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ABSTRACT

"Thinking Science," the Cognitive Acceleration through Science Education (CASE) curriculum, is a program designed for 11-14 year olds (in the first two years of secondary school) which encourages them to reflect on their own thinking and to develop their reasoning power in tackling novel problems. This study presents results that represent the first large-scale long-term test of the process of raising standards in schools by concentrating on a thinking skill approach. Overall, about 4,500 pupils in the CASE schools have been featured in the data in this report. Seventeen schools' data have been compared with added-value data from a greater number of control schools. Results indicate that the CASE methodology, even when tried for the first time, produced an average increase on the order of half as much gain in the percentage of pupils obtaining C-grade and above at the GCSE examination (an increase from a National average of 44% to 63% for science in 1996, and an increase from 43% to 57% in science for 1995. In addition, there was the same relative order of increase in achievement in mathematics and a somewhat lower improvement, though still substantial, in English. In schools where teachers had two or more previous years of experience with this approach, the schools more than doubled the proportion of their pupils showing National Curriculum achievement at level six or above in all three subjects. Contains 13 references. (JRH)

The Long-Term Effects of Cognitive Acceleration on Pupils' School Achievement November 1996

by
Michael Shayer
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The long-term effects of *Cognitive Acceleration* on pupils' school achievement, November 1996

Michael Shayer, King's College, London

In 1991 the effect of the ***Cognitive Acceleration through Science Education (CASE)*** programme on academic standards - shown by students gaining far more high grades at GCSE - was widely reported in national newspapers and weeklies, and led to two television programmes featuring the methods in action in schools. Our results then came from relatively small-scale research (one class in each of nine schools) but were striking enough to lead to a demand from many schools for training in the methods.

Thinking Science, the CASE curriculum, is a programme designed for 11 - 14 years olds (in the first two years of secondary school) which encourages them to reflect on their own thinking, and to develop their reasoning power in tackling novel problems. It is based on ideas of the development of thinking established by two psychologists: the Swiss Jean Piaget, and the Russian Lev Vygotsky (both of whom, as it happens, were born just 100 years ago in 1896). Equipped with increased reasoning power in early adolescence, pupils are able to learn more effectively, and so score higher in examinations in any academic subject.

In September 1991 we began to offer inservice training for whole school science departments, and for Advisers and others who wished to train schools in their areas. Pupils who began with ***Thinking Science*** in Year 7 in 1991 took their GCSE in Summer 1996, and so their school results to be presented here represent the first large-scale long-term test of the process of raising standards in schools by concentrating on a thinking skill approach. In addition, we present evidence from 1995 GCSE results from schools who began the ***Thinking Science*** approach in Year 8 in 1991, and Key Stage 3 results from 1995 and 1996 which show the effect on National Curriculum achievement by the end of the third year of secondary education (Year 9).

The 'Added-Value' approach

The only way in which results published by schools can be compared and assessed is by relating them to the range of abilities of the pupils at entry. Our added-value currency is tests of thinking ability which assess children's levels of thinking on a scale established by Piaget. These 'Piagetian Reasoning Tasks' (PRTs) were developed at Chelsea College and have been shown to predict future learning well, particularly in science and mathematics, but in other major school subjects as well. PRTs were used in 1974 and 1975 to conduct a survey of 14,000 ten to sixteen year-olds representative of the school population of England and Wales. The norms established by that survey can be used to standardise the test results of the whole year group who enter a school. For example, a school's intake can be described as "average for 12 year-olds" (the mean at the 50th percentile*), "considerably below-average" (say the mean at the 20th percentile) or, in the case of a typical grammar-school intake, at about the 88th percentile (i.e. selecting the top 20%).

The mean levels achieved by pupils in exams taken later - for example Key Stage 3 National Curriculum tests**, or GCSEs - can then be related to the school's intake. As a general rule, mean success rates of a school in external exams will be directly related to its intake level, and so the intake level can be used to predict likely outcome levels 3 or 5 years later. It is the extent to which a particular school exceeds or falls short of these 'predicted levels' that can be used as a measure of its success or failure in maximising the potential of its pupils.

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* The nth percentile is the score below which n% of the whole population lies. The 20th percentile is the score below which 20% of the population lies (and above which will be found 80% of the population).

** From 1995 all schools must test all their Year 9 (end of Key Stage 3) pupils with National tests in Science, Mathematics and English and soon they will also be required also to publish their pupils' results in terms of the numbers assessed at National Curriculum Level 3, 4, etc. in each of the subjects.

Example: Added-Value applied to the 1995 Key Stage 3 results

We take a sample of control schools (i.e. schools whose Year 9 pupils have not been involved with CASE and ***Thinking Science***), whose intakes cover the range of intakes in the schools we wish to assess, and plot their pupils' mean exam or external test performance against their intake levels. Figure 1 shows how this is done in the case of the 1995 Key Stage 3 Science results. The original intention was that the average pupil should be at the level 5/6 boundary by the age of 14. Hence the percentage of pupils assessed at level 6 or above in the National Curriculum, for schools who have not had the ***Thinking Science*** intervention, is plotted against the mean percentile of the school intake. The line through the scatter of points on the graph represents a running average of all the control schools.

The ***Thinking Science*** schools are then entered in on the same graph, and the extent to which their results lie above the control schools' regression line is a measure of the effect of the intervention.

In Figure 1 two sets of CASE schools are shown—the "Direct" CASE schools being those who had been trained from King's College, and the "Trainer" CASE schools who had been trained independently of King's by a trainer who had been trained at King's. The Trainer schools' results show that we have a methodology which can be transmitted at large, and not just by King's College staff who were involved in the original research. This is an essential step in the art.

Figure 1: Key Stage 3 Science 1995

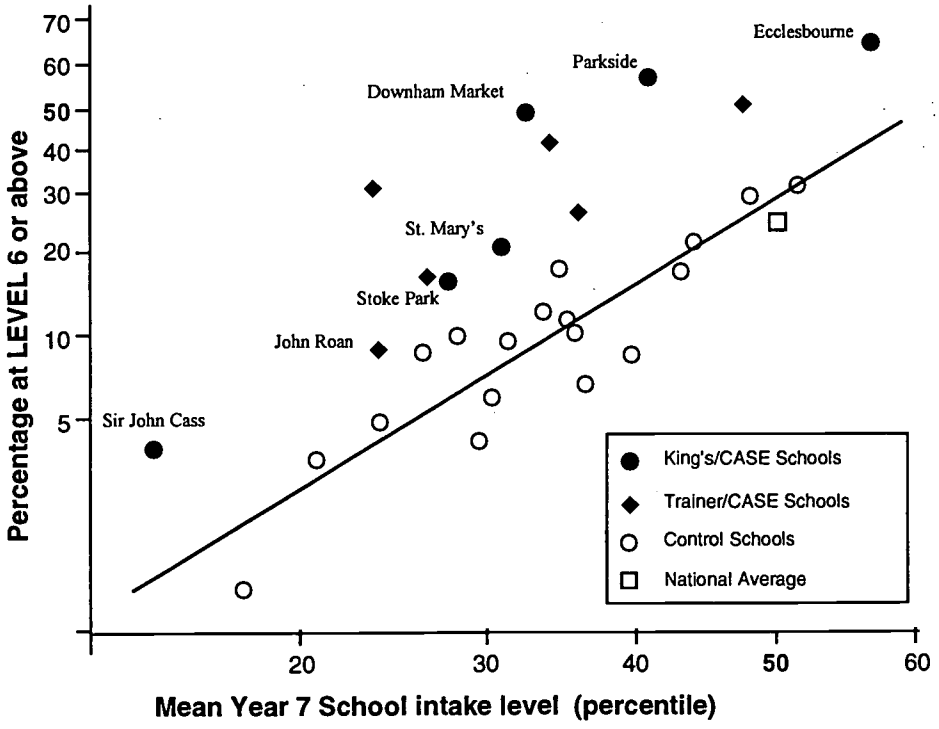


Table 1 shows each CASE school's results predicted on the basis of the norm established by control schools, and also the actual results obtained. When these results are averaged, after allowing for the difference between the position of the control regression line below the National average, they are equivalent to a raising of the National average at level 6 or above from 25% to 68%.

It will be clear that reporting results on this value-added basis requires the collection of a comprehensive set of test scores over a number of years. The results to be reported below make use of all the data available by November 1996, but cannot include results from schools which

took part in CASE training but which, for one reason or another have not yet supplied us with some part of their complete data

Table 1: Science Key Stage 3 1995 results for CASE schools

School	Mean %ile of 1992 intake	% level 6 or above predicted	% level 6 or above obtained
Downham Market	33	8	48
Ecclesbourne *(1 class)*	57	40	64
St. Mary's	31	7	21
Parkside	41	16	56
John Cass	14	1	4
Stoke Park	28	5	15
Trainer Schools			
John Roan *(1class)*	24	4	9
ME	48	24	50
FE	27	5	16
SE	34	9	41
OE	36	11	26
TE	24	4	31

Does the CASE method affect pupils' learning in general?

The original intention of CASE was to increase pupils' general thinking ability by planting a thinking skill approach within the context of just one major school subject, science. The first test is to see whether pupils' achievement in other subjects, such as Mathematics and English, is also affected. In Figure 2 the 1995 Key Stage 3 Maths results are shown from the same pupils whose Science levels were shown in Figure 1.

Figure 2: Key Stage 3 Mathematics 1995

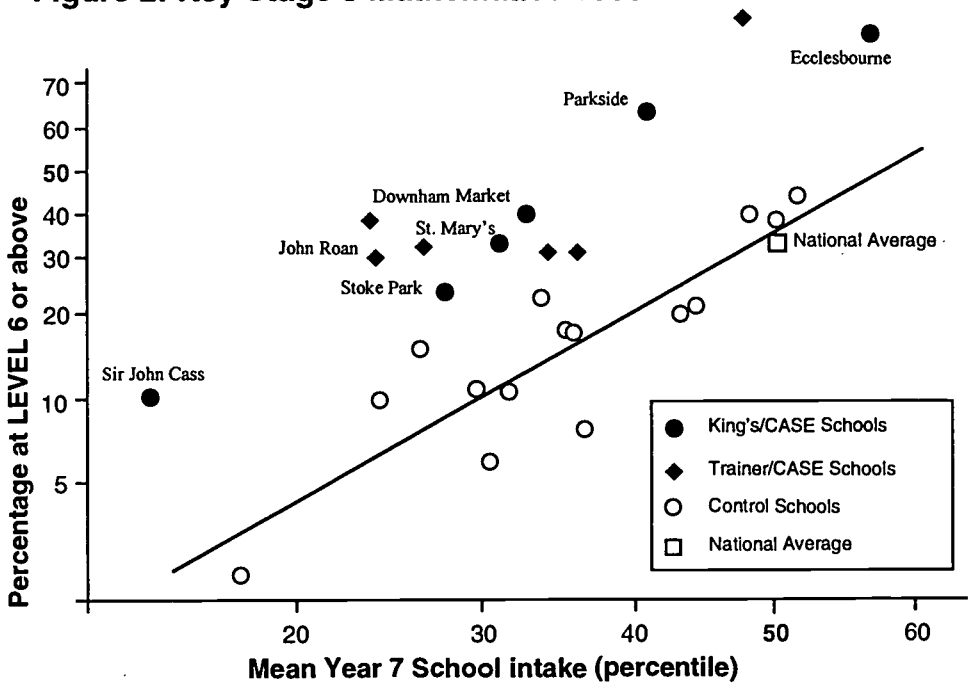


Table 2 shows the corresponding results for Maths compared with what would be expected from the control schools' performance. When these results are averaged, they are equivalent to a raising of the National average at level 6 or above from 33% to 70.2%

Table 2: Maths Key Stage 3 1995 results for CASE schools

School	% level 6 or above predicted	% level 6 or above obtained
Downham Market	13	40
Ecclesbourne *(1 class)*	48	79
St Mary's	12	33
Parkside	22	63
John Cass	2	10
Stoke Park	9	24
Trainer Schools		
John Roan *(1class).*	6	30
ME	32	81
FE	8	32
SE	14	31
OE	16	31
TE	6	27

In Figure 3 the 1995 Key Stage 3 English results are shown from the same pupils whose Science levels were shown in Figure 1.

Figure 3: Key Stage 3 English 1995

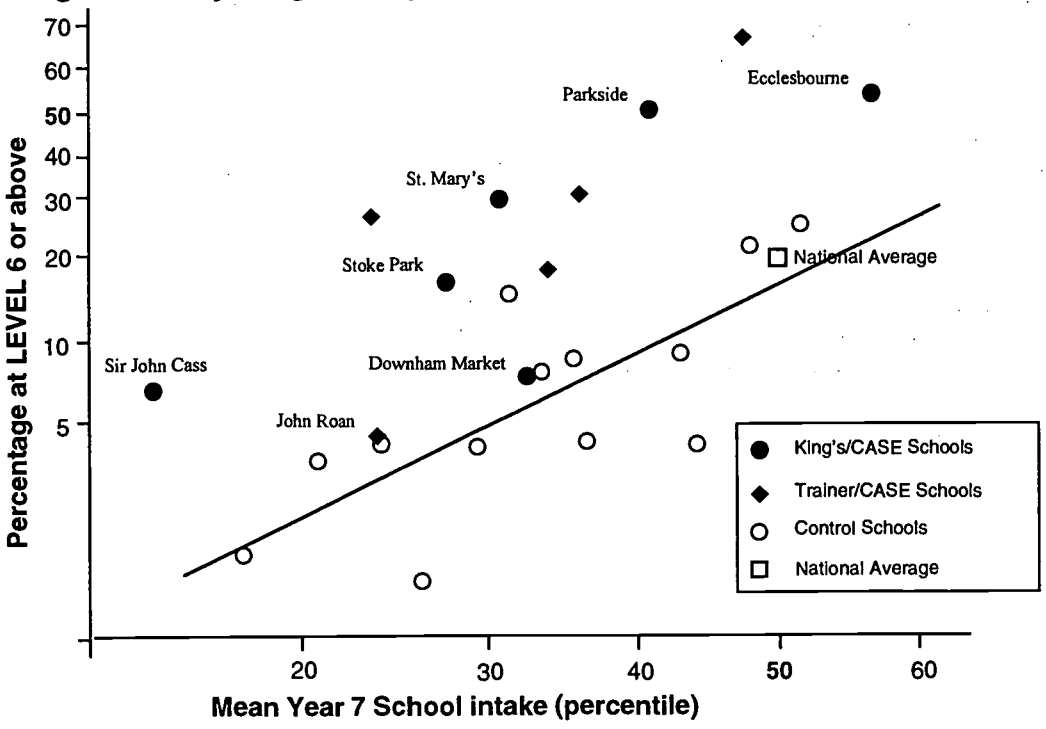


Table 3 summarises the difference between the results achieved as compared with those predicted by comparison with like control schools.

Table 3: English Key Stage 3 1995 results for CASE schools

School	% level 6 or above predicted	% level 6 or above obtained
Downham Market	6	7
Ecclesbourne *(1 class)*	27	54
St. Mary's	6	30
Parkside	12	50
John Cass	1	6
Stoke Park	4	17
TrainerSchools		
John Roan *(1class)*	3	4
ME	17	67
FE	5	-
SE	8	18
OE	9	31
TE	4	27

These school results, when averaged, would predict a raising of a school with a National average intake from the present 20% at level 6 and above to 56%.

It can be seen that the effects on Mathematics achievement appear to be just as large as those on Science. The effects in English are more variable, both for the CASE schools and the Control schools, which reflects the difficulties of getting consistent assessment standards in English. Nevertheless, they are substantial.

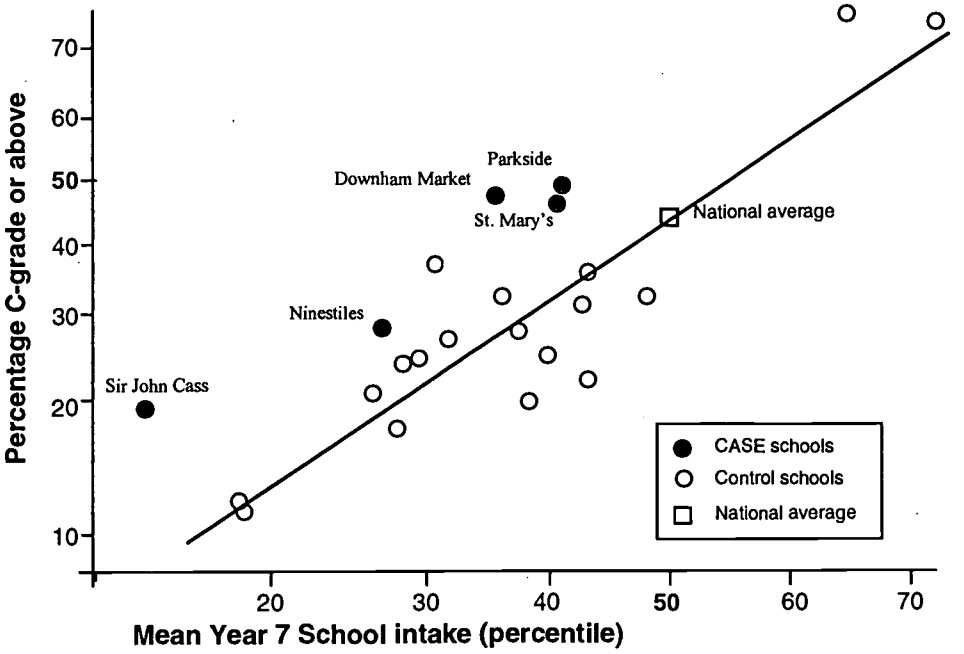
If one thinks of the CASE intervention gradually affecting pupils' thinking ability over the two years of its delivery, then this should begin to affect the learning ability of the pupils generally some time during this period. When they enter Year 9 they will then have a full year of academic learning in all their subjects before they take their Key Stage 3 National Curriculum tests. If CASE has worked, then the better learning ability should show by the end of this year 9, which it does.

Against the background of these Key Stage 3 results for 1995, showing the added-value approach, we can now look at the 1996 GCSE results.

1996 GCSE results

In Figure 4 results are shown for Science for four schools who began the CASE intervention with their Year 7 pupils in 1991, and one (Ninestiles) who began with their Year 8 pupils in 1992. Data for a further four schools who started with their Year 8 classes in 1991 are given in the 1995 GCSE results.

Figure 4: GCSE Science 1996



It can be seen that all the CASE school results lie well above the mean line for the control schools, so that there is no doubt that their pupils' science achievement was affected by the CASE intervention. In Table 4 each school's results can be compared with those predicted from control schools' results.

Table 4: Science GCSE 1996 results for CASE schools

School	Mean percentile of 1991 intake	% at Grade C or above predicted	% at Grade C or above obtained
Downham Market	35	27	47
Sir John Cass	14	8	19
Ninestiles	27	18	28
Parkside	41	32	49
St. Mary's	40	32	46

When these gains are averaged, they are equivalent to raising the National average* of 43.7% C-grade or above to 62.5%, and this is derived from data on about 800 pupils.

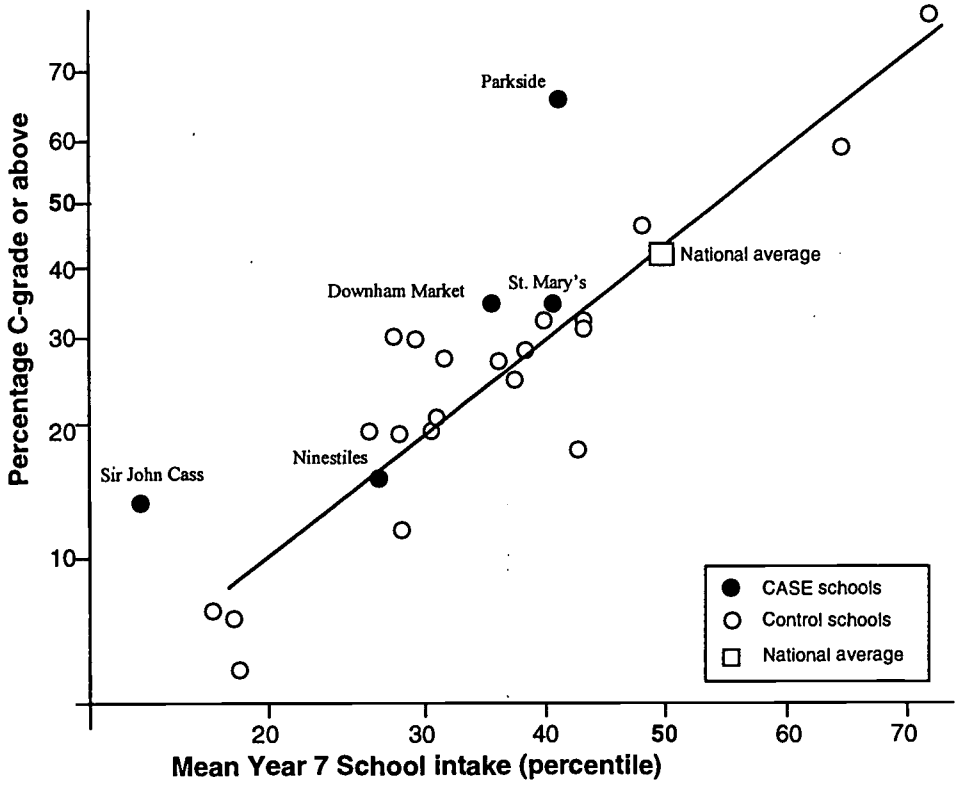
In the 1995 Key Stage 3 results just presented, it was found that the CASE intervention appeared to have affected pupils' achievement in Mathematics and English also. In Figure 5 are the corresponding results for 1996 GCSE Mathematics, and Table 5 shows the percentages of pupils obtaining C-grade and above compared with the percentage predicted in comparison with the control schools.

Table 5: Maths GCSE 1996 results for CASE schools

School	% at Grade C or above predicted	% at Grade C or above obtained
Downham Market	24	34
Sir John Cass	6	13
Ninestiles	15	15
Parkside	31	66
St. Mary's	30	34

* The National averages for 1996 GCSEs have not yet been published. All percentages have been calculated in relation to the total year 11 roll numbers. The 1995 averages were adjusted by adding 0.9% for Science, 1.7% for Maths, and -0.1% for English, these being the published differences between 1995 and 1996 for the percentage of pupils entered

Figure 5: GCSE Mathematics 1996



Averaged out over the five schools, these results are equivalent to raising the National average from 41.9% to 56.8%.

Figure 6 and Table 6 show the results for GCSE English. It can be seen that the results are more variable than for Science. Averaged out over the five schools, these results are equivalent to raising the National average from 50.3% to 65.9%.

Figure 6: GCSE English 1996

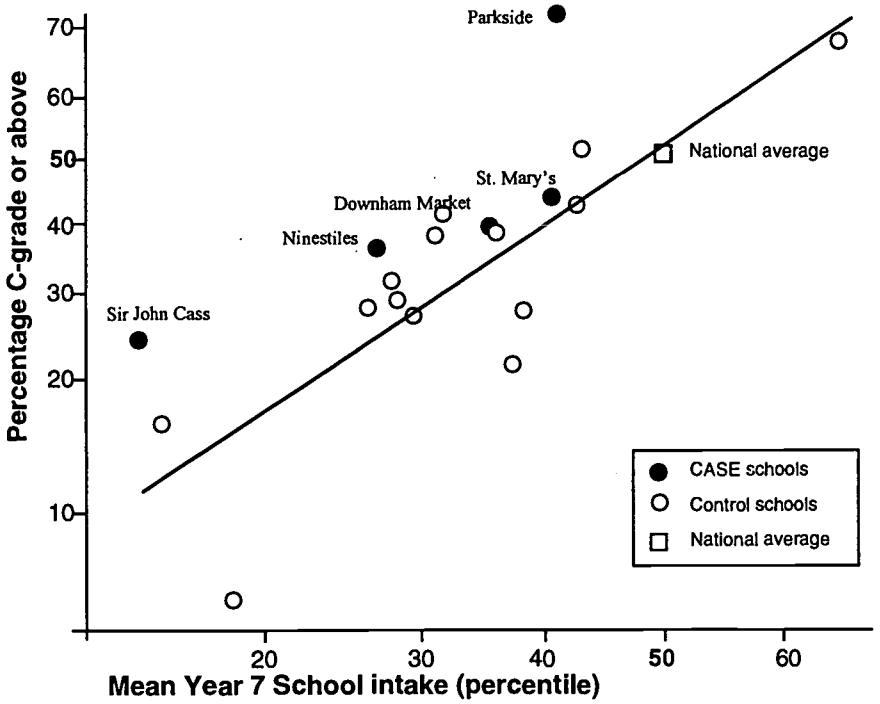


Table 6: English GCSE 1996 results for CASE schools

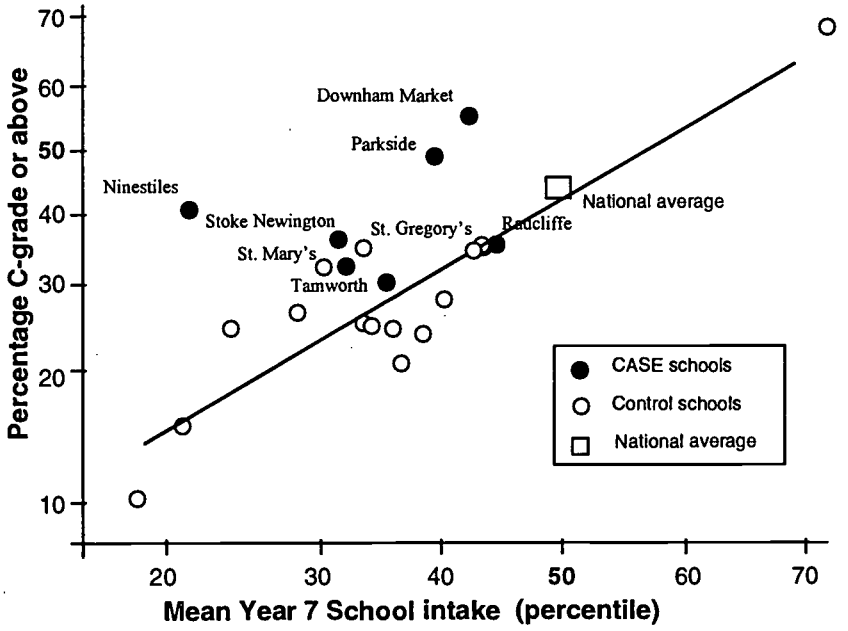
School	% at Grade C or above predicted	% at Grade C or above obtained
Downham Market	34	39
Sir John Cass	11	24
Ninestiles	24	36
Parkside	41	71
St. Mary's	40	43

With the exception of Parkside school, with whom the author has worked since 1989 and the CASE III project, it should be remembered that these GCSE results represent schools' first attempt to develop the teaching skills which promote the growth in pupils' thinking ability. By contrast, the 1995 Key Stage results were obtained from Year groups entering the schools in 1992, so the teachers were using the CASE approach for the second time, and benefiting from the experience gained already. Nevertheless, although the 1996 GCSE results for Mathematics and English are more variable than those for Science, the evidence does suggest that the pupils' learning ability was affected generally, and not just within science.

1995 GCSE results

In Figure 7 the results for seven schools are shown, of which all but Parkside began CASE with their Year 8 in 1991. There is more variation than with the 1996 results with Year 7 starts, but the overall effect is still substantial.

Figure 7: 1995 GCSE Science



In Table 7 the achieved percent C-grades and above are compared with their predicted values in comparison with the controls.

Table 7: Science GCSE 1995 results for CASE schools

School	Mean percentile of 1991 intake	% at Grade C or above predicted	% at Grade C or above obtained
Parkside	39	30	49
Downham Market	42	33	55
Radcliffe	43	34	35
Ninestiles	21	13	40
St. Mary's	32	23	32
St. Gregory's	44	36	35
Stoke Newington	32	22	36
Tamworth Manor	35	26	30

When these results are averaged, they are equivalent to raising the National average C-grade and above in Science from 42.8% to 56.8%

In Figure 8 the corresponding results for Mathematics are shown. In Table 8 these results are compared with the results predicted by comparison with the control schools.

Figure 8: GCSE Mathematics 1995

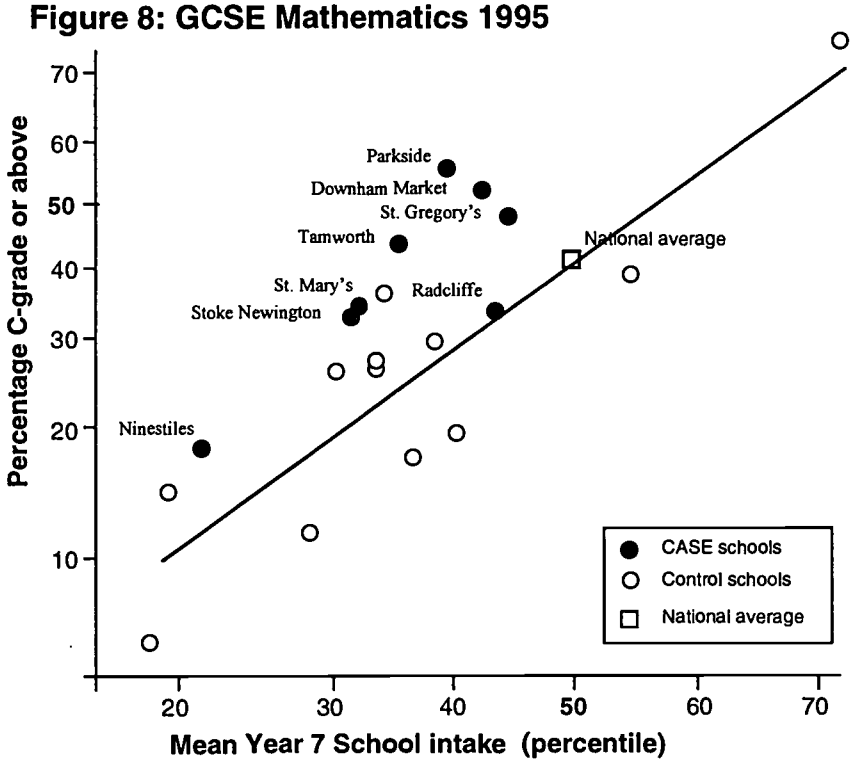


Table 8: Maths GCSE 1995 results for CASE schools

School	% at Grade C or above predicted	% at Grade C or above obtained
Parkside	28	56
Downham Market	31	52
Radcliffe	32	34
Ninestiles	11	18
St. Mary's	20	35
St. Gregory's	34	48
Stoke Newington	20	29
Tamworth Manor	24	44

When these results are averaged, this is equivalent to raising the National average from 41% C-grade and above to 58.2%.

In Figure 9 the corresponding results for English are shown. In Table 9 these results are compared with the results predicted by comparison with the control schools.

Figure 9: 1995 GCSE English

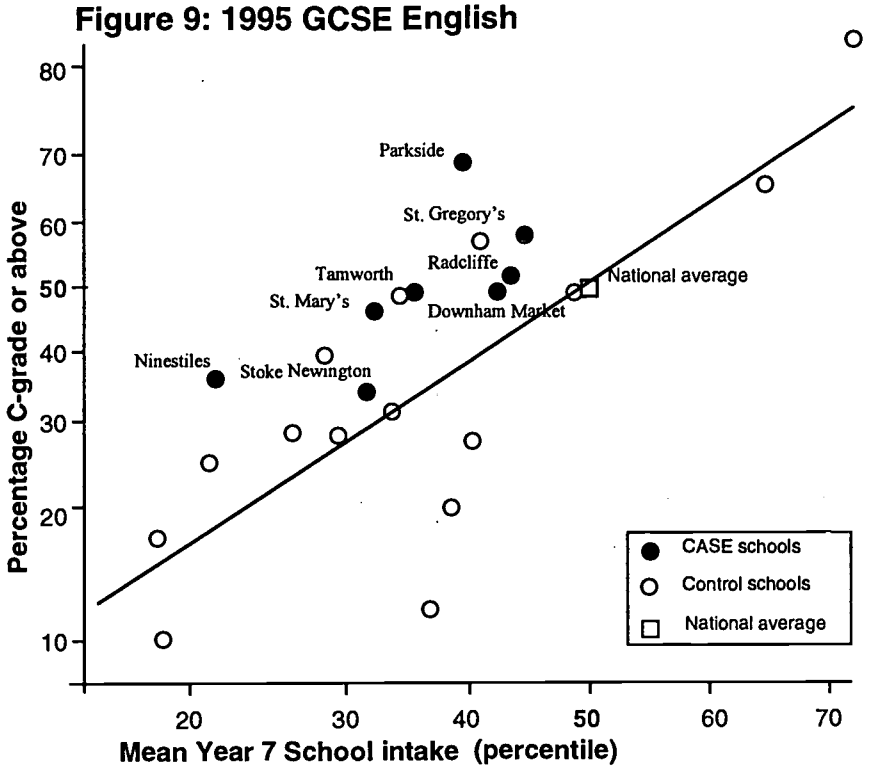


Table 9: English GCSE 1995 results for CASE schools

School	% at Grade C or above predicted	% at Grade C or above obtained
Parkside	38	69
Downham Market	41	50
Radcliffe	43	52
Ninestiles	18	36
St. Mary's	30	46
St. Gregory's	44	58
Stoke Newington	29	34
Tamworth Manor	33	49

When these results are averaged, this is equivalent to raising the National average from 50.4% C-grade and above to 65.8%.

1996 Key Stage 3 results

Finally, this summer's Key Stage 3 results for National tests on 14 year-olds are quite similar to the ones presented earlier for 1995. Since the National data for Key Stage 3 has not yet been published, the figures contain the 1995 averages. In the case of science, and even more in mathematics, it looks as though the 1996 averages will be higher, unless our sample of control schools themselves are performing at an above-average level.

Figure 10 and Table 10 present the 1996 data for Science.

Figure 10: Key Stage 3 Science 1996

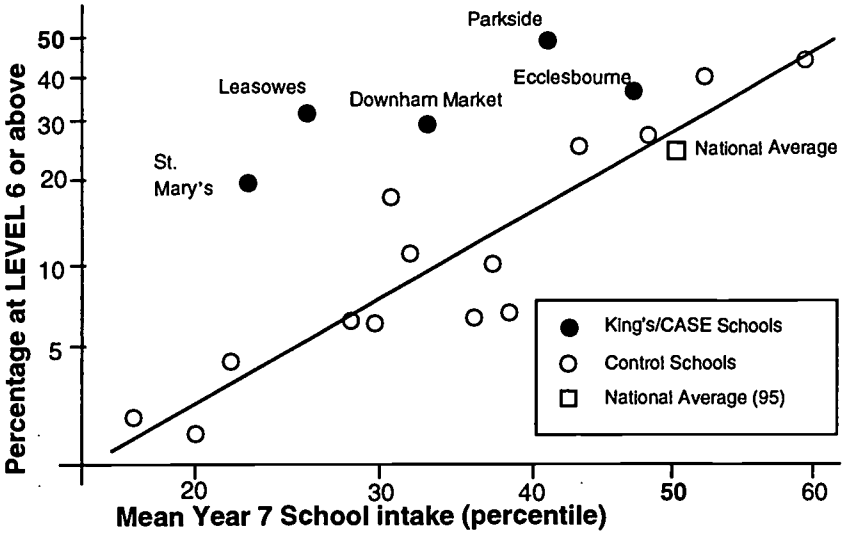


Table 10: Science Key Stage 3 1996 results for CASE schools

School	Mean percentile of 1993 intake	% level 6 or above predicted	% level 6 or above obtained
Downham Market	33	10	30
Parkside	41	17	49
St. Mary's	22	4	20
Ecclesbourne	47	24	37
Trainer school			
Leasowes	26	6	32

When these results are averaged, they are equivalent to a raising of the National average at level 6 or above from 25% to 59.5%

Figure 11 and Table 11 present the 1996 data for Mathematics.

Figure 11: Key Stage 3 Mathematics 1996

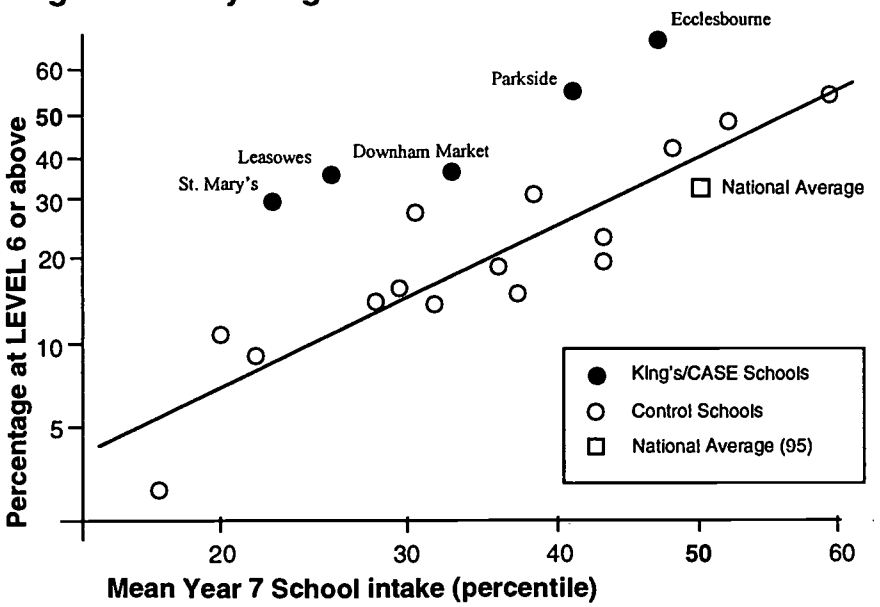


Table 11: Mathematics Key Stage 3 1996 results for CASE schools

School	% Level 6 and above predicted	% Level 6 and above obtained
Downham Market	17	37
Parkside	27	56
St. Mary's	8	31
Ecclesbourne	36	67
Trainer school		
Leasowes	10	36

When these results are averaged, they are equivalent to a raising of the National average at level 6 or above from 33% to 65.8%

Figure 12 and Table 12 present the 1996 data for English.

Figure 12: Key Stage 3 English 1996

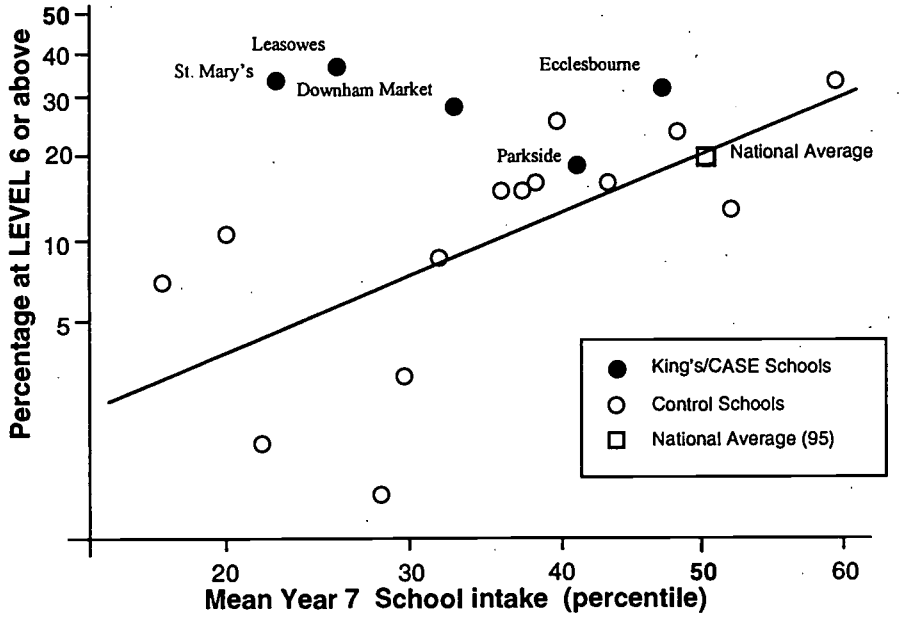


Table 12: English Key Stage 3 1996 results for CASE schools

School	% Level 6 and above predicted	% Level 6 and above obtained
Downham Market	8	29
Parkside	13	19
St. Mary's	4	34
Ecclesbourne	19	32
Trainer school		
Leasowes	5	37

When these results are averaged, they are equivalent to a raising of the National average at level 6 or above from 20% to 54.5%.

Conclusion

Overall, about 4,500 pupils in the CASE schools have featured in the data in this report. Seventeen schools' data have been compared with added-value data from a greater number of control schools. This represents a sample large enough to test the feasibility of raising standards in schools by concentrating on enhancing thinking skills in the first two years of secondary education. Not all the schools embraced the CASE training with open arms gladly; not all the science teachers even in the schools reporting good results put in an equal effort to mastering the new teaching and class-management skills required.

Yet we have shown that the CASE methodology, even when tried for the first time, has produced an average increase of the order of half as much again in the percentage of pupils obtaining C-grade and above at GCSE (e.g. an increase from a National average of 44 to 63% for Science in 1996, and an increase from 43 to 57% in science for 1995). There was the same relative order of increase in achievement in mathematics and a somewhat lower improvement, though still substantial, in English.

Even more striking are the Key Stage 3 National test results. Here the teachers have had two or more previous years of experience to draw on, and hence this represents a test of the CASE methodology after they have developed their skills. The schools have more than doubled the proportion of their pupils showing National Curriculum achievement at level 6 or above, in all three subjects . These enhanced results at 14 must predict a corresponding increase in success at GCSE two years later.

Thinking Science (TS) requires three things from teachers. Over a two-year period they teach some 30 ***TS*** activities, designed to focus on key reasoning patterns which underlie different aspects of science. During this time they also modify their ordinary science lessons to highlight the reasoning patterns pupils have met already in ***Thinking Science***. Finally they learn to use the class-management skills developed in ***TS*** activities together with their other science teaching skills in their planning and conduct of all their lessons. It is the combination of all three processes which we believe is responsible for the large effects on pupils' learning ability. There is thus a source of new teaching art which demonstrably delivers on school achievement, and which almost certainly is only the first word in something very important for school practice. Indeed the author of this report has already spent the previous three years researching the feasibility of placing a corresponding thinking skill intervention within the context of school mathematics (Cognitive Acceleration in Mathematics Education projects, funded by Leverhulme Foundation, Esmée Fairbairn Trust and the ESRC). I think we would claim that in the CASE approach we have married an equal emphasis on a structured approach to the specifics of a school subject with a use of collaborative learning by pupils. But the detail of how it is done, and most particularly how teachers can be supported in developing the necessary art, would need more space than is available here.

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