMS tests and pupils' subsequent GCSE mathematics grade in order to assess whether some areas of mathematics are particularly crucial. No evidence was found of any specific items having particular predictive power for GCSE outcomes.
- Pupils in the lowest 10 per cent of attainment, according to their KS3 teacher assessment in mathematics, had only a 7 per cent chance of achieving C or above at GCSE, whereas, of those in the top 30 per cent, over 99 per cent achieved C or above. The prospects for pupils who were low attaining at KS1 (i.e. aged 7) were not quite as firmly determined, though the relationship was still strong: 23 per cent of those in the bottom 10 per cent went on to achieve C or above, rising to 98 per cent for those in the top 10 per cent. This shows that low attainment in the early years of school can be overcome by some pupils.
- Pupils whose scores on any of the ICCAMS tests put them in the top half had a better than 80 per cent chance of going on to achieve C or above at GCSE. This compares with chances of around 30 per cent of gaining C or above for those whose ICCAMS scores were in the bottom half.

Successful teaching strategies

- Researchers looked at 76 meta-analyses and 31 other relevant papers to explore which teaching strategies have had most success in addressing low mathematics attainment in secondary school.
- Twelve strategies were found to have efficacy in the teaching of mathematics, not just for pupils in general, but also for low attaining pupils. Ranked from highest to lowest in order of the security of the evidence, they are: explicit teaching, computer-aided instruction, peer tutoring, heuristics (mental shortcuts), manipulatives, tutoring by adults, feedback to pupils, representations, feedback to teachers, self-instruction, cooperative learning, and student-centred learning.
- There is particularly consistent evidence to support use of explicit teaching for low attaining pupils. Explicit teaching emphasises carefully constructed explanations and structured practice materials that have usually been designed and evaluated by expert teams, incorporating both conceptual and procedural aspects of knowledge. Most explicit teaching interventions also involve feedback.
- Evidence was also found to support the use of early intervention for pupils at risk of low attainment. In general, the effect of an intervention reduced as the duration increased, although frequency was associated with increased benefits.
- Researchers looked at whether mathematics is currently taught in appropriate ways for low attainers. They used data from interviews with 70 pupils and 12 teachers who were experienced in teaching low ability pupils in Y9 and Y10.
- Most teachers reported that they believed building positive relationships was an especially important strategy for low attaining pupils. In line with this was the finding that most low attaining pupils enjoyed their mathematics lessons and valued their mathematics teacher, even though they mostly reported finding mathematics difficult. One danger of this approach is that some (but not all) teachers felt it was important to build pupils’ confidence by not allowing much struggle or failure.
- Pupils valued detailed explanations with methods broken into small steps, which links to findings about the efficacy of explicit and direct instruction.
- Teachers stressed the importance of derived facts, though most reported that they had not taught them explicitly and that their pupils rarely use them. Teachers also reported that pupils rarely estimate, although they perceived this to be an issue for high attainers as much as low attainers.
- Teachers were generally positive about the value of representations and manipulatives, although many teachers appeared to lack a consistent approach to their use of these.
- Many pupils reported finding number lines confusing and they were unfamiliar with arrays. Some pupils did however make use of strategies involving the use of fingers. We emphasise, however, that several teachers recognised this danger and attempted to avoid it.

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