An evaluation of a two year cognitive intervention programme in technology education for Key Stage 4

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Introduction

We reported (in Vol. 1 No 2 1996) an interim evaluation of the effects of a small-scale cognitive intervention programme in technology. The subjects in this study were 120 Year 10 students (15+) attending a girls comprehensive school in an inner London Education Authority. The students were randomly placed in eight all ability classes according to the normal school practice and policy. Three experimental classes (45 students) and five control classes (75 students) were identified. The new head of design and technology had targeted this year group in order to try to raise achievement of a group of students in a domain which had not previously performed as effectively as had been expected.

The teacher would be taking the three experimental groups designated 10.1, 10.2, 10.5. Two other teachers would have the responsibility of teaching the five control classes. Unfortunately we were unable to establish a control group being taught by the teacher of the experimental groups.

The model that was adopted for the study utilised principles from Cognitive Acceleration through Science Education (CASE) (the five pillars), from Instrumental Enrichment and from the Somerset Thinking Skills project. The essential feature of the study was to concentrate on enhancing the students' thinking, reasoning and problem solving capability with the teacher acting as a mediator and director of the activities and of the discussion that occurred. (For details see pp 121-124 Vol. 1 No 2 1996).

The results suggested that the intervention was having a positive but modest effect in technology achievement on the experimental classes, but that there was little or no effect in other areas of the curriculum that we were investigating.

This article is a follow-up to the original paper and presents further data showing the effects of the intervention after the full two years of the programme. The subjects, design and methodology adopted throughout this project are described in the original paper (Hamaker et al 1996).The established groups with their corresponding teachers are summarised in Table 1.

Each of the experimental classes had one core technology lesson replaced by an intervention lesson each fortnight. Class 10.2 had a further graphical communication option replaced by an intervention lesson each fortnight. The five control classes received a normal allocation of technology core and option lessons. The tests and measures used for analyses are similar to that already described (Hamaker et al 1996). Further clarification on the nature of these tests and measures can be obtained from the authors of this article.

Table 1

class	exp/con	% time spent on intervention	core teacher	option teacher
10.1	experimental	12.5	teacher A	teacher B
10.2	experimental	25.0	teacher A	teacher A
10.5	experimental	12.5	teacher A	teacher C
10.3	control	0	teacher D	teacher E
10.4	control	0	teacher F	teacher C
10.6	control	0	teacher D	teacher B
10.7	control	0	teacher F	teacher F
10.8	control	0	teacher F	teacher B

Teacher A is the head of department teaching the intervention methodology in core technology with additional intervention in the graphical communication option.
Teachers D and F are NQTs teaching the core technology component to the control classes.
Teachers B,C,E, are experienced technology teachers teaching the option modules to both control and experimental classes

	Mean Exp	S.D exp	N	Mean Con	S.D.con	N	t test	sig	Effect Size
Technology	3.86	1.77	42	3.14	2.01	66	1.85	p<.05	0.36
Science	5.10	1.68	42	4.82	1.75	66	0.83	ns	0.16
Maths	3.86	1.76	42	3.27	1.94	66	1.74	p<.05	0.34
English	5.43	1.33	42	5.23	1.47	66	0.54	ns	0.11
English Lit	5.21	1.37	42	5.11	1.50	66	0.36	ns	0.07
PRT	7.08	0.98	42	6.36	1.04	66	3.56	p<.0005	0.71
PRT pre-testt	6.49	1.05	42	6.42	1.16	66	0.32	ns	0.07

Each individual pupil's GCSE grade was transformed into an associated number for purposes of analysis. Thus grade A*/A = 8; B=7; C=6 etc and the overall mean grade and standard deviation computed for each of the above subjects for the experimental and control groups.
The scale for the PRT is different from GCSE scores since it is a form of psychometric test. Individual scores relate to Piagetian stages. Thus a score of 7 = early formal operational level; a score of 4 = early concrete operational level.

Table 2: Comparison of experimental versus control groups on GCSE results (t-test for unmatched groups)

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Results

Table 2 shows the tests for statistical significance for the difference between the means for the experimental versus the control groups (the t-test for unmatched groups). The computed Effect Size is also reported.

The results on the Piagetian test suggest that the experimental group have made a large gain (0.71σ on the test) when compared to the control group. This evidence supports the overall intervention intention, but unless increased thinking ability, as assessed by psychological tests, is accompanied by subsequent increased learning and achievement, there would be a strong suspicion that this intervention was simply 'teaching-to-the-test'.

Further inspection of Table 2 suggests that a modest significant gain has been made in technology GCSE 0.36σ:$p < .05$) and in mathematics GCSE (0.34σ: $p < .05$) for the combined experimental groups compared with the combined control groups.

The results for science and English are positive in each case, but are suggesting that little or no far transfer effects are apparent in these subjects. This is a similar trend to that obtained after one year.

A residual gain analysis was performed in order to compare the individual experimental and control classes as validly as possible using all of the available data that had been collected.

Because technology correlates with the Piagetian pre-test (for controls), we believe that the PRT is just as good an estimate of initial ability (probably better, as technology performance is linked also to personal predilection for the subject) as might have been a technology pre-test. The results for each class are compared and assessed by relating them to the range of abilities of the students prior to the start of the intervention in a similar manner as described previously (Hamaker et al 1996). This type of analysis allows us to establish a baseline from which to analyse possible value added effects. Individual class effects are shown in Table 3.

Inspection of the data suggests that in general, each of the three experimental classes is showing modest gains in technology GCSE and in mathematics GCSE when compared to the control classes. These gains for individual classes are not significant at the 0.05 level. Experimental class 10.5 is also showing a modest significant effect in English (0.56σ: $p < .025$).

All three experimental classes are showing significant gains on the Piagetian test. Class 10.2 is showing the largest effect. (It should be restated that this class received twice as many intervention lessons as the other two

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Table 3: Effect Sizes for individual experimental versus control classes (Residual Gain Analysis)

class	technology	science	maths	english	eng lit	PRT	N	
10.1	0.23	0.11	0.25	-0.10	0.04	0.64	12	experimental
10.2	0.26	0.10	0.25	-0.13	-0.07	0.82	15	classes
10/5	0.36	0.19	0.32	0.56	0.16	0.53	15	
10.3	-0.21	-0.40	-0.24	-0.51	-0.29	0.17	16	
10.4	0.02	0.07	-0.04	0.20	-0.02	-0.02	13	control
10.6	-0.29	0.19	0.16	0.17	-0.11	-0.19	13	classes
10.7	0.25	0.11	0.04	0.07	0.18	-0.17	13	
10.8	0.34	0.14	0.16	0.22	0.37	0.19	11	
overal	0.29	0.14	0.28	0.13	0.06	0.66		exp v con
sig	< .05	ns	< .05	ns	ns	< .0005		

Effect Sizes have been computed for subjects in each individual class. These are expressed in units of standard deviation. Positive effect sizes suggest gains, negative effect sizes suggest regression.
Statistical significance has been computed and reported for effects for the groups overall.

experimental classes). This is a similar trend to that found in the interim study. Control classes 10.7 and 10.8 are showing an effect in technology comparable to those for the experimental classes. These reported results are not found to be statistically significant.

Taken as two whole groups, an experimental and control group, the effects for the experimental group is now significant for the Piagetian test, technology GCSE and mathematics GCSE and is of the same order as one would expect when compared to the results of the t-test for unmatched groups, reported in Table 2.

Are these results suggesting that the intervention has had an effect? The Piagetian test scores for class 10.2 suggest that the intervention has had an effect on the cognitive development of the students in that class. Has the intervention pushed up technology scores?

To try to answer this question we decided to investigate whether there was a correlation between technology GCSE scores and differences between pre and post test Piagetian test scores (A copy of the scatterplot of this data can be obtained from the authors). The results did not yield a simple case of correlation, however. Some of the lower ability students did show gains on the Piagetian test, but they were not enough to put them in contention for higher technology grades. Furthermore, relative to the control group, there was a suggestion that for GCSE grade E and above, the Piagetian gains pushed up the experimental group technology grades. Thus, there appears to be some evidence that the intervention has had the effect of pushing up technology grades but only for some of the students!

Table 4 reports the percentage of students in each group that achieved the highest grades (A to C) in each of the subject domains under investigation. Included in this table for comparison is the percentage of students in each group that achieved five or more A to C grades in all subjects taken at GCSE together with the percentage of students who were operating above level 7, as assessed using the Piagetian pre-test, prior to the commencement of the intervention study. A score above 7.0 on the Piagetian test suggests that a student is well into formal operational thinking. To achieve five or more A-C grades at GCSE requires a student to exhibit the type of thinking and reasoning synonymous with formal operational thinking (Adey, P and Shayer, M 1994)

GCSE Subject	Control (N=66)	Experimental (N=42)
Technology	26%	45%
Science	30%	38%
Maths	17%	24%
English	44%	45%
E Literature	29%	36%
Percentage obtaining 5 or more A to C grades	30%	35%
Percentage at PRT level > 7.0 on pre-test before intervention study	26%	14%
Mean PRT pre-test scores	6.42	6.49

The individual subject percentages at GCSE (A - C grades only) are shown for the overall control and experimental groups. The percentage of pupils above Piagetian level 7.0 prior to the start of the intervention study is shown for comparison. The pre-test PRT scores are also included for comparison purposes.

Table 4: Percentages of students in each group achieving A-C grade in each subject

Inspection of the control group is somewhat revealing. The percentage of students achieving five or more A-C grades is 30%. The percentage of students well into formal operational thinking, prior to the commencement of the intervention study, is 26%. A similar pattern is observed for the percentage of students achieving individual grades A-C: technology (26%); science (30%); English literature (29%). However, for English language and mathematics this pattern has changed.

In all subjects other than English language, the experimental group is showing a greater percentage of students achieving grades A to C. However, inspection of the Piagetian pre-test percentages reveals that more students in the control group were capable of using formal operational thinking prior to the commencement of the intervention study, despite the fact that, as Table 2 reports, the mean Piagetian pre-test score for the control group is not significantly different from the score for the experimental group.

Now, let us hypothesise that for the control group, those students that achieved five or more grades A to C at GCSE were those same students that were using formal operational thinking as measured through the Piagetian pre-test prior to the commencement of the intervention study. It could be argued that such students are already at the level whereby they would benefit from 'normal' school instructional techniques. Any intervention methodology may not benefit such students to the same degree as it might for students operating at a concrete level as measured on the Piagetian pre-test. One of our original questions was to investigate whether the intervention could enhance information processing capability. Moving students from a concrete level to a formal level is an example of such enhancement.

We then investigated the possibility that the intervention had had a ceiling effect and that the more able student was not showing as large a gain, if at all, relative to the average or below average student. (Copies of this scatterplot can be obtained from the authors). Inspection of the data revealed that for the experimental group large gains had been made by students operating below level 7.2 as measured by the pre-test when compared to the control group. There is a suspicion here that there is a ceiling effect and that the intervention may have had a far greater effect on those students whose Piagetian pre-test level was below level 7.2. This may be a function of the particular intervention style that we adopted. The suspicion is that our intervention has had a minimal effect on the higher level thinkers (as well as having a negligible effect on the lower ability students as we have hinted).

In order to investigate further the magnitude of these gains it was decided to analyse the data after removing those students from both the experimental and control groups that had scored above level 7.0 on the Piagetian pre-test, prior to the commencement of the intervention study.

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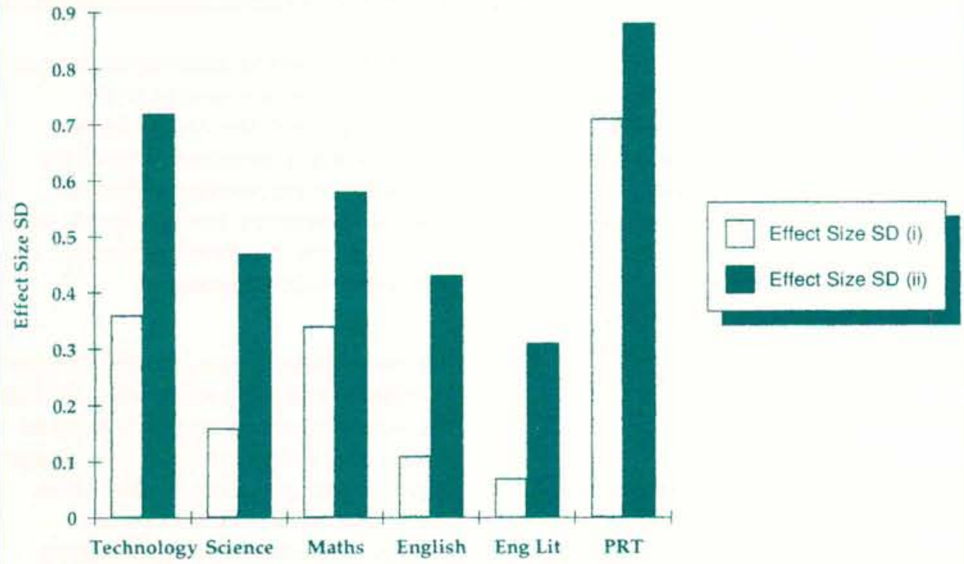
Table 5: Comparison of experimental versus control groups on GCSE results after removal of students > level 7.0 (t-test for unmatched groups)

	Mean Exp	S.D.exp	N	Mean Con	S.D. con	N	t test	sig	Effect Size
Technology	3.82	1.89	36	2.53	1.73	49	3.24	< .005	0.72
Science	3.91	1.74	36	3.20	1.31	49	2.13	< .025	0.47
Maths	2.61	1.77	36	1.69	1.47	49	2.60	< .005	0.58
English	4.30	1.33	36	3.84	1.31	49	1.92	< .05	0.43
English Lit	4.15	1.33	36	3.74	1.34	49	1.39	<.1	0.31
PRT	6.75	0.72	36	6.04	0.86	49	3.99	<.0005	0.88

Each individual pupil's GCSE grade was transformed into an associated number for purposes of analysis. Thus grade A*/A = 8; B=7; C=6 etc and the overall mean grade and standard deviation computed for each of the above subjects for the experimental and control groups.
The scale for the PRT is different from GCSE scores since it is a form of psychometric test. Individual scores relate to Piagetian stages. Thus a score of 7 = early formal operational level; a score of 4 = early concrete operational level.
Effect Sizes are reported in units of standard deviation.

Figure 1: Comparison of experimetnal group gains before (i) and after (ii) removal of students > level 7.0



The dark bars represent the effect scores in favour of the experimental classes after the removal of the more able student as measured by the Piagetian pre test.

The lighter bars represent the effect scores in favour of the experimental classes without the removal of the more able student

Table 5, displayed as Figure 1, reports the t-test for unmatched groups after the removal of these more able students. Positive significant gains can now be detected in all subjects although for English literature they are only significant at the 10% level. The positive gains are now much greater, suggesting that the average student has benefited enormously from the intervention.

The data for individual classes was analysed after the removal of such able students. The results are shown in Table 6 and displayed as Figure 2.

Inspection of Table 6 reveals a slightly different picture to that in Table 5. The individual experimental classes are all showing significant gains in technology and in the Piagetian test. Whilst all three are showing gains in mathematics, only class 10.2 is showing a large significant gain. A similar result occurs for science, with a significant gain for class 10.2. The results for English language and English literature, whilst positive, suggest that little transfer has occurred for classes 10.1 and 10.2 although the result for class 10.5 is significant. This is not too surprising since

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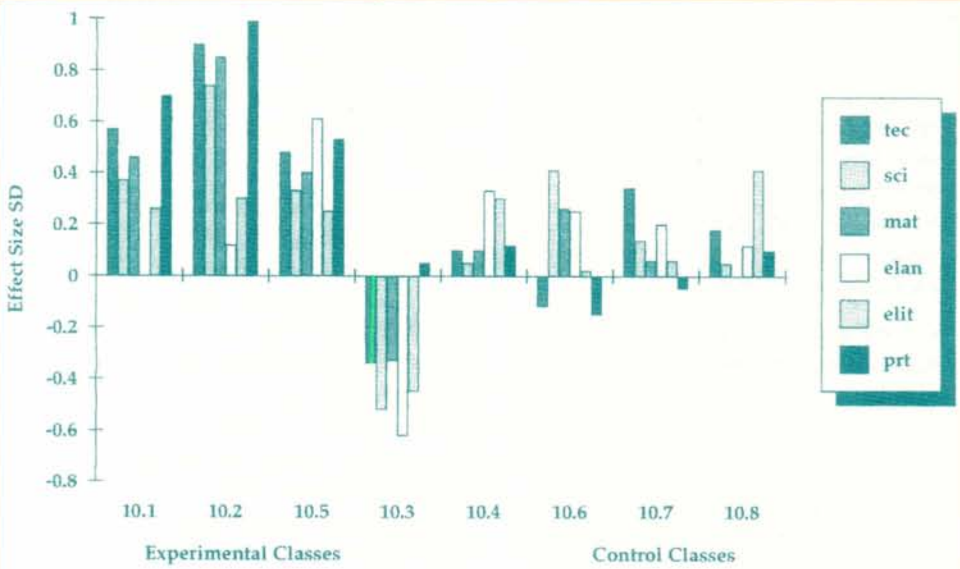
Class		technology	science	maths	english	eng lit	prt	N
10.1	exp	0.57, (p <.05)	0.37,(ns)	0.46, (p<.1)	0.00, (ns)	0.26, (ns)	0.70, (p<.025)	11
10.2	exp	0.90, (p <.01)	0.74, (p< .025)	0.85, (p<.01)	0.12, (ns)	0.30, (ns)	0.99, (p<.005)	11
10.5	exp	0.48, (p<.05)	0.33, (ns)	0.40, (p<0.1)	0.61, (p<.025)	0.25, (ns)	0.53, (p<.05)	14
10.3	con	-0.34, (ns)	-0.52, (.05)	-0.33, (ns)	-0.62 (p<.025)	-0.45, (p<0.1)	0.05, (ns)	13
10.4	con	0.10, (ns)	0.05, (ns)	0.10, (ns)	0.33, (ns)	0.30, (ns)	0.12, (ns)	7
10.6	con	-0.12, (ns)	0.41, (p=0.1)	0.26, (ns)	0.25, (ns)	0.02, (ns)	-0.15, (ns)	11
10.7	con	0.34, (ns)	0.14, (ns)	0.06, (ns)	0.20, (ns)	0.06, (ns)	-0.05, (ns)	11
10.8	con	0.18, (ns)	0.05, (ns)	0.00 (ns)	0.12, (ns)	0.41, (ns)	0.10, (ns)	7
overall		0.62	0.46	0.54	0.29	0.25	0.70	36
sig		> .0005	>.005	.005	>.05	>.1	>.0005	

Effect Sizes have been computed for subjects in each individual class. These are expressed in units of standard deviation. Positive effect sizes suggest gains, negative effect sizes suggest regression.
Statistical significance has been computed and reported for individual class effects and for the groups overall.



This figure allows the data from table 6 to be displayed in the form of bar charts in order to give a better visual comparison of the experimental classes with the control classes

From above, the first three classes are labelled as the experimental classes, the remaining five are the control classes

Above: Table 6: Effect Sizes for individual experimental versus control classes after removal of students > level 7.0 (Residual Gain Analysis)

Left: Figure 2: Graph of Effect Sizes for Experimental v Control classes after removal of students > level 7.0

the literature suggests that far transfer would be expected at least one year or more after the completion of the intervention (Adey, P and Shayer, M 1994)

Control class 10.3 is showing regression in all GCSE subjects, significant for science and English. The suggestion here is that the three experimental classes have made consistently higher scores in technology, science, maths and in the Piagetian test compared to the controls. The evidence for English language and English literature is less conclusive. Overall, these results are showing an order of magnitude similar to that obtained for the t-test in Table 5.

Discussion

In this small-scale study, we set out to investigate whether the intervention could answer the following three questions:

- Would such an approach actually improve their general information processing capability?
- Would such an approach improve their technology capability?
- Would such an approach allow for transfer into other areas of the curriculum?

The results are somewhat suggestive. The Piagetian test results are suggesting that more students have moved from a concrete operational level to a formal operational level of thinking and that this gain has allowed some students to improve their technology GCSE grades. These results also suggest that the intervention has had less of an effect on both the more able and less students. Our hypotheses are that

- the more able students were already operating at a level that would already allow them to benefit from normal effective class instruction and that our intervention is affected by a ceiling effect, due to the function of our particular design, and
- the less able students did show cognitive enhancement but it was not sufficient to put them in contention for better GCSE grades.

Class 10.2 received twice as much intervention compared to classes 10.1 and 10.5. The results shown in Table 6 suggest that they have really benefited since their gains in technology, science and maths are nearly twice the order of magnitude compared to that of the other experimental classes. There is strong evidence here, we believe, that the effect is due to the intervention.

The results for science and mathematics suggest that in the short term there is some evidence of far transfer, whilst the results in English language and literature are less conclusive. Again, the results for science and mathematics are surprising as one would not expect such transfer until much later.

The students remained in these classes for technology only. They were grouped differently for science and mathematics and remained in their individual tutor groups for English language and literature. This is important since one could argue that such gains could be due to a Hawthorn type effect; that the enthusiasm and commitment of the teacher of the experimental classes towards special 'brain training' lessons, and this enthusiasm being conveyed to the students, was responsible for their apparent enhancement in technology rather than through the nature of the intervention lessons themselves. This is less likely to be the case with students being scattered amongst a number of different teachers for their different subjects. As one colleague commented "If it is due to a Hawthorn effect, then schools should introduce more Hawthorn effects." Whilst not agreeing with such a conclusion, we understand such sentiments! However, the results for class 10.2 suggest that with more intervention, the effect became greater, thus suggesting that the intervention was responsible for these gains.

The results reported here show a similar pattern to those reported from the one year interim evaluation reported elsewhere (Hamaker et al 1996), thus suggesting that the intervention was beginning to have an effect much earlier than even we had expected. We reiterate that the intervention lessons were not additive (i.e. in addition to) but replaced normal technology lessons as already described. Further evidence that the intervention has had a significant influence on the apparent enhanced scores.

The results for those students who were well below average on the Piagetian pre-test suggest there is an argument for introducing such a methodology earlier into the school curriculum in a similar way to the CASE project in science. The results for those students deemed above average on the Piagetian pre-test suggest that activities establishing a greater degree of cognitive challenge (or cognitive conflict) need to be designed as well as starting such an intervention at an earlier period of their schooling. Having argued thus, is it possible to isolate those aspects of the intervention mainly responsible for these apparent gains? The basic answer is no. We did not set out to investigate this and did not establish the required controls to answer this question.

The experimental class teacher attempted to utilise all of the principles of the intervention methodology in each lesson. Early observations of this teacher failed to filter out any particular aspect of the classroom methodology as a dominant feature, although subsequent observations during the second year of the intervention were made less frequently.

If anything the weakest aspect of the intervention, as determined through initial classroom observation, was the bridging sequences. For successful bridging, the teacher should try to get the students to make explicit links into other lessons and areas of the curriculum by using the successfully generated solutions and strategies to problems encountered in the particular thinking lesson they had just experienced. This is no easy task since it requires the teacher to have some insight as to the types of procedural thinking required in other subject areas as well as their own.

However, for this particular teacher, once such a weaknesses was highlighted, the teacher would ensure that during the next intervention lesson this aspect of the methodology was incorporated. Discussion with the teacher suggested that the methodology had been internalised well by the end of the intervention.

Conclusion

We believe that these results are very suggestive. We were very apprehensive to implement such a study at Key Stage 4 in the first place on ethical grounds. If the results had suggested significant regression for the experimental classes compared to the control classes, then we would be open to criticism that such a study was ill-conceived for students about to study for important external examinations. Indeed, we are still open to such criticism, despite the suggestive nature of the results. However, as already explained, the head of department had targeted the Key Stage 4 technology curriculum as a possible area for intervention due to the previous apparent under achievement at GCSE in technology.

Our interim evaluation suggested that there was evidence of a modest effect after one year and that certainly the intervention did not appear to have a retrograde effect. That was the point of the interim evaluation and hence the decision to continue with the intervention.

The results obtained for class 10.2 after the removal of the more able students suggests that the intervention has had a considerable effect on that class and indeed further supports our belief that it has been responsible for the improved technology scores. The literature suggests that such intervention programmes are better suited to students in the earlier years of schooling. That there is a critical window of opportunity beyond which such programmes will have minimal effects if any at all (Adey and Shayer 1994). There is little evidence that programmes delivered to 15 and 16 year old children do enhance the thinking and reasoning skills of such students.

Our study was a context-dependent study which we believe to be partly responsible for the results obtained. We do not believe that the same results would have been achieved had the intervention occurred outside of a subject domain, for instance in a special 'thinking skills' slot on the school curriculum.

Our study was also designed first, by

- identifying deficient strategies and concepts from previous GCSE cohorts, and
- implementing activities that could remedy such deficiencies and lead to subsequent increased effects on achievement through technology.

We would be very interested in hearing from individuals or establishments who have reproduced similar results to this study or who would be interested in attempting to repeat such a study. We realise that this small scale study is merely suggestive and that a study similar to the CASE (II) study would greatly enhance the notion of cognitive intervention methodology in technology.

References

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If you would like a longer version of this paper including full tables and graphs of the data produced, please contact:

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