A Study into the Improvement in the Mathematical Academic Attainment of Low Attainers in Year 7 (11 – 12 year olds) when Accelerated Learning is used as a Teaching Pedagogy in the Classroom

KERRIDGE, SUSAN

Mrs Susan Kerridge

A Study into the Improvement in the Mathematical Academic Attainment of Low Attainers in Year 7 (11 – 12 year olds) when Accelerated Learning is used as a Teaching Pedagogy in the Classroom

Abstract

As a practitioner with over 20 years of classroom experience, I felt that low attainers in mathematics had a fear of failure and that this had a negative effect on the pupils' academic attainment. In order to address this I instigated a pilot study with low attainers in year 7 using accelerated learning.

The pilot study used descriptive narrative to capture the teacher's and pupils' responses and in the vignettes presented the reader will see how these fears were addressed. Statistical analysis of pupils' academic attainment demonstrated unequivocally that pupils in the experimental group had improved more than the pupils in the parallel control group.

As a researcher I realised that this warranted further investigation however, this pilot study was conducted as a practitioner and needed to be placed into a more rigorous academic framework. In this context, causes of low attainment, key theoretical principles and practical intervention strategies that address these causes are discussed. These theories and strategies are categorised under 3 key elements of environment, communication and memory. The suitability of accelerated learning as a teaching pedagogy is also discussed.

As a research practitioner I carried out two case studies and actual lessons are described capturing the teachers' and pupils' responses. Statistical analysis shows that in approximately 70% of the cases the academic attainment of the low attainers improved more than the pupils in the control group.

A toolbox that can be utilised in effective teaching and learning was developed. The tools are underpinned by the key theoretical principles and practical intervention strategies and are expressed in terms of the three key elements; environment, communication and memory.

In conclusion the pilot and case studies provide strong evidence that the mathematical academic attainment of year 7 low attainers improves when accelerated learning is used as a teaching pedagogy.

A Study into the Improvement in the Mathematical Academic Attainment of Low Attainers in Year 7 (11 – 12 year olds) when Accelerated Learning is used as a Teaching Pedagogy in the Classroom

Volume 1 of 1

Mrs Susan Kerridge

Doctorate of Education

Department of Education

Durham University

2010

Dedication

I would like to dedicate this work to my husband and best friend, Simon. He has been my rock over the last 8 years, always believing in me even when I didn't. He has picked my thesis out of the rubbish bin more times than I can remember and for this I thank him.

I would also like to dedicate this thesis to my parents, Eric and Rita Hart whose encouragement and guidance in my childhood helped to make me the person I am. I hope that I take the values they taught me into my classroom, encouraging my pupils to become confident, well adjusted adults who are no longer afraid of Mathematics.

Acknowledgements.

There are many people I would like to say thank you to for their help and advise during my doctoral studies. I would like to start by thanking the Gatsby Foundation who affording me the opportunity of putting accelerated learning in my classroom via my Gatsby Teacher Fellowship.

I would also like to acknowledge the staff at Barnard Castle School who covered my lessons when I went on courses and of course the pupils who just simply made me smile whilst I was conducting the case studies.

My supervisors, Tony Harries and Rob Coe encouraged me to complete this work and at times that was no mean feat.

Over the past few years my daughter Samantha and son Benjamin, and my grandchildren Izzy and Alex have not seen as much of me as they would have liked. Well Alex you can come over to sleep at Nana's anytime you want now.

Lastly I would like to acknowledge all of the puppy therapy that our dogs Holly and Jasmine gave me.

Contents

List of Tables

List of Figures

Declarations and Copyright

I declare that no materials in this thesis have previously been submitted for a degree in this or any other university and that the work contains no contributions from other researchers.

The word count: 86,271

Chapter 1 Introduction

This chapter describes the issues behind the thesis that led to a pilot study being conducted. It describes in brief the pilot study, the literature review, the methodology used to collect the quantative and qualitative data. The reader is given a flavour of the ethnographic case studies and the data analysis and finally an outline of the summary and recommendations chapter is given.

1.1 Background to the thesis

In education there are, according to Mayers et al (2007), two types of professionals, those who *do* teaching and those who *research into* teaching. Research practitioners aim to bridge the gap between these two professional worlds by taking the research produced by one type of professional and implement it in the classroom as the other type of professional. It is to this end that I entered into my doctorate, with the goal of taking research theory into my classroom.

My own experience over the past 20 years as a teacher has lead me to believe that low attainers in mathematics:

- have a fear of failure
- have preconceived, negative ideas from parents
- have often been taught using the same method over and over again
- have different learning styles
- have under-developed communication skills
- have poor short term memory

I felt that these issues had a negative effect on the pupils' academic attainment and I wanted to try to find a teaching pedagogy that might address this. All of this was merely my own view and was not based on any academic research, i.e. I was a practitioner.

1.1.1 **Accelerated Learning**

I had recently been on an INSET course for accelerated learning provided by Sunderland County Council. The course was based on Thinking Maths, Cognitive Accelerated Maths Education, (CAME, Adhami et al, 1998) and I realised that this might benefit the low attainer groups that I taught. It advocated a supportive learning environment in which pupils were encouraged to go out on a limb even though this might mean that they got things wrong, addressing their fear of failure.

Because of the multi-activity approach to teaching that accelerated learning advocated, pupils could access new knowledge in a way suitable for them and pupils were not taught using the same method over and over again. An example of one of these approaches was to use a 'recall and retention' strategy such as asking 5 – 10 questions as the introduction to the lesson. Further details on 'recall and retention' and how this technique was actually used in the classroom can be found in the pilot study chapter.

Teachers facilitate different learning styles through the main 'activity' for the lesson and pupils are encouraged to 'demonstrate' their knowledge during the lesson. Again these activities and methods of demonstration will be discussed in the pilot study chapter.

As a consequence of the course, I decided to use accelerated learning as a teaching pedagogy in my classroom with low attainers. I had taught using accelerated learning during an OFSTED inspection lesson where the pupils were told that they were ‘not doing maths’, and the assessing inspector had mistaken these pupils for high flyers, as we will see in the pilot study chapter. As a consequence of this successful lesson and other similar experiences, I applied for and was awarded a Gatsby Teacher Fellowship to develop four accelerated learning units specifically written for low attainers.

1.1.2 Gatsby Teacher Fellowship

The four purpose written accelerated learning units that I developed during my Fellowship year were based on the main mathematics curriculum strands of Number, Algebra, Shape and Space and Data Handling. The topics focused on had been identified by the DfES (2003) as among those that were habitually misconceived by pupils. It would seem that these misconceptions had their roots going back many years as I had heard many times at parents evenings things such as ‘I wasn’t very good at maths’ and ‘I can not help her with her homework as I never understood algebra at school’. Consequently in the development of these units I also addressed the preconceived negative ideas from parents changing ‘I can’t’ into ‘I can’.

These four units were used as a starting point for the pilot study described in this thesis and were subsequently used to complement the overall accelerated learning pedagogy adopted.

In the following section I will describe the structure of the thesis with some brief examples that give an insight into the contents of the chapters and the claims and evidence they contain.

1.1.3 The Pilot Study

The pilot study is approached from a practitioner's viewpoint. It was conducted in order to alleviate the fears previously detailed, that I felt pupils had of mathematics, by using accelerated learning as a teaching pedagogy.

A narrative approach is used in the pilot study describing classroom scenarios where the accelerated learning pedagogy is implemented. It uses 7 stages plus a supportive environment and these stages and environment are described in detail in the pilot study chapter.

Pupils in the pilot had taken internal school's examinations at Christmas 2003 and this data was used to measure any improved academic attainment. This was achieved by comparing KS2 SATs results used as a starting benchmark, against the pupils' internal Christmas 2003 examinations results.

At this stage the pilot study did show that the low attainers had improved their academic attainment and although this was not the main aim of the pilot study, it warranted further investigation. However, these results were based on the practitioner's viewpoint and in order to change this into a research practitioner's stance and hence put the thesis into an academic framework issues that needed to be clarified are identified.

The literature review and methodology chapters address these issues and provide a framework within which 2 detailed case studies are carried out. The following gives a brief description of each of these chapters.

1.1.4 The Literature Review Chapter

In the literature review chapter we will see a discussion on why low attainers was chosen as the label to be used to describe the pupils in the experimental groups. This is followed by a discussion on definitions of low attainers, with the actual definition to be adopted in the thesis being decided upon.

Next causes of low attainment are discussed and key theoretical principles and practical intervention strategies are suggested as a means of addressing these causes in the classroom.

The historical background to how accelerated learning came into being is then given and it will be shown that this teaching pedagogy is underpinned by the key theoretical strategies and practical intervention strategies shown to address the causes of low attainment. Next we will see how CAME is also underpinned by these principles and strategies.

And finally we will see the categorisation of the key theoretical principles and practical intervention strategies under the three key integral elements of:

- Environment
- Communication
- Memory

1.1.5 The Methodology Chapter

The methodology chapter discusses options for data collection and suggests that a mixed methods approach should be adopted in particular triangulation is to be provided via ethnographical narrative, documents and archival records. This approach is used in the case study chapter.

However as the hypothesis poses a question about improved attainment, a method of measuring this had to be found. In the methodology chapter it is suggested that improved attainment can be measured in a summative way, by comparing initial and final examination results. Here the KS2 SATs are agreed upon as a standardised summative assessment benchmark against which potential improved attainment can be measured. The school in the case studies also had an entrance test and this was used as a second summative benchmark.

The data provided from these examinations will be statistically analysed by calculating the mean, standard deviation, scatter graphs, ANOVA and linear regression.

In order to attribute the improved academic attainment to accelerated learning other large case studies that demonstrate academic improvement in the 3 themes of communication, environment and memory are discussed and compared. This discussion aims to identify links between the 3 elements, identified as under-pinning accelerated learning, and improved attainment.

1.1.6 The Case Studies Chapter

A mixed methods approach is used in this chapter beginning with an ethnographical narrative to discuss and describe some of the actual accelerated learning lessons in case studies. A statistical analysis is performed in order to ascertain whether the low attainers have improved their academic attainment when compared against the control group.

The case studies are described under section headings of the 3 key elements environment, communication and memory. In these sections details of how the negative beliefs held by the pupils can be found, often in the form of pupils' responses, e.g. in the communication section open ended questions are posed and pupils' responses to these are described. Detailed narratives are provided in which peer to peer communication is described and it is shown how this affects the learning of the group

Examples of how the environment was used to allay the fear of failure, and to address the preconceived negative beliefs from parents are described in this chapter. It also describes how questioning techniques were used in the classroom and how reward systems can be influential in changing the negative to positive.

Memory strategies used in the classroom are also discussed in this chapter and examples are detailed, e.g. the use of posters. It also shows how formative assessment was used to inform the teaching and learning and this is described through narrative examples where the teacher's and pupils' responses are captured.

Summative assessment is used in order to produce the quantative data on which statistical analysis was performed. In this statistical analysis is carried out comparing the attainment of the control group against the experimental group (or groups), in order to ascertain if the intervention had had any statistically significant effect on attainment.

Data from the case studies is checked for normal distribution. This included the initial data for the case studies, i.e. the KS2 SATs and the school's entrance test results. The internal examinations, both Christmas and summer results were used as final data against which the initial data was compared. The mean and standard deviation is analysed followed by ANOVA and linear regressions.

The results from the ethnographic study and statistical analysis showed an improvement in the academic attainment of the low ability pupils. Other studies on communication, environment and memory that demonstrated improvement in academic attainment were then compared and contrasted with the pilot and case studies in order to address the hypothesis that:

'The academic attainment of low attainers in year 7 (11 – 12 year olds) improves when accelerated learning is used as a teaching pedagogy in the classroom'

1.1.7 Summary and Recommendations Chapter

In this chapter the implications for teaching and learning of low attainers in mathematics are described by linking the findings from the case studies to the key theoretical principles and practical intervention strategies shown to address the causes of low attainment.

A toolbox matrix is developed showing how various tools can be used within the 7 stages of accelerated learning across the key elements of environment, communication and memory. Specific recommendations of the three most important tools are suggested of small white boards, scaffolding and group work.

The limitations of the study are then discussed and suggestions for further research are made under the headings of the whole school, the teacher and the pupils.

1.2 Summary

The pilot study was conducted as a practitioner using accelerated learning, to allay pupils' fears of mathematics. Consequently it was realised that the low attainers' academic attainment had improved.

The suggestion that the academic improvement had been made due to accelerated learning being used as a teaching pedagogy in the classroom is made at the end of the pilot study.

In order to put these findings into a research practitioner's arena, more rigorous research was undertaken in the form of in-depth case studies. This lead to the following research questions being asked:

- Who are low attainers (the subjects of the experiment)?

- What is learning and in particular why is accelerated learning a suitable pedagogy for the experiment?
- What is academic attainment and how can we measure improved academic attainment?

and these are addressed in the literature review chapter.

The methodology chapter suggests options for data collection and a mixed methods approach with ethnographic narrative and archival is shown to be the most suitable method to use. Ways for measuring starting and final attainment data are given and statistical analysis tools for analysing the data collected are described.

The case studies chapter describes the experiment using a mixed methods approach using ethnographical narrative with the data collected then being statistically analysed.

Finally the summary and recommendations chapter describes the implications for teaching and learning via a toolbox matrix and the three most important elements are identified. The limitations of the study are then discussed and suggestions for further research possibilities described.

In the next chapter we will look at the detailed pilot study from a practitioner's viewpoint. This is achieved by using both a narrative approach and, in order to ascertain if there was any academic improvement, statistically.

Chapter 2 The Pilot Study

2.1 Chapter Introduction

We have seen in the introduction to the thesis how low attainers being taught using accelerated learning reacted to ‘not doing maths’ in an OFSTED inspection lesson and just designed desks instead. The inspector had mistaken the pupils for high flyers, thinking that,‘ the cream of Y7 taken from all the other mathematics classes in order for them to be exposed to accelerated learning’. This had enthused me and hence I decided to initiate a pilot study to see if accelerated learning could address the negative beliefs and fears that I believed affected the academic attainment of low attainers in mathematics. This was, as discussed in the introduction chapter, based on my experience as a teacher and hence it should be noted that the pilot study was undertaken as a practitioner.

These fears were:

- A fear of failure.
- Preconceived, negative ideas from parents.
- Often having been taught using the same method over and over again
- Pupils have different learning styles.
- Pupils have under-developed communication skills.

  Brown (1982) states that pupils are fluent in listener oriented speech but need to practice message oriented speech.
- Pupils have poor memory.

  Pupils may have immature strategies for memorisation. (Wood, 1991).

We will see examples of these fears being addressed in both this and the case studies chapters.

I also needed to ascertain if the pupils had made any improvement in their academic attainment. This was to be achieved by summative assessment based on internal examinations conducted at Christmas 2003. The results from the pupils in the experimental group in the pilot study were then compared with pupils' results in a control group.

The pilot study was a tool from which the research questions for the main case studies were to be elicited. These are discussed at the end of this chapter.

Accelerated Learning

I had, as already stated, recently been on an accelerated learning course provided by my local LEA. The course was based on Thinking Maths (CAME) (Adhami et al, 1998), and suggested that accelerated learning consisted of a supportive environment and 7 stages that are taught in a cyclic fashion. The supportive environment must be created first and be one where the pupil feels supported but challenged. It should promote high self esteem and be stimulating.

Next the 7 stages were taught cyclically. These are:

- Connect to the learning.

  In this stage the pupils would connect the learning to some experience they have had either in or out of the school environment., e.g. using shoe sizes from the class when discussing mode.

- The Big picture

  Pupils are shown how the new knowledge fits into former knowledge, e.g. How the area of a triangle can be connected to the area of a rectangle. (Halving)

- Describe the outcomes

  Here the pupils need to know what they will achieve either in that particular lesson or over a whole series of lessons, e.g. In the lesson we will learn how to calculate the use the area of a circle.

- Input

  All learning styles such as visual, kinaesthetic and auditory are facilitated, e.g. Using teachers TV clips, measuring lengths and widths of things outside the classroom to calculate areas etc.

- Activity

  The learning activity should have multiple approaches such as problem solving, flash cards, video etc. e.g. playing ‘follow me’, CAME lesson etc.

- Demonstrate

  Pupils should be allowed to demonstrate their learning through presentations, written assessments, peer-to-peer explanations etc. e.g. Pupils write their answers on the board for comments from the other pupils.

- Evaluate learning

  Evaluation of the pupils’ learning can take many guises such as a rewards system, tracking, self esteem, under-achievement combined with action plans. All of these would be used to inform the subsequent teaching, e.g. Using assessment sheets which can be placed in the front of exercise books.

All of the above is to be taught in a cyclic fashion although realistically only one cycle would normally take place in any one lesson. On occasions such as revision lessons, the cycle can be used again for each topic.

During the narrative description of the pilot study, I will give examples of how these 7 stages and the supportive learning environment were used within the classroom.

I also used the accelerated learning units developed by myself as part of a Gatsby Teacher Fellowship as part of the teaching pedagogy in the pilot study. These were funded by the Gatsby Technical Education Projects (GTEP) charity. These 4 purpose written accelerated learning units addressed topics within the strands of number, algebra, shape and space and data handling that had been identified from the DfES (2003) as being habitually misconceived by pupils.

I also used CAME lessons (Cognitive Accelerated Maths Education) (Adhami et al, 1998). This is a series of 30 lessons that details the thinking skills being developed, the educational objectives and mathematical content to be covered in each lesson. More details of CAME can be found in the literature review chapter but at this point the lessons were only thought of as being another way of delivering accelerated learning in the classroom.

The low attainers in the pilot study were chosen as they all had KS2 SATs results under level 4 and they had been placed in a lower set by the school because of these results.

The pupils in the school all took examinations after one term in order to ascertain if any improvement in academic attainment had taken place. The KS2 SATs results were selected as the most appropriate starting benchmark from which to measure improved attainment in the pilot study. The internal Christmas 2003 examinations were used as a final attainment measure.

So I had selected a teaching pedagogy and subjects for the pilot study experiment plus a method of measuring starting and finishing attainment.

The above set the framework in which the experiment took place and now I will go on to discuss the actual pilot study experiment in detail using narrative to describe classroom situations and relate these to the supportive environment and 7 stages of accelerated learning.

This will be followed by the statistical analysis of the quantative data. The mean and standard deviation of the pupil's KS2 SATs and Christmas 2003 examination results were calculated and used to show any differences in the groups. Then scatter graphs are presented in order for the reader to gain a pictoral view of the KS2 SATs results plotted against the pupil's Christmas 2003 examination results. Finally a linear regression was performed in order to calculate a predicted result for the Christmas 2003 examinations.

2.2 The Narrative Study

2.2.1 Introduction

This pilot study was conducted at a state school in the north east of England between September 2003 and January 2004. The school had approximately 1100 pupils ranging from age 11 to 16 all from a similar socio-economic background with 48% (eteach, 2009), of pupils being entitled to free school meals.

Pupils entering the school were allocated to mathematics sets based only on their KS2 SATs results. The experimental group consisted of year 7 pupils, 11 – 12 year olds who were set 3 of 4, 4 being the lowest attaining set. There were 21 pupils in the experimental group with one teacher plus one classroom assistant. The control group had 22 pupils also with one teacher and one classroom assistant. The control group was a parallel group, i.e. set 3 of 4. All of the pupils were working at level 3 or below as indicated on their KS2 SATs results and were regarded as low attainers.

Experimental group	**Control group**
21	22

Table 1 Numbers of pupils in the pilot study.

At this school mathematics was taught in 50-minute lessons, 4 times a week. During these lessons the accelerated learning pedagogy was used, including 5 – 10 minute starters plus a 5-minute plenary.

The experimental group was taught using the accelerated learning pedagogy as described previously. The control group were observed on several occasions by myself and were not, as far as could reasonably be ascertained, taught using accelerated learning. The control group was taught by the head of mathematics at the school who confirmed that they had not intentionally used accelerated learning as a pedagogy in his lessons.

Teaching Pedagogy for the pilot study

The pilot study was conducted using the accelerated learning pedagogy with its supportive learning environment and 7 stages. It was supplemented by the accelerated learning units developed by the author as part of a Gatsby Teacher Fellowship that are based on the pedagogy, and also CAME lessons.

I will describe the pilot study below by using narrative with vignettes to examples of how accelerated learning was used in the classroom, referring to the supportive environment and 7 stages described above.

2.2.2 Environment

As part of the accelerated learning course provided by Sunderland City Council Education department, I had learned that a supportive learning environment should be facilitated in which pupils felt supported and challenged. One that facilitated:

- discussion - both group and peer
- rewards and sanctions
- listening skills
- different types of learning styles
- low stress

- stimulating – high challenge
- high positive esteem
- assessment which fed into teaching

Classroom narratives are detailed below on how this was achieved in the pilot study. The narratives for the environment are described in two sections, the internal and the external environment.

2.2.2.1 Internal Environment

Creating a Safe Environment

In order to create a safe environment in the pilot study I initiated the use of small white boards on which the pupils could write their answers but in the knowledge that they could rub them out if they then changed their minds. The first time we used these in this respect was to investigate area and perimeter, one of the Gatsby fellowship developed units. I told the pupils that they had 20 metres of wire to form a fence. I asked them to draw a shape that had a perimeter of 20 metres. They were using the squared side of the boards with 1 cm representing 1 metre. They had to hold the boards in the air when they had found a shape. The pupils began drawing and holding their boards up when they had a shape, but also started looking around. Some of them had not made their shapes meet as they had left a gap in the fence. They quickly took their boards down and started to draw again.

I recorded on the board the shapes they had found but then made it into a competition of who could find different shapes as all of the ones found at that point were rectangles. They started to draw different shapes and count around the edge to see if they had used the correct number of metres. They held up their shapes and as a group we then counted around them to check the number of metres used. Some pupils used the wrong amount but they often realised before we had counted them all and took their boards down rubbing out the extras and starting to work on a new shape. They were not discouraged but rather seemed to want to find another shape before the rest of the pupils.

After this I changed the challenge to 'if you have this area what is the largest perimeter you can have?' Here the pupils did not have to hold up their board, but bring it out to me to check if they had the largest one. Again a competition, but the main aim of the exercise was not mathematical, but enabling the pupils to be comfortable in the classroom even when they were moving out of their seats and talking. (Of course the largest area is actually a circle but at this point in the curriculum areas of circles had not been introduced).

Here, as well as the supportive environment needed, we can see that the pupils can connect to the learning as I was using the example of my own son's puppy. The lesson also facilitated different learning styles and the activity allowed for multiple approaches. When the pupils held up their boards they were demonstrating their learning. So we can see that although this lesson is an example of a supportive learning environment, it also covered the 7 stages.

In fact, as stated above, the following example lessons should be seen in this light, i.e. although they are written under specific headings, the lessons described also facilitated the learning environment and 7 stages.
When using the CAME pedagogy pupils work in groups. As such the group takes responsibility as a whole for the answers and solutions. This eases the

pressure on any individual pupil and helps to dispel the fear of failure. In the CAME lessons pupils have to explain to each other within the group how they have come to their conclusions. They then, as a group, present their findings to the rest of the class. Anyone can then ask questions of the group, choosing any group member to answer. As the group have previously discussed their findings with each other they were all more confident in how they got their solution and could explain this to the class. On one occasion a normally very quiet but intelligent pupil came ‘to the rescue’ of one of his group members when a particularly hard question was asked of them, taking it on himself to explain.

2.2.2.2 External Environment

External environmental influences also had an effect on the achievements of the pupils. These were thought to be mainly due to parental preconceptions.

Often if a pupil struggled with their homework they would ask their parents. Many times the pupils then came into the lesson to tell me that their parents have said that they could not do mathematics when they were at school so “don’t worry if you can’t do it”. This was repeated at parent’s evening when the parents informed me that they could never do algebra or long division. So how did I try to undo this? With algebra I did not tell the pupils that this was the topic we were studying until after the main part of the lesson, I just started talking about sweets and how many there were in the bag which I had. After this lesson on algebra a pupil said that he thought algebra was hard but now he knew how to do it and he was going home to teach his elder sister. Although he was not recognising that he was not able mathematically to do so, the aim here was to break the mould of the preconception ‘I can’t do because my parents say so’.

Some parents at parents evening asked me if there is one way which is best to teach their child a topic. This could stem from the fact that as children themselves they were taught that there was only one way to do for example long multiplication. Even after years of failing using this method, they were still taught it in that way the following year and the year after that. This re-enforcement of failure could have had the affect on them that they thought that there was only one way of approaching long multiplication.

With the accelerated learning pedagogy of multiple approaches to topics pupils were taught several methods of solving problems such as long multiplication. None of these was the correct way for the class as a whole; there were only better methods for individuals. Pupils became more confident and the influence of parental failure became less of a problem. This was seen when at parents night parents informed me that their son or daughter had said something on the lines of, ‘That’s not the way I got my answer. I understand this way and it works’. Or that they no longer were asked to help with homework as the pupils understood how to do it ‘this way’.

2.2.3 Accelerated Learning: The 7 Stages

Demonstrate / Input

It has been suggested in the introduction that low attainers have under-developed communication skills. One of the ways in which I addressed this was to use CAME lessons.

When I first introduced CAME lessons I asked how much time they spent in each lesson talking as individuals to me. Their first reaction was 50 minutes, the lessons being 50 minutes long. I then asked if I spoke to only them as an individual pupil, when did I talk to the other pupils in the classroom? We then divided the lessons 50 minutes by 21 to see how much time this could potentially give each pupil. We agreed on about 2 and a half minutes each if I talked continuously throughout. This was not the case they decided, so we then agreed on about 1 minute maximum. I then asked how long they talked to their friends during a day. All the time was the common reply. So you spend far more time talking to each other than you do teachers. Does this mean that you can explain things to each other? Yes was their reply. Do your friends understand you? Again yes they said. So in mathematics lessons you can explain things to each other and get your friends to understand. This they thought was a good idea and was used extensively during the subsequent lessons in order for the pupils to demonstrate their knowledge.

In fact when working on the CAME unit about mode, median and mean (best size desk lesson), the one that the OFSTED inspector had observed, communication was used extensively. We were discussing what size desk would be needed for a new school. The desk would have to be suitable for all pupils from Y7 to Y11. This at first created a problem as there was a big difference in the size of the pupils in this class of Y7s let alone the size difference between Y7 and Y11 pupils. One of the Y7 pupils was very small and one very tall so the pupils decided to measure the smallest and the largest. They could not decide quite who was the smallest so they asked two pupils who seemed to look the smallest to stand with their back against the white board. A pupil then marked where the top of their heads came to on the board. This was repeated for the tallest and the difference was measured. Now they had a range to work with.

It was decided that a major factor would be the arm span as this would dictate how far you could reach and hence how long you needed your desk. The pupils started to measure their arm spans with a partner.

The results were put on the whiteboard. They ranged from 1.39 to 174. I wrote down exactly what they had said even though I had realised that they meant metres for the first and centimetres for the second. I was trying to teach active listening skills. I asked how can this be right as 1.39 is tiny and 174 is much larger. The pupils replied that one was metres and one centimetre. This begged the question of how do we convert centimetres to meters and visa versa but this topic was not due to be taught at this point. However I did not have to make this decision, it was made for me when one pupil stated that we needed to times by 100 because there is 100 centimetres in one metre. So the pupils had started to follow their own agenda as they had moved from the initial problem of measuring onto multiplying by units of tens and finally to converting centimetres to metres. They were deciding which topics were needed and using this information to solve the problem.

The pupils now had to decide which actual measurement to use for the length of the desks and, given that we had a big difference in size, this could have proved quite difficult for them. All of the measurements from the arm spans were still on the whiteboard and one pupil suggested that we took the middle measurement as then everyone would be OK. It was decided that we should put the results in order and choose the middle one. When we had the measurements in order the pupils showed me how to get the middle one by putting your hands out in front of you and move them in, in jumps. What they were actually describing was knocking one measurement off each end. We put the results in order but there were 2 ‘middle’ numbers. 1.56 and 1.57. The pupils had not come across 3 decimal places so this needed to be resolved. At the pupils suggestion a number line was drawn with 1.56 at one end and 1.57 at the other. This was marked into 10 sections and again the pupils used their hands to ‘jump’ in. They landed on 1.565. This, I explained, was the median.

Within one lesson the pupils had covered topics as diverse as multiplying by 10s, to median, to measuring, to comparing units etc, most of which were not due to be taught at this stage. The pupils had discovered ways of solving most of the problems as they arose. The main problem of what size desk we should have was a real life problem and putting the decisions in context had helped the pupils visualise a solution. Also in this case I had decided to teach the topic as it was needed and not when it occurred in the framework. This could be seen as the ‘connect to the learning’ and ‘the big picture’ stage when a topic is taught in context and when needed, not when it arises in the curriculum.

With the experimental group I started by mainly asking closed questions in the starters and the plenaries. The main starter was to ask 5 – 10 questions based on any topic the pupils had studied within the last year. They answered these, at first, in the back of their exercise books and marked them themselves. I informed them that although I was interested in their answer, I was more interested in the method that they had used to get that answer and hence did not take in any marks. In order to check answers I would often choose a pupil to explain how they had arrived at their answer. The pupil could either explain verbally or use the white board to demonstrate their explanation. As the 5 – 10 questions were on any subject previously studied, they could be seen as the pupils ‘connecting to the learning’ and ‘demonstrating’ their answers.

Activity

Open-ended questions were used in the main part of a lesson, and multi-activity approaches to the activity were enabled in order to answer these questions. An example was when I asked the pupils ‘What can you tell me about circumferences and radii of circles?’ I asked the pupils to go into groups of four to investigate this. I made resources available to them such as compasses, rulers, pencils, lengths of string, and squared paper.

After 5 minutes I walked around the room observing the pupils. Most groups asked what they should do. This I expected as they had not been exposed to open ended questions before in my lessons. I answered by asking what the other members of the group thought should be done. One pupil drew a circle with a radius of 5cms on the squared paper. He then used the string to measure around the circle.

I asked him to explain to his group what he was doing. He informed them that this was an easy way of seeing how big it was around the circle. He then put a pen mark on the string to show the circumference. I asked the group to then explain this to the rest of the class. They did so, the pupil who had the original idea leading the explanation.

I then noticed one of the other members of his group hurriedly drawing a circle with a radius of 10 cms. He quickly got another piece of string and measured around. By this time the other members of his group had noticed him and all of the group tried as quickly as possible to measure the two pieces of string against each other. They were worried that the other groups would now get the solution before them. I asked them, now that they had two pieces of string how would they compare them? One pupil then grabbed the longer piece of string and put the shorter one on it, marking where it went to. He then took it off and moved it onto the remaining part of the longest string. 'Yes Miss it does' was the shout. I took this to mean that doubling the radius doubled the circumference.

With any of the above questioning techniques the pupils were always giving enough time to process their thoughts before answering. This thinking time was allowed in order that the pupil has time to manipulate the information and their thoughts allowing the pupils to 'search for meaning and process the information'. This was also facilitated in the activity through the peer to peer and group discussion, allowing time for understanding and assimilation of information by the student.

Communication and lateral thinking puzzles were used to enhance problem solving skills. They also encouraged listening and communication skills which, although were in themselves generic skills, feed cyclically back into the pupils' mathematics lessons. These puzzles also encouraged pupils to search for meaning and process information that is required in the main activity part of the accelerated learning lesson.

Examples of these puzzles used in the pilot study were:

- 10 horses
- Scientists

The 10 horses lateral thinking puzzle is where you ask how can 10 horses be put in 9 stables but have a stable each. The pupils say put 2 in together as one stable might be bigger than the others or build another stable. I explain that you can't put 2 in together as they will fight and the farmer has no extra money to build an extra stable. The actual answer is to spell out, TENHORSES. Each of the letters then fits into one stable.

The logic puzzle seen below is where 4 scientists who have been captured by cannibals. They are buried in sand up to their heads. They each have a hat on. They know that there are two number 2 hats and two number 1 hats but do not know who has which hat on. One scientist is on one side of a brick wall and the other three are on the other side.

I drew the following on the board.

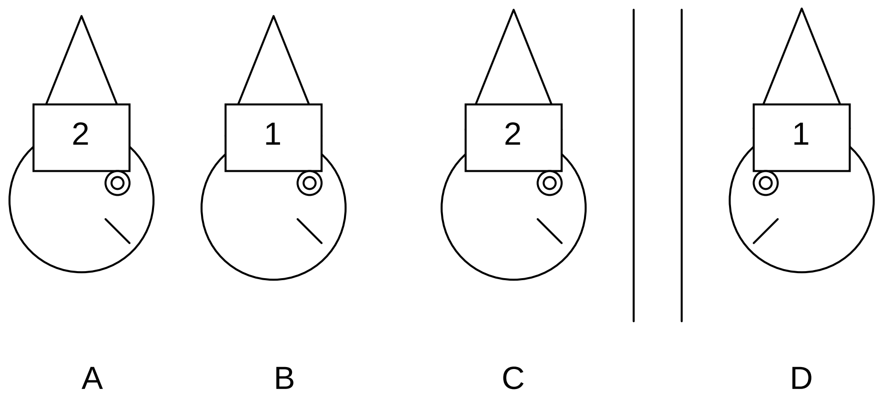


Figure 1 Scientists.

All of the scientists are facing the wall and they are not allowed to speak to each other. If the first scientist to say which hat he has on is correct, they will be allowed to go free by the cannibals. If he is wrong they will all be eaten. The pupils gave many answers and ideas but all depend on either the scientists being allowed to talk or being allowed to move so that they can see other hats.

The answer is B as if he had a number 2 hat on then the person behind him (A) would shout out as he (A) would be able to see two number 2 hats in front of him and hence know that he (A) had a number 1 hat on. But he (A) does not shout out anything so B knows that he must have a number 1 hat on.

These puzzles were used mainly at the end of a lesson or as homework. I would not tell the pupils the answers, but I would give then hints. Often the puzzle lasted over a week with pupils stopping me in the corridors and asked if their solution was correct.

Evaluate Learning. (Review, Recall and Retain)

I believed that the low attainers had poor short term memory skills and in order to address this I used the review, recall and retain stage of accelerated learning pedagogy. A number of memory techniques were employed throughout the pilot study and the section below describes some of the techniques used in the classroom.

Memory Games

The first game was on the way to market. Here one pupil starts the game by saying 'on the way to market I bought a …..', then the next pupil repeats this and adds an item of their choice, followed by the next pupil and so on. I would choose the next pupil at random. In the beginning I asked the pupils to choose an animal starting with A, then the second pupil had to choose one beginning with B. This made the memorisation easier at first and we progressed to any item. The pupils eventually memorised approximately 20 random items.

Another memory technique used was to place 10 items such as a red pen, a rubber, a pair of scissors etc on a tray. I would then cover the items and remove one. The pupils had to remember not only the item removed but also its position on the tray. Again they progressed onto taking away 5 items by the end of the year.

Posters were also used to help pupils memorise topics. These were placed around the walls of the classroom and pupils were able to look at them during the starter questions. An example of this was the topic of fractions, decimals, percentages, where the pupil would be asked to convert a percentage to a decimal or a fraction to a percentage etc. There would be posters which the pupils themselves had produced, around the classroom depicting how to do these conversions and also the standard conversions such as ½ = 50% = 0.5 or ¼ = 25% = 0.25.

The stage of evaluating learning was also facilitated in that pupils at the school were rewarded by means of merits. These merits counted towards their particular house and the pupils in this year group seemed to identify with their houses. Most pupils did not seem to see any advantage with showing these to parents and had a greater sense of loyalty towards their peers.

If a child got 5/5 or 9/10 or 10/10 on their starter questions then they got an A. If they got 3 As at any time either for these starter questions or for their main work for that day, they got a merit. Once this reward scheme was understood and implemented the pupils would work hard to obtain their last A in order to get their merit.

It seems that the reward system did have an effect on the environment as the As and merits were displayed on a chart on the classroom wall. Pupils often went to look at the chart to see how many more As they needed to get a merit or how many merits they had compared to others in the class and this appeared to encouraged the pupils to work harder.

2.3 Summary for the Narrative Study

In the above we have seen how the supportive environment together with the 7 stages of accelerated learning have been used in the classroom. Because of the integrated nature of accelerated learning it is difficult to separate the environment from individual stages in the examples. Hence although individual headings have been used, the reader can see how the environment and 7 stages are inter-twined.

Examples of how the internal environment was created to support but challenge the pupil were shown. As we have seen this is an important element of accelerated learning and it appeared to be both stimulating and promoted the self-esteem of the pupils' as can be inferred from the narrative.

The fear of failure was addressed by the use of groups in the CAME lessons and within the vignettes we can see that the reward system enthused the pupils, encouraging them to work harder.

The pupils had started to use communication, both peer to peer and group, helping them to process and link information in order to come to their own conclusions. This was seen in the 'conversations' the pupils had between themselves and with myself.

The use of open-ended questions in the main activity for the lesson dispelled the belief that pupils listen and teachers talk. It also facilitated different learning styles helping pupils access problem solving techniques.

When considering the benefits from using the communication and lateral thinking puzzles, it is difficult to separate the benefits from listening skills, communication skills and the environment provided in which this discussion takes place. The pupils had to listen carefully, a skill that has been shown to be important in accelerated learning, but also they had to be able to communicate their answers to the rest of the group. They had to link the information from other pupil’s answers and analyse the question fitting together this already known information in order to form their answer. Although most of the above could be seen as generic skills, they are important in a mathematical environment in that they provided the pupils with a scaffold from one skill to another in order to solve problems.

We have also seen above that memory games were used with the intention of improving the short-term memories of the pupils however it cannot be said whether these techniques actually did improve the short-term memory of the pupils’ and more will be said on this subject in the case studies.

So we can see that from a practitioner’s viewpoint, accelerated learning appears to address the fears I felt the low attainers held. This will be discussed from a research viewpoint in the literature review chapter and as a research practitioner in the case studies chapter.

I performed statistical analysis to measure the academic attainment of year 7 low attainers during the time in which the experiment took place. The following section details the statistical analysis that was performed.

2.4 Pilot Study statistical analysis

2.4.1 Introduction

The pilot study involved one class of 21 pupils with one teacher plus one classroom assistant. The control group had 22 pupils with one teacher and one classroom assistant. The groups were parallel in terms of academic ability, both being set 3 of 4.

In order to measure improvement in academic attainment there must be a benchmark that can be used as a starting point from which to measure value added. The following paragraphs detail the pupils' KS2 SATs results for both the control and experimental groups in the pilot study that were subsequently used as this starting benchmark.

The pupils in the pilot study all took internal examinations that consisted of two written papers, taken from the previous year's progress tests, plus the mental test that accompanies them. These test papers are aimed at levels 3 to 5 and are used to ascertain if the pupils in Y7 have reached the Y7 targets set by the government. Details of these targets can be found in the methodology chapter.

The data was processed using Microsoft Excel and SPSS. It comprised the KS2 SATs results and the internal Christmas 2003 examinations results. The analysis compared both groups' Christmas 2003 internal examination results against KS2 SATs as follows:

Groups involved

- Experimental group
- Control group.

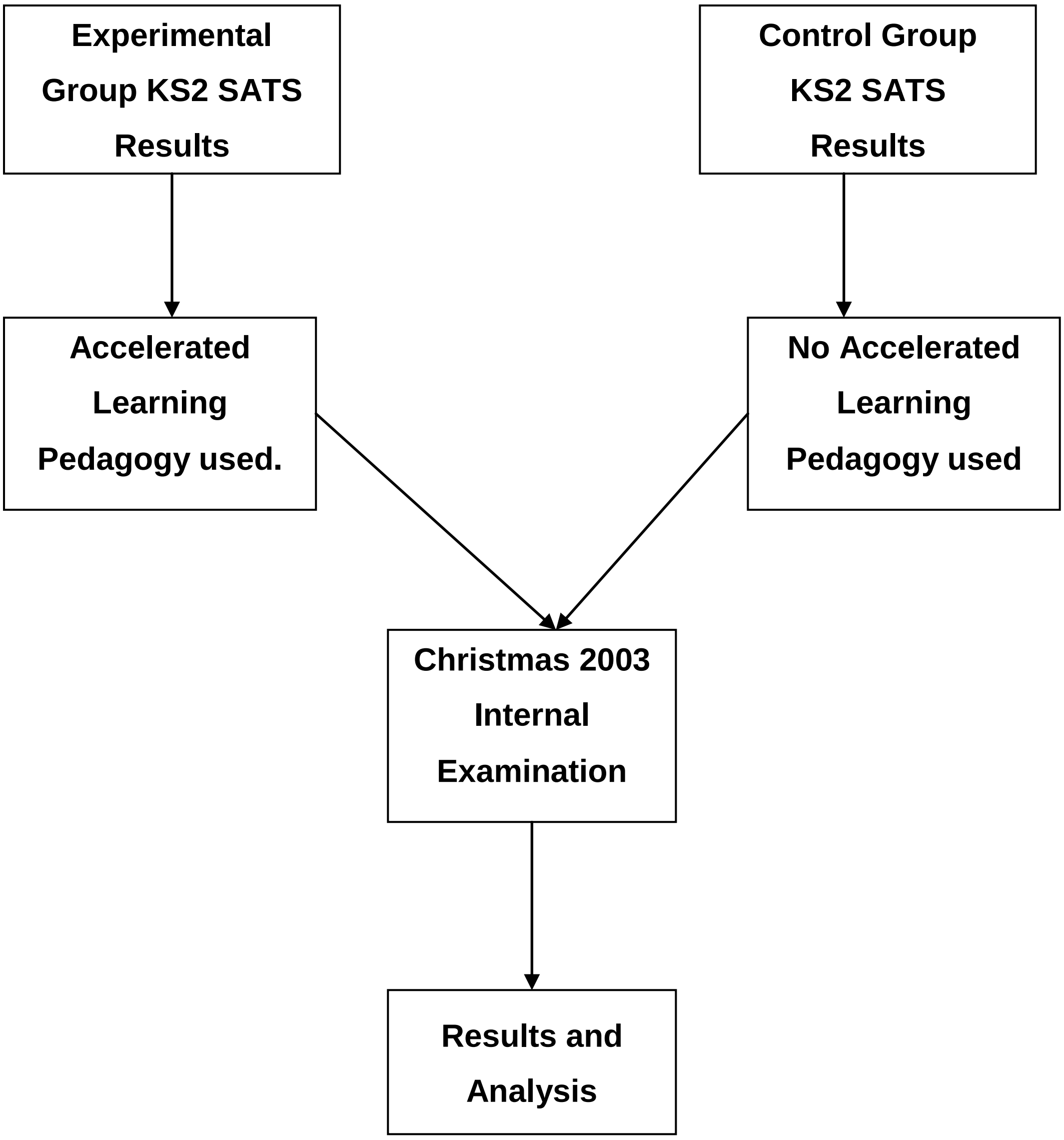


Figure 2 Case Study 1 Design View.

This following section starts by looking at the mean and standard deviation of the pupil's Christmas 2003 examination results. Then scatter graphs are presented in order for the reader to gain a pictoral view of these results plotted against their KS2 SATs results. Finally ANOVA and linear regression are performed to give a predicted estimate of the Christmas 2003 examination results.

2.4.2 Mean and Standard Deviation

The mean and standard deviation results are shown in the table below.

	Experiment		Control	
	KS2 SATs	**Christmas 2003**	**KS2 SATs**	**Christmas 2003**
Count	21	21	22	22
Mean	30.48	63.81	38.73	47.27
StdDev	5.94	16.26	7.55	12.02

Table 2 Pilot Study Mean and Standard Deviation

The mean of the experimental group's KS2 SATs results was 30.38 and this was 8.25 less than the control group's mean. This shows that although the 2 groups were judged by the school to be parallel in terms of academic ability at the start of the academic year, they were in fact different. However, all pupils fell within the adopted definition of low attainers for the pilot study of they did not achieve a level 4 or above in their KS2 SATs and hence the sets were deemed to be similar on this premise.

The mean of the Christmas 2003 examinations for the experimental group exceeded the control group's by 16.54, indicating that the experimental group had improved their academic attainment more than the control group.

When looking at the standard deviation we can also see that the groups were different at the start of the experiment. The experimental group having a KS2 SATs mean of 30.48 and a standard deviation of 5.94, giving results between 24.54 and 36.42 for one standard deviation. The control group had a KS2 SATs mean of 38.73 and a standard deviation of 7.55 giving results between 31.18 and 46.82 for one standard deviation.

Now looking at the Christmas 2003 standard deviations we can see the situation is reversed in that now the experimental groups' standard deviations are higher than the control groups'. In fact the range for one standard deviation for the experimental group is 47.55 and 80.07 whereas the control group's range is 35.25 to 59.29. This can be seen pictorially on the chart below.

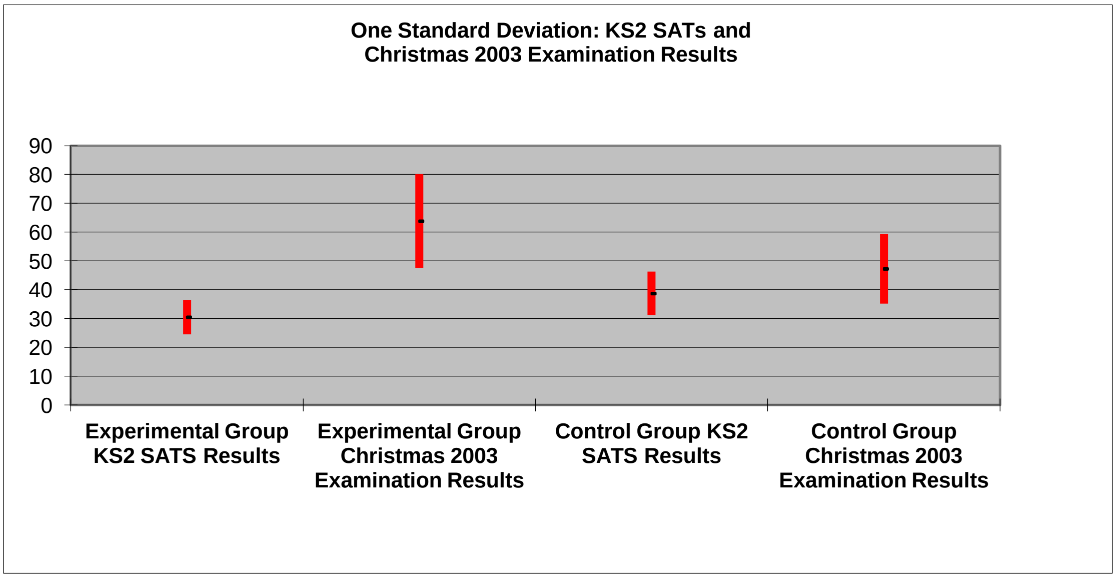


Figure 3 Pilot Study One standard deviation results: KS2 SATs v Christmas 2003 Examination Results.

2.4.3 Scatter graph

The scatter graph below shows the KS2 SATs results v the Christmas 2003 examination results. It can clearly be seen that the experimental group did make greater improvements in their academic attainment when compared against the control group's academic attainment.

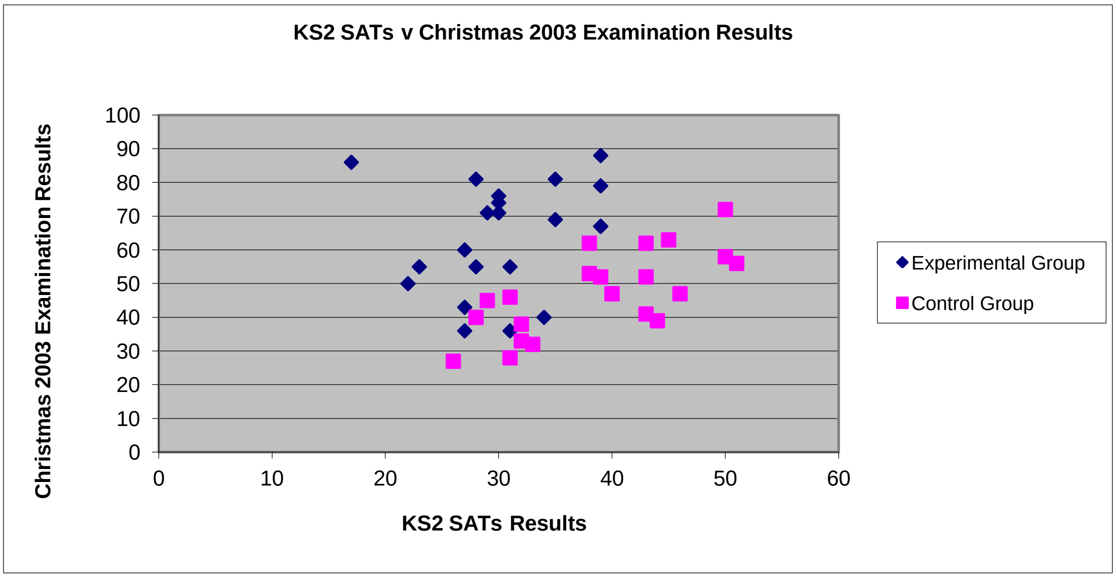


Figure 4 Pilot Study Scatter Graph. KS2 SATs v Christmas 2003 Examination Results.

2.4.4 Linear Regression

When a linear regression (control group) line was added to the graph shown below, Christmas 2003 examination results can be estimated given the KS2 SATs results. This is based on the experimental and control groups' actual KS2 and Christmas examination results, i.e. if we took a KS2 SATs results of 23 for the experimental group and using the linear regression line for the control group, we would expect that pupil to get 30 in their Christmas examination. In fact a pupil with 23 actually got 55 in the Christmas examination. There are only two instances where the pupil in the experimental group would have scores less in the Christmas 2003 examinations using this linear (control group) line as can be seen of the graph below.

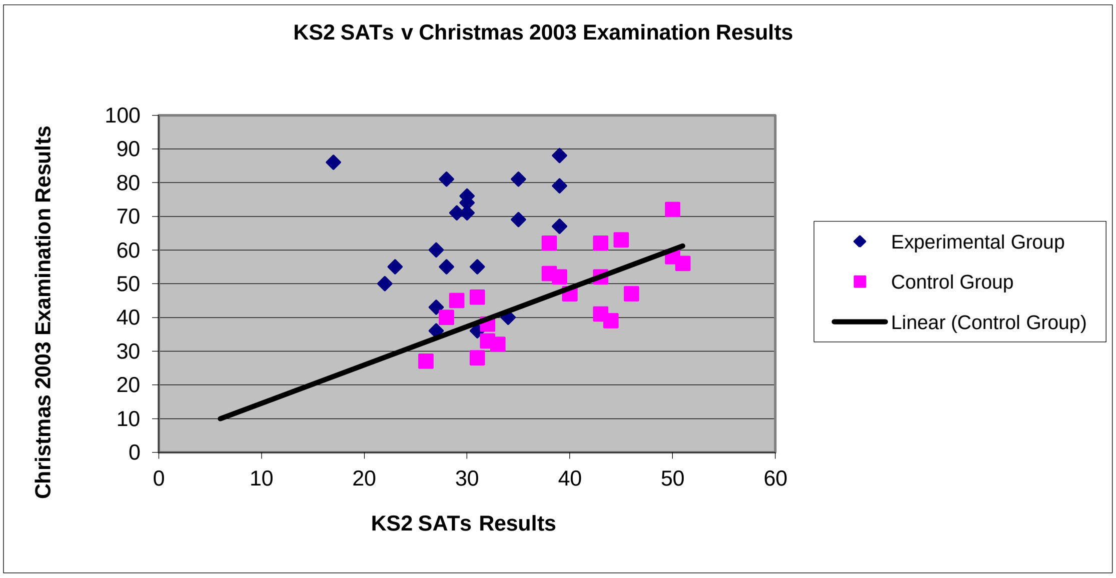


Figure 5 Pilot Study Linear Regression Lines. KS2 SATs v Christmas 2003 Examination Results.

Linear Regression Co-efficients

Next I looked at the linear regression co-efficients. This is a method that uses the linear regression to predict the Christmas 2003 examination results using the KS2 SATs results as a starting attainment benchmark. I used the following formula, details of which can be found in the methodology chapter, however a brief description is given below.

Linear regression is based on a straight line slope of the form Y'= MX + C

In the pilot study there were two groups, namely the experimental group and the control group.

So in the pilot study analysis the:

Y' is the Christmas 2003 examinations.

C value is shown as the constant (Regression constant)

M1 is the multiplier for the SATs.(Regression co-efficient)

M2 is the multiplier for the group number (2^{nd} regression co-efficient)

Hence the

$$Y' = M1 \times SAT + M2 \times \text{group number} + C$$

i.e. Predicted Christmas 2003 examination result (Y') = M1 X SATs or entrance test + M2 X group number constant (C)

Results Table for the linear regression co-efficients

	Christmas 2003 examination	**Standard Error**
Baselines	**M2 Co-eff**	**M2 Co-eff**
KS2 SATs	**-23.582**	**4.777**

Table 3 Pilot Study Linear Regression Co-efficients.

We can see from the above that there was a negative co-efficient for all of the Christmas 2003 examination results, e.g.

For the experimental group:

Christmas examination prediction = M1 x KS2 SATs + (-23.582 x 0)+ C

Christmas examination prediction = M1 x KS2 SATs + **0** + C

For the control group:

Christmas examination prediction = M1 x KS2 SATs + (-23.582 x 1) + C

Christmas examination prediction = M1 x KS2 SATs -23.582 + C

That is, based on the KS2 SATs baseline the control group were predicted 23.582 less than the experimental group for the Christmas 2003 examinations.

This shows that the pupils in the experimental group did have a greater improvement in their academic attainment. However we must take into consideration the assumption violations. The samples were small and were not perfectly matched as can be seen in the means and standard deviations, however there was no alternative but to use these samples. In fact both the experimental and control groups fell within the adopted definition of low attainers. Given the linear regression results these problems were unlikely to make a large difference to the conclusion for the pilot study, i.e. the pupils in the experimental group had made a greater improvement in their academic attainment than the pupils in the control group.

2.5 Summary for the Analysis

We have seen above that although there was a difference in the groups when considering their mean and standard deviations, these groups were still used in the experiment. This was due to the fact that no better matched groups were available and they did have a KS2 SATS result of less than 4.

The scatter graph clearly showed an improvement in the academic attainment of the experimental group when compared with the control group.

This improvement was reflected in the linear analysis where the linear co-efficient was –23.582. This was weighed against the assumptions made when performing a linear analysis but in view of the large (negative) co-efficient it is suggested that these problems were unlikely to make a large difference to the conclusion for the pilot study, i.e. the pupils in the experimental group had made a greater improvement in their academic attainment than the pupils in the control group.

2.6 Chapter Summary

So what does the pilot study show?

- The pupils were low attainers as deemed by the school.

The pupils had a SATs result of 3 or below and had been placed in the mathematics sets due to this.

- Accelerated learning was used in the classroom.

The detailed ethnographical narrative of the pilot studies gives an insight for other teachers and professionals into how the supportive learning environment and 7 stages of accelerated learning were used in the classroom throughout the pilot study.

- Academic attainment has improved.

From the statistical analysis we can see that there was an improvement in the academic attainment of the experimental group. This was shown pictorially via the scatter graph and statistically via the linear regression. This appeared so significant that it was felt further investigation was warranted.

The above demonstrates that academic improvement had been made and that accelerated learning was being used as a teaching pedagogy in the classroom ,however, no causal link has been demonstrated.

In order to provide evidence to test these claims further more rigorous investigation was undertaken. In-depth case studies were carried out in an academic framework as a research practitioner to address the hypothesis:

'The academic attainment of low attainers in year 7 (11 – 12 year olds) improves when accelerated learning is used as a teaching pedagogy in the classroom''

The following literature review chapter looks at the hypothesis in light of answering the questions identified in the pilot study of:

- Who are low attainers (the subjects of the experiment)?
- What are the causes of low attainment and in particular why is accelerated learning a suitable pedagogy to address these causes?
- What is academic attainment and how can we measure improved academic attainment?

Chapter 3 Literature Review

3.1 Chapter Introduction

In order to address the questions identified in the pilot study in an academic framework this chapter will start by looking at labels and why low attainers was chosen as the label to be used to describe the pupils in the experimental groups. Definitions of low attainers are then discussed, with the actual definition to be adopted in the thesis being decided upon.

Next we will see a discussion on the causes of difficulties in mathematics for low attainers. This is followed by learning interventions that could theoretically address these causes together with practical interventions as a way of moving these intervention theories into the classroom.

It will then discuss the literature underpinning accelerated learning, including the historical background of how accelerated learning was developed. We will then see a discussion on what accelerated learning is followed by consideration of key theoretical principles and practical intervention strategies that underpin the pedagogy.

The differences between accelerated learning and CAME (Cognitive Accelerated Maths Education) will be discussed and a brief history of CAME will be given. Again we will see what the CAME pedagogy consists of and how it is underpinned by key theoretical principles and practical intervention strategies that address the causes of difficulty in mathematics for low attainers.

Next the rationale for categorising the key theoretical principles and practical intervention strategies previously shown to underpin accelerated learning and CAME under the elements of environment, communication and memory is discussed.

We will begin by considering labels used to describe pupils.

3.2 Labels

When we are considering pupils who have difficulty in mathematics many labels have been used. The following section discusses such labels as special needs (Friend et al, 1996), less able (Haylock, 1991), slow learner (Cooter et al, 2004), underachiever (Boaler, 1997), low attainers (Denvir et al, 1982) and suggests reasons why the label of low attainers was chosen for this thesis.

3.2.1 Slow learners

According to Cooter et al (2004), slow learner is a term used to identify pupils with special needs. They state that it is the only term found at that time in professional literature that does so and it is used to describe pupils who on psychometric tests were measured as having an intelligence quota of between 70 and 85. Average ability, they say, being between 90 and 100. These slow learners learn to read at a much slower rate and have, according to Cooter et al, diminished potential. However, they say, this diminished potential should not be judged merely on the IQ scores as slow learners score low on both norm and criterion-referenced achievement tests.

Biggs (1985) uses the term slow learners to describe pupils identified as such by their teacher of the head of school. No other reason is given for the choice of this label. These appear to be a very narrow view of terms used to identify pupils with learning difficulties and infact professionals such as Haylock (1991) described other labels such as less able, slow learners, under-achievers and low attainers. He also describes the label of slow learners as pupils following the same learning path, where some proceed along it at a slower rate than others. This view is reiterated by Giles (1993), who describes slow learners as students who have learning handicaps and are characterised by slower rates of learning new information and developing cognitive skills. These students he says, are not low attainers because of their learning handicaps, but students who have a low success rate in learning normal tasks and find it harder to acquire new information.

Given all of the above we can see that the implication of the label slow learner is that these pupils could eventually acquire the desired ability but it will merely take them longer to do so. They would progress through the same syllabus as other pupils and given enough time, may learn and be able to apply the new information. Infact a slow learner may well understand, say, simultaneous equations by the time they are 20 years old rather than the average age that this would be expected of 14 (as per the KS3 SATS, Y9).

This label does not imply a difficulty within the understanding of mathematics only a difficulty in understanding in a certain timeframe. It would be impossible to say whether the pupils could or would eventually acquire and be able to apply the mathematical knowledge at the same level as their average peers and hence this label is not suitable to be used for the experiment to describe pupils who have difficulty in mathematics.

3.2.2 Special Needs

According to Friend et al (1996) special needs is a label used to describe pupils who have disabilities. These can range from physical disabilities such as blindness or deafness or mental disabilities such as dyslexia, ADHD or dyspraxia. These pupils, they say, can be educated in an inclusive school often under the guidance of the special needs department.

Special needs may arise from personal disabilities and environmental circumstances and often a combination of the two, giving another description of special needs (Gulliford, 1971). He says that such things as emotional difficulties and cultural and social disadvantage can be categorised under this label and that in the future specialised provision should be made for pupils who are multi-handicapped, e.g. pupils who are from a different culture and have a personal disability.

The label of special needs appears here to be a catch-all label, where pupils with physical, mental, emotional, cultural difficulties all fall under the banner. Infact a pupil who has only one arm would fall into this category but it is unlikely that this special need would affect their academic attainment. Likewise a pupil from a different cultural background again could fall under this category however this would not necessarily affect their attainment. Infact in the SATS, protocols have been put in place to address this such as using multi-cultural names in questions.

Hence some special needs pupils would not necessarily have their academic attainment affected by their special needs. However other pupils who are not labelled as special needs may not achieve academically. So we can see that special needs is not a label that can be used in the experiment as it encompasses pupils who do not have difficulty in mathematics and yet does not apply to some pupils who do have difficulty in mathematics.

3.2.3 Less able

Haylock (1991), says that he does not find the label of less able a helpful one in that it implies that the problem lies with the ability of the pupil. He also says that once a pupil has been labelled as less able then the expectations of the pupil are limited. He cites examples of pupils who are less able in mathematics rising to the challenge when given a task that engages and excites them, e.g. less able 8 and 9 year olds arranging a football match.

If we consider Haylock's views then we must also ask the question less able to do what? The pupils in his experiment although less able in mathematics were capable of organising the football match. So do we use one label to describe these pupils mathematical ability and another to describe their organisational skills? In this thesis we are considering the pupils who have difficulty in mathematics and not if they are less able in any challenges.

We must also ask the question less able than what or whom? Less able than their peers? Less able than pupils in a higher set? We need some term of reference or benchmark from which to judge whether a pupil is less able. A pupil in set 3 of 4 (set 1 being the highest ability set) could be seen as less able than a pupil in set 2. However the pupil in set 2 could be seen as being less able than the pupil in set 1 and so on. In choosing a label we need to be able to distinguish the pupils as pupils who have difficulty in mathematics. Hence this label would not be applicable.

3.2.4 Underachievers

Underachiever is a term that can be used to describe pupils who have the potential to achieve much more than they are presently achieving, given the appropriate encouragement and appropriate curriculum (Haylock, 1991). He goes on to say that it is more often used in a negative sense, to describe pupils who constantly misbehave, are antisocial and have a lack of interest in school tasks. These pupils, he says, often underachieve across the curriculum.

Using Haylock's definition this label can also be used to describe any pupil who is not reaching their true potential. A pupil who has been predicted an A* in their GCSEs, may only achieve a B. Under this definition this pupil would be an underachiever however they would not be an underachiever because they had difficulty in mathematics. It maybe, as Haylock suggests, that they misbehave or have a lack of interest in mathematics.

In Boaler experiment (1997), she describes girls in a top set as underachievers. This label was arrived at after consideration of their success in Y7 and Y8, their GCSE results and their teacher's opinion. Again here it could be that these pupils misbehave or lacked interest however they cannot be described as having difficulty in mathematics if we consider their successes and the fact that they are in the top set.

Neither of the descriptions given above of underachievers alludes specifically to pupils who have difficulty in mathematics and as such it is not deemed a suitable label for the pupils in the experimental groups.

3.2.5 Low attainers

When we consider the label of low attainer it implies comparisons of pupils attainment and a benchmark from which to measure that attainment be it average, low or high. Haylock (1991) states that low attainers are in the bottom 25% of a notional ability range for their peer group. 25% of pupils is a measurable quantity however a notional ability range for their peer group gives us some difficulty in assessing exactly which pupils would fall under this label.

Denvir et al (1982) define low attainers as the pupils in the bottom set or the set immediately above. This is also the case for Baker et al (2002) who define low achieving students based on their performance on standardised or informal tests or by their being placed in the remedial class for that school. In these definitions the pupils may or may not have difficulty in mathematics. If we take, for instance, a high attaining school, the bottom set in Y7 may consist of pupils with a KS2 SATS score of 6 or above. These pupils would not be classified as pupils who have difficulty in mathematics. Pupils in Y7 bottom set in a school that is in special measures may have a KS2 SATS result of a level 3 or below, however both bottom sets would fall under Denvir's and Baker's label of Low attainer.

We can see that Denvir et al and Baker et al have not used a standardised benchmark that would apply to all pupils equally across the UK. Infact some schools in the UK have entrance tests and here the bottom 25% of these pupils would be labelled as low attainers. Other schools have internal tests and again the bottom 25% of pupils in these schools would be labelled as low attainers. However as we have seen, the same pupils may not be labelled low attainers in other schools as they are not standardised from school to school throughout the UK and hence could not be used as a national benchmark.

There are many other examples of the use of standardised test being used to define low attainers such as by Woodward et al (1997) who included all pupils that scored below the thirty-forth percentile on the Iowa tests of basic skills or Heller et al (1993) who used the fiftieth percentile of the Philadelphia citywide norms. Here we can see that standardised tests have been used but these cannot be applied to all schools and hence could not be used.

However Denvir et al do go on to say that nationally low attainers can be classed as the lowest achieving 20% of pupils, a similar definition to Haylock who quotes 25%. But they do not say how this achievement is measured or against what criteria it is measured.

Dunn et al (2010) do use a standardised benchmark of the KS2 SATS and state that 6% of all pupils in the UK fall short of the National Curriculum level 3 expected by the government. This could be used as a benchmark and will be further discussed in the low attainers' definition section below.

In conclusion we have seen that slow learners indicates some timeframe in which the pupil may or may not conquer their difficulty in mathematics. Special needs is a label used to describe any pupil who has a difficulty be it physical, such as deafness or mental such as ADHD. These special needs do not automatically indicate that the pupil would have any difficulty in mathematics. Next we considered underachievers. We have seen that this label could be applied to a pupil who has the potential to achieve much more but does not apply themselves to their mathematics. It does not imply a difficulty with the understanding of mathematics. And finally we discussed the label of low attainers. It provided a description of those pupils whose attainment is in the bottom 20% (Denvir et al, 1982) or 25% (Haylock, 1991). This level of attainment does indicate that these pupils do have difficulty in mathematics. So this label could be applied to pupils if a standardised benchmark can be defined that would allow us to compare pupils' attainment across schools. This standardised benchmark would allow the label of low attainers to be used to identify specific pupils in any school throughout the UK. It would allow other practitioners to specifically identify low attainers in their school and infact is the chosen label to describe the pupils in the experimental groups in this thesis.

Now that we have discussed the reasons why low attainers is a suitable label for pupils who have difficulty in mathematics, in the following section we will consider definitions of low attainers.

3.3 Definition of Low attainers

Now having discussed why the label of low attainers was chosen, we will consider definitions of low attainers and select one for the adopted definition for the thesis. We will start by considering some definitions of low attainers that are based on performance levels as we could define a low attainer according to which level they had attained in the hierarchy.

3.3.1 Hierarchy levels

According to Haylock (1991) much of mathematical learning can be analysed in a hierarchical way. In a sequential manner each learning step leads to another. If we consider that in mathematics objectives are set and assessments of the understanding of those objectives made, then it would be appropriate to apply this form of assessment to low attainers. If they could be defined as the pupils who do not achieve the objectives on the next step of the hierarchy then we could consider learning hierarchies to define low attainers.

We will begin by considering Piaget's schemes that could, he believed, be organized in a hierarchical manner. Behavior, Piaget theorised, is controlled through mental organisations called schemes that the individual uses to represent the world and decide on actions. He maintains that we are born with schemes that operate at birth which he calls 'reflexes'. As infants use these reflexes within their environment they change and are replaced by constructed schemes. He describes two processes that are used by individuals whilst they are developing.

The first is assimilation, whereby the individual uses or transforms the environment in order that it will fit within the pre-existing cognitive structures. The second is accommodation whereby the cognitive structures are changed in order to accommodate something new from the environment. An example of an assimilation scheme would be adding two single digits together then change the scheme to add two double digit numbers together. An accommodation process could be where the adding scheme is changed when the pupil multiplies two single digits together.

Schemes become more complicated and are then called structures and as these become more and more complex, they are arranged in a hierarchical manner.

- Sensorimotor stage: At this stage there is no language (symbol) ability and knowledge is demonstrated through physical interaction and experiences.
- Pre-operational stage: Here language matures and memory and imagination are developed but egocentric thinking predominates.
- Concrete operational stage: Language is used in a systematic logical way. Operational thinking develops that is the ability to reverse mental actions and egocentric thought is lessened.
- Formal operational stage: At this stage individuals can use language related to abstract concepts. There is a return to egocentric thought early in this stage.

Under Piaget's theory children are encouraged to discover things for themselves and parents and teachers challenge children's abilities but do not try to over stretch them. Concrete experiences are used to help children learn such as group work etc. Piaget believed that biological developments moved an individual from one stage to another.

According to Piaget the prime motivator of developmental change in a child is a 'dis-equilibrium'; i.e. a state of conflict in the child due to the difference in what they expect to happen as an outcome to a situation and what actually happens. It is because of this that a teacher can facilitate cognitive change in a pupil. The teacher can help a pupil discover implicit contradictions in their own thinking as long as these contradictions are latent in the pupil's knowledge base. Wadsworth (1971) also agrees with this when he describes how learners go through a process of assimilation and accommodation of new knowledge that is then integrated into existing schemas. However we must consider the case of a pupil not having some latent innate knowledge that could be activated. They would not have had development changes and hence could not progress to the next stage. This could give us a definition of a low attainer, i.e. a pupil who does not progress to the next stage.

However it is impossible to ascertain whether a pupil does not have the required latent innate knowledge to progress from one stage to another or if it has not yet been activated. In the latter case how long do we wait to see the activation? If the knowledge is not seen within the timescale in which the topic is first taught is the pupils a low attainer? In the Key Stage 3 National Strategy Framework for Teaching Mathematics (2001), a topic such as algebra in Y7 is visited 5 times. The first lessons cover sequences and functions (6 hours), the second formulae and equations (5 hours), the third integers powers and roots and sequences, functions and graphs (6 hours), the fourth equations and formulae (4 hours) and the fifth sequences functions and graphs and equations and formulae (8 hours). We can see here that topics are repeated throughout the year. If a pupil does not display the latent innate knowledge the first time the topic is taught then we could class them as a low attainer however if they then go on to display the knowledge the second time the topics is taught are they now not a low attainer? We can see that it would not be possible to use this hierarchy as a definition for low attainers as the definition would have to be fluid throughout the time span a topic was to be taught in.

We must also consider that Piaget theories are about child (pupil) development and not learning. He does not believe that development can be accelerated, but is dependant on the development stages. He does, however, say that it maybe possible to accelerate learning but this would be dependant on the stage that the child (pupil) is at that time and the topic being studied. However as we have seen pupils maybe at different stages in different topics or infact different stages within one topic. In algebra they may understand formulae and sequences but not integers powers and roots. In this case pupils maybe categorized as low attainers in one topic but not another.

This idea of pupils being on different level in different topics is reiterated by Herscovics et al (1994) who argue that there is a cognitive gap between arithmetic and algebra and that this gap can be characterised as the students' inability to operate simultaneously with or without the unknown. Infact they say that the low attainer does not have the ability to generalise the skill to fit a new situation or adapt the skill to fit a new situation without the intervention of the teacher. Thus we could use the achievement in algebra of the pupils to determine whether they are low attainers. However we have seen above that this would also be problematic in the definition of low attainers in that this is only one topic that is taught several times during one academic year. Infact this is further complicated as pupils in the UK study five strands: numbers and the number system, algebra, shape, space and measure, handling data and using and applying mathematics to solve problems (DfEE, 2001). Over the year pupils will achieve different levels of understanding in different strands and in different topics within these strands, hence this does not provide a clear definition of low attainers that could be applied equally to all pupils throughout the UK.

Next we will consider Haring et al's hierarchical approach to learning and development. Haring et al (1978) state that there are 4 levels of performance:

- Acquiring the behaviour (e.g. adding two single digits together)
- Performing the required behaviour fluently (e.g. being able to perform the calculation with few errors and unaided)
- The ability to generalise the skill to fit a new situation (e.g. being able to add numbers of, say, fruit together)
- Adapt the skill to fit a new situation. (being able to add two 2 digit numbers together)

These levels of performance, they says, form a learning hierarchy. We could use this as a definition of low attainers if pupils are at the first level of performance, acquiring the behaviour.

However they do not state a time frame in which these performance levels should take place. If we consider a pupil in Y2 then they may be able to add the two single digit numbers together but cannot do any of the other levels of performance. However by the time the same pupil is in Y7 they can add two 2 digit numbers together. Does this make them a low attainer in Y2 but not in

Y7? Does the pupil have to demonstrate all 4 levels of performance in one lesson or over a series of lessons or over a year? It is unclear how these performance levels can be applied with any consistency over a topic, or time span. Again as with Piaget's stages, it would also be difficult to use these levels of performance to describe which 'rung' of the performance hierarchy pupils were on as they may be on one level in say algebra but another in shape and space etc. Given all of the above it is not thought that a definitive description of low attainers can be elicited from Haring et al's learning hierarchy with the addition of a timeframe.

Bloom's taxonomy of educational objectives (Bloom et al, 1956) suggests categories of objectives that are arranged in a hierarchy and below we will discuss whether we could define a low attainer according to which level of learning objectives they had attained.

In Bloom's taxonomy there are two domains that have pre-requisite levels within them. These are:

- Cognitive
    - Knowledge
    - Comprehension
    - Application
    - Analysis
    - Synthesis
    - Evaluation
- Affective
    - Characterising

- Organising
- Valuing
- Responding
- Receiving

Bloom suggests that pupils should not move onto the next level before they have an understanding of the previous level. In the cognitive levels knowledge is the lowest level and evaluation is the highest.

Objectives in the affective domain are about emotions, interests, attitudes and values and as such are long term objectives (Haylock, 1991). Pupils develop these over a period of time he says, and they are not attained through a specific programme of learning. As such the affective objectives will not be considered here as we are only considering possible hierarchical models that could be used to define low attainers.

So we will only consider the levels in the cognitive domain. Although this domain does give teachers a basis to judge attainment, it should be noted that different disciplines require different kinds of thinking. If we compare mathematics with physical education for example, different skills and techniques would be needed to attain the next level. In one subject a pupils maybe on one level and the same pupil maybe on a different level in another subject. This principle could also apply to topics within subjects. So what are these levels for mathematics?

The National Curriculum Council disaggregates aspects of learning into attainment targets in the Key Stage 3 National Strategy Framework for

Teaching Mathematics (DfEE, 2001). The first attainment target in the curriculum of ‘Using and applying mathematics to solve problems’, could be considered to address the higher objectives in the cognitive domain that require analytical thinking and problem solving skills. If we consider the level one attainment for Y7 it reads ‘Solve word problems and investigate in a range of contexts’ or in Y8 ‘Solve more demanding problems and investigate in a range of contexts’ and in Y9 this becomes ‘Solve increasingly demanding problems: explore connections in mathematics across a range of contexts’. The wording is so similar that it would be difficult for a teacher to ascertain the difference between solve word problems, solve more demanding problems and solve increasingly demanding problems even though examples of each are given in the framework. If this hierarchy were to work it would have to have descriptive attainment levels for all years and all topics in the mathematics syllabus but these would still be open to interpretation by the teacher. This is subjective and one teacher could decide that the pupil had attained this level whereas another teacher may decide that they had not. Hence this is not suitable to be used as a definition of low attainer in this thesis.

We have seen above examples of learning hierarchies and a case has been made as to why these are not suitable to be used as a basis to define low attainers. If we consider the mathematics National Curriculum non-statutory guidance (NCC 1989) which says that although mathematics does contain a hierarchical element, learning mathematics does not necessarily take place in completely predetermined sequences. Mathematics is a structure composed of a whole network of concepts and relationships, From this we can see that mathematics is too complex to have learning objectives that cover all topics in the curriculum. Where these learning objectives are available they are subject to interpretation by individual teachers. In essence we can see that hierarchical levels cannot be applied consistently to all pupils over all topics and hence this cannot provide us with a usable definition of low attainers.

So we will now consider definitions that are normative based which, as we have seen, is a crucial factor for a definition of low attainers.

3.3.2 Normative Based Attainment

Denvir et al (1982) define *low attainers* as the pupils in the bottom set or the set immediately above. This is also the case for Baker et al (2002) who define low achieving pupils as pupils placed in the remedial class for that school. This is an example of a normative based attainment within a particular school as it reflects the relative position of a pupil on a measure decided upon by the school. However we have seen when we compared the high flying school to the school in special measures that this definition would not be applicable equally to pupils in all schools.

Barnes (2005) defined low attainers as pupils who do not reach the standard of mathematics performance as set out by the school, again an example of a normative based attainment definition specific to an individual school. He does not go on to state a percentage of the schools population who fall short of reaching this attainment who would then be defined as low attainers. In many secondary schools targets are set of a percentage of pupils who obtain a C or above in GCSE giving a normative based attainment that is nationally based and could be seen as falling under Barnes' definition of a low attainer. The implication here is that in some schools all pupils achieve above a GCSE level C thus they would have no low attainers when measured against the schools benchmark of a C or above. In other schools only 25% of pupils achieve the standard set by the school of a level C and hence they would have 75% low attainers. However often schools set a second target for GCSEs of 15% A or above. In this case both schools may have low attainers. Schools often set many internal standards that they hope pupils will attain. This leaves us with the problem in Barnes' definition of low attainers as to which of the schools' standards is he referring to. Is it a normative school standard or a normative standard that can be applied nationally? Again we also have the problem that schools standards need themselves to be standardised if this definition is to be applied to any school in the country.

Nationally according to Denvir et al (1982) it is the lowest 20% in terms of mathematical achievement. According to Haylock (1991) this is 25%. We did also see in the labels section that these definitions could only be applied to any pupil in a school in the UK if this 20% (or 25%) was based on a standardised benchmark from which to measure.

However, the Cockcroft Committee stated that low attainers in mathematics were deemed to be pupils in the lowest 40% nationally in terms of achievement in mathematics (Backhouse, 1989). This is double the percentage quoted above by Denvir et al. Again here we have the problem of having something to measure the achievement against.

In summary if we take Barnes' definition as pupils do reach the standard as set by the school we must take into consideration that the school could use any internal standard they chose. This is further complicated when we consider Denvir et al's (1982) definition of the pupils in the bottom set of a particular school, who could infact be in the top 60% of attaining pupils in the country. So these pupils are low attainers according to Denvir et al but not according to the Cockcroft Committee.

We have seen definitions based on 20%, 25% or even 40% in terms of mathematical achievement across the country. However a case has not been made as to which of these percentages should be used as they are arbitrary. None of them are based on a standardised benchmark that would make them equally applicable to all schools across the country and hence an alternative definition is required. In the following section we will consider threshold-based attainment that can provide us with a standardised benchmark.

3.3.3 Threshold Based Attainment

We have previously seen examples of the use of threshold based attainment tests used to define low attainers such as pupils that scored below the thirty-forth percentile on the Iowa tests of basic skills (Woodward et al, 1997) or the use of the fiftieth percentile of the Philadelphia citywide norms (Heller et al, 1993). Here standardised tests were used but these cannot be applied to all schools and hence could not be used for this thesis.

However we have also seen a standardised definition of 6% of pupils representing those pupils who scored below a level 3 in the KS2 SATS (Dunn et al, 2010) that could be applied to all pupils in the UK and hence we will consider the KS2 SATS as a benchmark.

In the UK the government had mandated the use of the Standard Assessment Tests (SATS). These are standardised assessment tests taken by pupils in Y2 (Key Stage 1 SATS), Y6 (Key Stage 2 SATS) and Y9 (Key Stage 3 SATS). This could provide the standardised benchmark against which we could define low attainers. Hence the following section will discuss the SATS to assess their suitability for this purpose.

The UK government introduced the National Numeracy Strategy in 1996 originally called the National Numeracy Project. Its main aim was to look at perceived weaknesses in the teaching of mathematics paying particular attention to the skills of calculation and computation. A framework for teaching mathematics was produced in 1997 and the government launched the National Numeracy Strategy in 1998 with the introduction of the numeracy hour. An outline of the teaching to be completed during each term was produced for pupils from reception to year 6. This was not compulsory at this stage. The strategy was piloted in 17 LEAs during the academic year 2000-2001 and in April 2001 it was ‘rolled out’ nationally. Within this is the KS3 Framework, a DfES publication, which;

- sets targets for 14 year olds,
- provides catch-up classes for Y7 who did not achieve a level 4,
- provides training programmes and a numeracy framework for teaching.

The KS3 Framework provides a focus which:

- establishes high expectations for all pupils and sets challenging targets for them to achieve;
- strengthens the transition between KS2 and KS3 and ensures progression in teaching and learning across KS3; and
- promotes approaches to teaching and learning that engage and motivate pupils and demand their active participation.

This strengthens teaching and learning through a programme of professional development and practical support (DfES, 2001). In 2003 the primary national strategy was launched which included the national numeracy strategy and this was updated in 2006. However we must note that the government announced in 2009 that from 2011 schools would no longer have to rely on centralised national strategies for support in teaching literacy and numeracy.

One of ways of testing the government's performance indicators was via the Standard Assessment Tests (SATS) that were introduced in 1991 by the Conservative government as part of their commitment to raising standards. They were, until 2010, a statutory requirement and assessed pupils according to the National Curriculum programme of study as detailed above. They were originally based on the teachers' observations but this became too time consuming and consequently a paper based test was introduced in 1995. The tests focused initially on Mathematics and English and gave a performance indicator that could be reported to the Department for Education and Science (DfES). Parents were also given access to this information not only about their own child but, through the publication of performance tables, to schools throughout the country.

In the United Kingdom the government have set performance indicators of level 5 via the SATs, for 14 year olds, i.e. Y9 in Mathematics, English and Science. These can be seen as threshold based attainment targets that can be applied equally to all pupils in the UK. Below are the target and actual results for 2001, 2002, 2003, 2004 and 2007.

	2001 Actual	**2002 Actual**	**2003 Actual**	**2004 Target**	**2004 Actual**	**2007 Target**	**2007 Actual**
English	65%	67%	68%	75%	71%	85%	74%
Mathematics	66%	67%	70%	75%	73%	85%	76%
Science	66%	67%	68%	70%	66%	80%	73%

Table 4 U.K. Government Target and Actual Grades.

We have also seen that the government expected all pupils to have attained at least a level 5 in their KS3 SATS and a level 4 in their KS2 SATS on entry to secondary education. This KS2 level is reiterated by Watson et al (2003) who say that a level 4 on the national curriculum for England and Wales is seen as the ideal minimum level on entry to secondary schools. This gives us an actual benchmark against which attainment can be measured. Given the evidence above we can conclude that the SATS were a standardised summative benchmark with national target grades based on the learning objectives prescribed in the national numeracy strategy.

However we must consider that the target grade of a level 4 in mathematics is based on an amalgamation of all questions in the KS2 SATS mathematics examination. Questions are asked on all five strands of the curriculum: applying mathematics and solving problems, number, algebra, shape, space and measure and data handling. It maybe that the pupil correctly answered all questions in number and incorrectly answered all questions in applying and solving problems thus camouflaging a pupil's difficulties with specific topics or strands. Unlike the hierarchical definitions discussed above this would not give us a picture of specific weaknesses a pupil may have.

Infact this level 4 is the result of two written tests (one calculator and one non-calculator) plus one mental test. And if we consider Messick (1995) who states that when assessing a pupil's work inferences can be made from the students' portfolio about the quality, knowledge, skills and other attributes. However with the SATs there is no opportunity for the students to demonstrate these characteristics, as they do not present any portfolios to the examiners; they merely take the two written and one mental examination. Their performance indicator is based solely on these examinations. He goes on to say that assessments can be either too narrow or too broad. There maybe extraneous clues in the question that make some pupils respond correctly to the 'extra' information but incorrectly to the actual question being asked. It is so embedded that it is not obvious to some pupils what the 'real' question actually is. From this we can conclude that summative assessment of a portfolio as a snapshot of the pupils' ability for that year without the formative assessment of teacher judgement would not give a true reflection of that pupils' actual ability and hence the KS2 SATS would not be a true reflection of the pupils potential attainment.

In 1999 the DfES (it was the Department for Education and Employment (DfEE) at the time of the report) produced the Weighing the Baby report (DfEE, 1999). They say that teacher assessment of pupils' performance should be more highly thought of and that it could be better used than in checking the threshold marks. So here we can see that the SATS that do not allow for teacher assessment cannot be viewed as a method of accessing pupils attainment throughout the academic year.

Tests focus pupils' time and attention on the test objectives and this influences teaching pedagogy to teach only to the test (Shepard, 1990). Some of the directors of testing in the United States of America see this as potentially changing the curriculum to only cover aspects which are to be included in the test. This appears to be what has happened in the U.K. in the teaching of secondary pupils when we consider the SATS. The 'Guide to teacher assessment' was prepared by the schools examination assessment council to be used for in-service training (INSET). It contained details of how lessons should be taught according to attainment targets. In conjunction with this the National Curriculum Programme set out the order in which pupils should learn. This left no room for interpretation by teachers and essentially teachers were teaching to the test as prescribed in the teacher's assessment guide, INSET, attainment targets and the National Curriculum Programme.

But even given these directions of how to teach and assess, how did the government actually measure attainment? The SATS were used to provide authoritative data on the effectiveness of schools. The schools are held responsible for the pupils' outputs, i.e. their SATs results, by the local authorities and central government. But how do they calculate effectiveness? The U.K. government is committed to a raw score approach to reporting performance indicators (see table above on national targets). This is where the pupils' numerical results are reported, not the difference in their score from say the Key Stage 2 SATs to the Key Stage 3 SATs, e.g. if a pupil entered a secondary school in Y7 with say a level 2, and achieved a level 4 in their Key Stage 3 SATs they would have made a 2 level advancement. The government however, would see this as failing by the performance indicators as a level 5 is required by Y9. Another pupil might enter the same school with a level 4 and then achieve a level 5 in their Y9 SATs. This meets the governments required performance indicators even though the first pupil had actually made a greater improvement in their academic achievement. This can have a negative effect on the pupils who has 'only' achieved a level 4 and yet has made greater gains than the level 5 pupil who improved from a level 4 to a level 5. So we can see that the performance indicators for the SATS do provide a benchmark from which students attainment can be measured if the value added is ignored.

However in the discussion on labels at the beginning of this chapter, we discussed how a standardised benchmark from which to measure attainment would allow us to define low attainers. This benchmark has to be equally applicable to all pupils in schools in the UK. We have seen that although hierarchical levels have the potential to give us a clearer picture of a pupil's attainment in individual topics, this would not be a feasible option in the classroom. An argument has been presented that although the SATs do have some weaknesses, they are a standardised summative benchmark from which improved attainment can be measured. Pupils from different schools would have an examination mark that was standardised and consequently could be compared. We have also seen that the government sets a minimum performance indicator of a level 4 on entry into secondary school. Watson et al (2003) also say that a level 4 is the ideal minimum level on entry to secondary schools. This indicator can be used to identify pupils who have not reached this standard and can apply to all pupils in schools in the UK thus standardising our identification of pupils. Hence the definition of low attainers adopted for the experiment will be:

Pupils who have not achieved a level 4 in their KS2 SATS.

Next we will consider the causes of low attainment as although Denvir et al's (1982) definition of low attainer states that you can use the observed outcome without implying a cause for the low attainment, if we do not understand the cause of the low attainment then it is more difficult to address the difficulties low attainers have in mathematics. Hence in the following section we will look at the causes of difficulty in mathematics for low attainers in order to identify interventions, both theoretical and practical, which could address these difficulties.

3.4 Causes of difficulties in Mathematics for Low Attainers

In order to address the difficulties for low attainers in mathematics, we will look at the theoretical causes of these difficulties. Barnes (2005) states that there are many reasons why pupils have difficulty in mathematics including memory, generalisation and transference of learned knowledge, inadequate use of problem solving strategies, reading and language problems and physical and psychological problems. The following sections discuss potential causes of low attainment from internal and external perspectives.

3.4.1 Internal Theories

Firstly we will consider causes of difficulty in mathematics for low attainers that are internal to the pupils such as memory, communication, cognitive development and physical or psychological problems.

3.4.1.1 Memory

We have seen in the previous section on labels that students who have learning handicaps are characterised by slower rates of learning new information and developing cognitive skills (Giles, 1993). These pupils, he says, find it harder to acquire new information. If we further consider Wood (1991) who states that pupils may have immature strategies for memorisation and Wertsch (1978) who says that it is also important for the pupils to be able to remember the new knowledge in order to be able to apply it in subsequent lessons or situations, we can see that poor memory can be a cause of low attainment. If we consider the Key Stage 3 National Strategy Framework (DfEE, 2001), we can see that there is no allowance in the example planning charts and units for years 7,8 or 9 that would accommodate this slower rate of learning. Teachers are merely advised that 36 hours should be devoted to work in the autumn term, 33 hours in the spring term and 36 hours in the summer term. If the units are taught at the same rate for all abilities then pupils who demonstrate the poor memory skills above would be at a disadvantage.

Staver et al (1988) describe working memory as being the ability to manipulate numerous pieces of information within one's mind providing links between them, and fitting them together. They state that this has the capability to increase understanding. According to Barnes (2005) low attainers have poor memories for facts and procedures and consequently would not be able to fit and link information together. Consequently we could say that if a low attainer has poor working memory they would lack the capacity to increase their understanding. If we consider that one part of the SATS is the mental test in which pupils are required to mentally manipulate information in their heads, we can conclude that poor working memory can also be seen as a cause of low attainment.

In the previous section a definition is given of a low attainer as a pupil who has not achieved a level 4 or above in their KS2 SATS and Watson et al (2003) state that one of the reasons for this could be poor short-term memory. Again here we must consider that the SATS examinations are linear, containing questions from topics taught throughout the academic year. Consequently short term memory also can be seen as a cause of low attainment if linear examinations such as the SATS are used as a measure of attainment.

When pupils use surface learning such as rote learning (Warburton, 2003) they merely memorise facts and answers to a test. If we consider multiplication tables, pupils need to memorise many facts in order to apply them to questions. In mathematics summative tests contain questions that depend on memorisation of facts such as the times tables. These tests are often used to measure any improvement in the academic attainment. Infact in 2001 the DfEE produced the Key stage three National Strategy Springboard 7. This was a programme of planned lessons targeted at level 4 in the national numeracy strategy. One of the objectives in this document is to know by heart all multiplication facts up to 10 X 10 and quickly derive corresponding division facts. Hence we can see that low attainment could be caused by the lack of ability to memorise facts.

In conclusion we can see that poor working and short term memory skills have been shown to be a cause of difficulty in mathematics for low attainment. In the interventions section we will see how this cause can be addressed.

3.4.1.2 Communication

According to Haylock (1991) low attainers have poor language skills in speaking, reading and writing and this can be a cause of their low attainment. Watson et al (2003) also suggest that lack of communication skills causes low attainment. They state that reading, writing and language difficulties are reasons why a pupil does not achieve a level 4 or above on entry to secondary schools.

Much of mathematics is built on communication skills and in the Key Stage Three National Strategy Framework for Teaching Mathematics (DfEE, 2001), one of the appendices is a vocabulary checklist. This contains such words as verify, theoretical probability and congruence. On a lesson plan keywords to be used in a lesson will be noted and at the end of a lesson pupils should, according to the framework, be tested to see if they both understand and remember these keywords. Ginsberg (1977) states that the language of mathematics can cause difficulties for pupils and hence in this example poor language skills or poor memory skills can be seen as a cause of low attainment. We will see in the intervention strategies section of this chapter how teachers facilitating communication in the classroom can address this.

We can consider Vygotsky (1978) who showed that in order to understand cognitive development we must understand the interrelationships between thought and language, where language is seen as an essential tool for the formation of thoughts. Thomas (1993) states that advanced modes of thought are communicated to a child via language and hence language plays a critical part in the development of thought. From this we can see that once pupils have mastered language and communication they will be equipped, according to Vygotsky and Thomas, to master thoughts and the next section looks at cognitive development as a cause of low attainment.

3.4.1.3 Cognitive Development

Haylock (1991) tells us that there should be a shift of emphasis for low attainers from routines and procedures to developing an understanding of mathematics. He says that tasks should be meaningful for the low attainers in order that they will engage with the lessons. This could be achieved, he says, by using examples from real life. This is also in line with Driver et al (1986) who suggest that understanding is dependent on the pupils’ prior experience and knowledge. Further we must also consider Kischner et al (2006) who believe that real life examples are important. However if these experiences are unguided they could leave the pupil less competent than when they started.

We will see how this could be addressed in the following section of this chapter.

We have seen in the labels section that according to Piaget (1991), one reason for low attainment is that pupils are unable to access their latent innate knowledge base and hence are unable to understand the implicit contradictions in their own thinking. There it was argued that a pupil might not have the latent innate knowledge required for the particular contradiction or in fact that the latent innate knowledge had not yet been activated. We saw how in the Framework for teaching Mathematics (DfEE, 2001) that topics are revisited over years 7,8 and 9 and a suggestion was made that the latent innate knowledge could be triggered at some point. Consequently we can see that the inability to access this latent innate knowledge base could be a cause of low attainment.

This revisiting of topics is also important as learners go through a process of assimilation and accommodation of new knowledge that is then integrated into existing schemas (Wadsworth, 1971). We have seen that the Key Stage Three National Strategy Framework for Teaching Mathematics (DfEE, 2001) knowledge is built up over periods with topics being revisited over the academic year. Pupils are required to be able to apply their new knowledge of a topic based on their existing knowledge that they may have learnt months previously. If a pupil cannot remember the previous knowledge, as discussed in the previous section, then they cannot apply the new knowledge correctly. Consequently this lack of cognition where pupils cannot assimilate and accommodate new knowledge into existing schemes could be seen as a cause of the low attainment.

3.4.1.4 Physical or Psychological Problems

Watson et al (2003) also suggest that the physical and psychological problems or social and /or emotional difficulties are causes of low attainment. However we have also previously seen that a pupil who has physical and psychological problems or social and / or emotional difficulties may not be labelled a low attainer in this thesis. In the labels section we discussed how these pupils could be labelled as special needs. Examples were given where a pupil who is deaf (a physical problem) may be a special needs pupil but not necessarily a low attainer. This also applies to the psychological, social and emotional difficulties as previously discussed. Hence these causes cited by Watson et al will not be considered as causes of low attainment for this thesis.

3.4.2 External Theories

In this section we will discuss theories that cause difficulty in mathematics for low attainers that are caused by outside influences.

3.4.2.1 Communication

We have seen above that poor communication skills are an internal cause of low attainment. (Haylock, 1991; Watson, 2003). However poor communication skills can also be seen as an external cause as it is taking place in the classroom. According to Brown (1982), there are two different functions of spoken language in the classroom:

- Listener oriented speech
- Message oriented speech

In listener oriented speech the prime goal is to establish and maintain good social relations with the listener, whereas in message oriented speech the speaker has a particular goal and tries to change the listeners state of knowledge through the conveyance of a message. It is important that the listener actually listens, understands and remembers the message. We have seen above that low attainers have problems with memory or cognition and this could lead to difficulties when they use listener oriented speech.

Brown (1982), goes on to suggest syntactic attributes of listener oriented speech as being a slow delivery rate that has been broken into chunks and has many pauses. The structure of the conversation is such that the speaker presumes that the listener will work out for themselves the relevance and the linking of the 'facts'. The speaker relies on physical evidence, e.g. whilst looking at a large dog they might say 'It's big isn't it'. The speaker uses such phrases as 'I like this' without naming the specific action. Which item or component a speaker is referring to may not be explicitly named.

A more efficient packaging of information is used in message oriented speech (Brown, 1982) where words such as 'because', 'therefore' and 'consequently' are used in conjunction with specifically naming items such as triangle or vertices. Pupils in general, she believes, are fluent in listener oriented speech but need to practice message oriented speech. However normally within the mathematics classroom the teacher practices message oriented speech and pupils practice listener oriented speech, i.e. the teacher talks and the pupils listen. However Luria (1976) believed that all fundamental cognitive attributes are shaped by a matrix of social history and form the products of socio-historical development. That is, society says that a child should be seen and not heard. This would not allow pupils to engage in message oriented speech and they would also find it difficult to express their opinions or question the teacher in this environment. The pupils are trying to maintain the acceptable social interaction with the teacher and hence they often try to appear interested in the topic whilst not really understanding the message. We have seen that movement from listener oriented speech to message oriented is difficult for the low attainer (Brown, 1982) and this cause can be addressed if a teaching pedagogy in which pupils can use message oriented speech and break with socio-historical beliefs is adopted. With this in mind we will now look at teaching pedagogies.

3.4.2.2 Teaching Pedagogies

Vygotsky (1978) believed that pupils who were taught using a pedagogy that did not allow for abstract thinking not only failed 'retarded' pupils but the use of this pedagogy re-enforced their 'innate handicaps'. This method of teaching, he says, suppressed the pupils' ability to form abstract thoughts. Amongst other things in the Key Stage 3 National Strategy Framework for Teaching Mathematics (2001) pupils are required to:

- Pose problems
- Predict Outcomes
- Decide on data to be used
- Choose appropriate methods and resources
- Interpret, discuss and justify results
- Identify further information required to pursue a supplementary enquiry.

In order that these objectives can be met a teaching pedagogy that promotes active thinking should be used.

It is suggested by Hokanson et al (2000) that there has been a change in education from instructivism to constructivism and from teacher centred to learner centred education. According to Cohen et al (1997) this change to constructivism has led to effective teaching and learning being based on: higher order thinking skills, deep and superficial learning, metacognition and cooperative learning. One of the strands in the Key Stage 3 National Strategy Framework for Teaching Mathematics (DfEE, 2001) is ‘Using and Applying Mathematics to Solve Problems’. This strand is underpinned by thinking skills, problem solving, communication and reasoning. Hence we can see that pupils could be disadvantaged if a constructivism approach is not applied to the teaching of mathematics within the Key Stage 3 Framework. A more detailed description of constructivism is given later in this chapter.

We have seen that a cause of low attainment is the use of an inappropriate teaching pedagogy. Furthermore not being taught by a maths specialist or the teacher having limited teaching methods is also a cause of low attainment according to Watson et al (2003). It would not be acceptable for a pupil to be taught by a non-specialist at A level however low attainers are often taught by non-specialists. It could be argued that teachers of low attainers need a greater understanding of the subject in order to transfer this understanding to their pupils. They need to have many different methods of approaching a topic and many ways in which to explain how to get to a solution. We will see in the following section interventions strategies that address these causes of low attainment.

3.4.2.3 Causes of Low Attainment Summary

In summary, low attainers may demonstrate many or all of the above characteristics. We have seen that memory, communication, cognitive development, and physical or psychological problems are internal causes of low attainment. Similarly communication and teaching pedagogies have been shown to be external causes. However these causes are often a result of the instructional learning that the pupil receives and the teaching-learning environment in which the pupils experience the learning (Barnes, 2005). We have seen examples in the discussion above that support this and next we will consider how these causes can be addressed.

3.5 Key Theoretical Principles and Practical Intervention Strategies addressing the Causes of Low Attainment

The next section will consider the key theoretical principles that address the theoretical causes of low attainment. It then goes on to discuss practical intervention strategies that address these theories. For example; one of the causes of low attainment is poor short term memory and key theoretical principle that might address this is rote learning, and the practical intervention strategy employed in the classroom for this rote learning to take place could be chanting tables.

3.5.1 Memory

We have seen in the previous section of this chapter that poor memory is one of the causes of low attainment. Wood (1991) states that pupils may have immature strategies for memorisation and we will now consider key principles and practical intervention strategies that address how memory skills can be enhanced. Bruner (1961) suggests that pupils are more likely to remember materials when they are actively engaged, and Mayer (2004) suggests that pupils need to be cognitively active during learning. An intervention strategy that puts learning in context can address poor memory as a cause of low attainment (Biggs, 1985; Ginsberg, 1977; Haylock, 1991; Piaget, 1991; Watson et al, 2003).

However when we put learning in context we should consider Thom (1973) who believed that there are only right and wrong answers in mathematics and the methods used to obtain these answers are tried and tested. Hence if you use these methods you will arrive at the correct answer but where is the opportunity for discussion or opinion in mathematics? If there are only right or wrong answers why should we need learning to be in context? Consider 6 divided by 4 is 1.5, however if the question was how many 4 seater cars do you need to take 6 people to the cinema, the answer to 6 divided by 4 (in this context) is 2. So Thom is correct in that there are only right and wrong answers but this has to be tempered with the context in which the question is asked. The answer to the car problem is only correct if the pupil has answered 2 but this assumes that the pupil has thought not only about the mathematical numerical problem, but also about the mathematical context in which the problem is set, i.e. interpreted the result in a real life situation (Haylock, 1991;

Piaget, 1991; Vygotsky, 1978; Watson et al, 2003). The above example demonstrates a question that has been put in context and needs pupils to be cognitively active which aides memory. The use of real life experiences or putting things in context is a practical intervention that promotes factual recall by low attainers, addressing a cause of low attainment (Wood 1991). Real life examples are discussed in detail in the teaching pedagogy section below.

As we have seen it is important for the pupils to be able to remember facts and information in order to be able to apply it in subsequent lessons or situations (Wertsch, 1978). The intervention strategy he suggests is to ask a series of structured questions of a pupil. The number of questions needed to enable the pupil to bridge their new knowledge will vary. It maybe that only two questions are sufficient, for example a pupil is trying to calculate the perimeter of a rectangle but does not remember what perimeter means. The teacher could ask ‘When a soldier is on patrol and is guarding the perimeter where does he walk?’. Then ’So if the soldier was walking around the perimeter of the rectangle where would he walk?’. This maybe a simple example but low attainers not only relate the new knowledge they learnt say last lesson but it is also putting the learning in context, an intervention strategy described above. However some pupils may take many more questions to achieve understanding. This presents a problem if there are, say, thirty pupils in a class. If we allow 5 seconds per question and the pupil needs 10 seconds to manipulate information and their thoughts (Pimm, 1987; Cohen et al 1996; Wellington et al, 2001) this makes 15 seconds per question. If we consider 5 questions per pupil, each pupil would need 75 seconds per problem. This intervention strategy assumes a one to one interaction with a pupil and so if it is used for all pupils in a class then we would need to multiply this by the number of pupils. In a class of 30 the actual time taken to apply this intervention once to each pupil could be 37 and a half minutes. This would not be feasible in large classes, however low attainers are usually taught in much smaller groups and hence this could be a useful intervention strategy.

This strategy is known as scaffolding (Cockcroft, 1982; Cohen et al, 2004; Boaler et al, 2010). Scaffolding is a term used to describe tasks being broken down into a series of steps aiming towards a specific goal. The Teacher provides guided steps by means of this scaffolding technique, in order for the pupil to achieve the end goal but the overall goal would not be simplified (Staver, 1988). Scaffolding is facilitated within a supportive learning environment and it will be discussed in more depth in the following teaching pedagogies section.

Ginsberg (1977) and Dowker et al (2007) also suggest that memory can play an important part in the understanding of mathematics. They say that one of the key theoretical principles is that pupils must be able to derive and predict unknown mathematical facts. In order to do this, pupils need to locate the appropriate arithmetical principle they need in their memory. Dowker et al give examples of interventions used from their 2007 Numeracy Recovery Scheme Pilot where an answer to a problem is given and pupils have to use this to derive the answer to an associated problem, e.g. 23 X 14 = 322. What is 23 X 140 ? Here pupils need to locate in memory the arithmetical principle relating to multiplying by 10s. This type of question is used in both the written SATS questions and the mental questions and hence again it could be concluded that the lack of memory skills to derive mathematical principles could be a cause of low attainment.

A significant factor in identifying pupils who have difficulty in mathematics is the knowledge of number facts (Russell et al, 1984), and this is reiterated by Dowker et al (2000) who state that a key theoretical principle is the retrieval of these facts. Hence we can see that if a pupil had poor memory skills they would be disadvantaged. An intervention strategy suggested by Dowker et al to address this is to play games that promote memory skills. We will see examples of such games used as a practical intervention strategy in the case studies.

Poor memory is a cause of difficulty in mathematics for low attainers and this can be addressed by surface learning (Warburton, 2003). One method of achieving this, as we have seen above, is rote learning. Dowker et al (2000) also suggest rote learning to address the principles and procedures related to counting. An example of an intervention strategy that addresses rote learning is chanting tables or pupils repeating correct answers to questions (Dowker 2004). However rote learning must be underpinned by understanding (Biggs, 1985) and when using rote learning to understand the role of place value, different approaches should be used (Dowker et al, 2000). Examples of this could be the use of money, number lines or using fingers and thumbs when considering multiples of 10s.

However pupils may still memorise answers to a question without any real understanding. (Dunn et al, 2010). If we consider a question that is based on multiplication tables from the KS3 SATS such as 2 X 3 then the pupil could apply their knowledge of multiplication tables and answer the question. If however this question was 0.2 X 0.3 then a surface learner might incorrectly use the rote-learned multiplication table to arrive at 0.6. Here the pupil did not have a true understanding of place value when attempting the multiplication question and so misplaced the decimal point, even though they have completed the actual multiplication of the integers correctly. However rote learning does have its advantages in memorising facts that are a prerequisite for some summative examination questions such as in the KS3 mental tests.

3.5.2 Communication

We have seen that one of the causes of low attainment is poor communication skills including poor language skills (Haylock, 1991; Watson, 2003), and with this in mind we will now discuss key theoretical principles and practical intervention strategies that address this.

When pupils are in their zone of proximal development they need some form of aid in order to solve problems on their own (Vygotsky, 1978), and he suggests that assistance should be offered at points in the zone of proximal development at which performance requires assistance. If pupils are allowed to work on activities in groups, explaining one to another how they came to a solution, they are in the actual development level, and when benefiting from the aid of other pupils they are in the zone of proximal development. Vygotsky says that this can only take place when the child (pupil) is interacting in their environment and in co-operation with their peers. This, according to Vygotsky is social scaffolding and takes place if pupil to pupil communication is allowed in the classroom. The facilitation of social scaffolding is a practical intervention strategy that can be used to enhance communication.

Cohen et al (2004) also state that peer provided scaffolding is motivating and meaningful. They say that collaboration enhances learning, as students talk about the issues involved with each other as well as with the teacher. The facilitation of collaboration as a practical intervention strategy addresses the causes of low attainment identified by Luria (1976) (Socio-historical beliefs) and Brown (1982) (Message oriented speech) detailed in the previous section. This type of scaffolding does not give us the time resource problem described in the previous section as it is peer scaffolding and is not reliant as much on the teachers' time. However this does bring its own problems as pupils could scaffold each other to an incorrect conclusion.

We must also consider the case where pupils use deflecting questions (Pimm 1987). Deflecting questions are questions used by pupils to lead the teacher from a topic that, for whatever reason, they are not comfortable with. These questions lead to talk about something completely different such as what they did on holiday. Some pupils are very accomplished with this technique and the teacher needs to be aware that this is happening in order to achieve the objective for the lesson and not end up discussing unrelated topics. These deflecting questions could be seen as one of the main problems in the introduction of discussion as a pedagogy in the classroom. Hence teachers would have to be aware of the scaffolding taking place and guide pupils where appropriate to enable understanding (Chin, 2006).

So we could say that the key principle of communication should be facilitated in the classroom in order to address low attainers' poor language and communication skills. Pimm (1987) and Biggs (1985) agree with this stating that teachers should facilitate more pupil to pupil discussion and this facilitation of communication would, according to the Hay McBer report (2000), provide an effective teaching and learning environment.

Pimm (1987) also talks about the sacrifices teachers have to make in order to allow communication within the classroom. By allowing pairs or groups to work and talk together they are essentially releasing control of their classroom. Pupils may ask questions of a theory that underpins the topic being discussed or another topic that would not normally be introduced at this point. In this case the teachers would need to be prepared to go down any path and be confident in their mastery of any topic which the pupil leads the discussion onto and this can be a major concern for teachers. Enabling scaffolding as described above would be an ideal intervention strategy here whereby the teacher could support the pupil's movement from one stage to another without allowing them to stray too far away from the main objective. So we can see that it is important to know what impact 'discussion' would have in the classroom and the environment that the teacher creates is influential in not only facilitating this discussion but also controlling it.

We have seen above a description of the learning theory of message and listener oriented speech. The practical strategy for implementing this in the classroom could be seen as allowing and encouraging pupils to express thoughts aloud in words. According to Pimm (1987) this helps pupils to clarify and organise their thoughts and the same can also be said of reading questions aloud. He says that there are two main reasons why pupils do this, the first being the organisation of the thoughts for themselves and the second being an attempt to get others to understand the thought or to pass on information. Pimm calls the second 'talking for others'. A practical intervention strategy would be the creation of an environment in which the pupils feel safe enough to try this method and are encouraged to explain their answers (Dowker et al, 2000). We have discussed in the peer scaffolding above that if a pupil can correctly explain a method or a fact to their peers then the teacher could reasonably conclude that the pupil understands the fact. In the classroom pupils can demonstrate their new knowledge by explaining to their peer groups the steps that they have used to come to their conclusions. Here we are combining the safe environment required with communication skills and scaffolding in order to address the poor communication skills of low attainers.

Watson et al (1998) also discuss communication as a key theoretical principle in mathematics and suggest that both closed and open questions should be used in the classroom. An example of a lesson using open questions is the circumference and radii lesson described in detail in the case studies chapter. We will see that the use of open questions does not rely on the pupil being able to remember how to 'do' a question but puts the onus on the pupil being willing to 'go out on a limb', sharing their reasoning and methods. We have seen that Thom (1973) says that there are only right and wrong answers in mathematics however all contributions to the solution of a problem are regarded equally in this context. Knowing where a mistake in calculations has been made and being able to explain this to your peers / hearing it from your peers can lead to a greater understanding of the topic. This is an example of the use of both message and listener oriented speech (Brown, 1982), the lack of facilitation of which can be a cause of low attainment. Here the intervention strategy is to use open questions. However teachers may be reluctant to use open questions as they can lead down any path, maybe to a topic with which the teacher is not confident (Watson et al, 1998). They say that prompts could be used as an intervention to keep the pupils on track and to promote mathematical thinking. This concern of teachers should not be the case in KS3 or even KS4 but if we use this pedagogy in KS5 more complex answers will be required. Hence some teachers are not comfortable with this method of teaching. We have already seen examples of this being used in the pilot study where decimal places were introduced in the inspection lesson.

Boaler et al (2010) suggest that facilitating collaboration and discussion would allow teachers to formatively assess students' progress. In the experiment they describe teachers walking around the classroom, asking questions and using scaffolding to enable the pupils to answer. The pros and cons of this will be discussed in detail in the teaching pedagogies section below.

So we can see that the facilitation of many forms of communication is an important intervention in addressing the causes of low attainment. However as Brown (1982) says this is not a sufficient educational goal. Pupils must use communication as a means to gaining understanding and Thomas (1993) goes further and links language to the development of thought. In the following section we will consider cognition key theoretical principles and practical intervention strategies that, as we have seen above, are often linked with communication.

3.5.3 Cognitive Development

A key principle from Piaget's theory (1991) is that children are encouraged to discover things for themselves and parents and teachers challenge children's abilities but do not try to over stretch them. He also states that the prime motivator of developmental change in a child is 'dis-equilibrium'; i.e. a state of conflict in the child due to the difference in what they expect to happen as an outcome to a situation and what actually happens. Wadsworth (1971) also describes how learners go through a process of assimilation and accommodation of new knowledge that is then integrated into existing schemas. This can be viewed as pupils having to look at the previous knowledge in order to accommodate the new knowledge. They may think that they know the answer based on previous knowledge but in fact they may draw the wrong conclusion. It is then that they are in the stage of dis-equilibrium. An intervention strategy that facilitates dis-equilibrium enabling activities to occur provides opportunities for pupils' cognitive development.

This is reflected by Wood (1991) who suggests that a vital basis for learning through instruction comes about when a learner has an incomplete understanding of what he has been shown or told (what is perceived). This is reflected when a child is in their zone of proximal development as described above where they can have a partial understanding of what an adult or peer has done or said and learn from it. This can be facilitated where there is a cognitive conflict, the pupil knows the "facts" but they do not fit the explanation and pupils can use bridging techniques whereby they know the ideas and methods from other activities and need to transfer these to the current problem. However as we have seen low attainers have poor memory skills and hence an intervention strategy would be needed for them to be able to remember the methods they had previously been taught. This intervention strategy could be one of the strategies described above in the memory section such as the facilitation of scaffolding whereby the teacher can prompt pupils through the cognitive conflict and help them whilst they are in the zone of proximal development.

We have also seen another key principle from Haylock (1991) who believed there should be a shift of emphasis for low attainers from routines and procedures to developing an understanding of mathematics. In order for low attainers to engage with learning tasks, they should be meaningful. An intervention that could achieve this, he says, is by using examples from real life, presented in a way that low attainers can relate to. He describes when learning how to tell the time the school day could be used. All pupils understand that the school day starts, has lunch and ends at a specific time. This is, he says, an idea opportunity to use real life to teach a topic that many low attainers find difficult. Watson et al (2003) re-iterate the intervention strategy of putting mathematics into context with pupil participation to address some of the difficulties low attainers face in mathematics.

Vygotsky (1978), as we have already seen, believed that a teaching pedagogy should allow for abstract thinking. If we consider Dowker et al (2000), who state that writing symbols for numbers proves difficult for some pupils, and that pupils cannot translate problems written in concrete (kinaesthetic problems), verbal (word problems) and numerical (written problems) formats. However we also saw above that the Key Stage 3 National Strategy Framework for Teaching Mathematics (DfEE, 2001) does require abstract thinking from pupils and an intervention strategy that could address this, Vygotsky and Dowker et al suggest, would be that teachers provide practical tasks encompassing real concepts.

Driver et al (1986) say that understanding is dependent on the pupils' prior experiences and knowledge; they also suggest that much teaching is performed in a teacher lead way and the pupils are passive learners. In my experience low attainer pupils tend to be passive and do not willingly share their experiences or knowledge and examples of this can be seen in the pilot study. Here we can see that if a teacher can address the problems posed by socio-historical development (Luria, 1976), as described above, then pupils would be more willing to use pupil to teacher communication. An intervention strategy that could be used would be for the teacher to enable communication such as listener and message oriented speech (Brown 1982), talking for others (Pimm 1987), peer to peer and pupil to teacher communication (Watson 2003) as described in the communication section above. This would mean that pupils become less passive and more willing to contribute their experiences and knowledge and hence, according to Driver et al, would promote understanding.

But we must also consider Kirschner et al (2006) who say that in order for learning to be meaningful experience is important. They also says that although the activities could be motivating for the pupils, if they are unguided, they can leave the pupil less competent than before they started the activity. However pupils must be allowed the chance to practice and gain feedback that will equip them to complete the problem next time it is encountered. So there must be a balance between allowing the pupils to experience things for themselves and the guidance of the teacher prompting but not telling the pupil the answer. If pupils are unguided and use peer scaffolding to get to the incorrect answer then this would have a negative effect on the pupils' attainment. We could see this as a form of scaffolding, as described above, and the intervention of facilitating teacher provided scaffolding can address this concern.

If we consider practical intervention strategies used to address the key elements of memory, communication and cognitive development discussed above, we can see that there is a dependence on the teaching pedagogy used in the classroom, e.g. actively engaged (Bruner, 1961) message oriented speech (Brown, 1982) and scaffolding (Woods et al, 1984; Cohen et al. 2004). Hence next we will consider teaching pedagogies as interventions that address the difficulties in mathematics for low attainers.

3.5.4 Teaching Pedagogy

3.5.4.1 Constructivism

We have also seen that one of the strands in the Key Stage 3 National Strategy Framework for Teaching Mathematics (DfEE, 2001) is 'Using and Applying Mathematics to Solve Problems' and that this strand is underpinned by thinking skills, problem solving, communication and reasoning. Constructivism embodies higher order thinking skills, deep and superficial learning, metacognition and cooperative learning leading to effective teaching and learning (Hokanson et al, 2000). Hence it would be reasonable to conclude that pupils whose mathematics education is based on the Key Stage 3 National Strategy Framework for Teaching Mathematics would be disadvantaged if a constructivist approach is not applied to their teaching.

With this in mind we will now discuss constructivism. There are two types of constructivism; cognitive constructivism based largely on Piaget's theories, and social constructivism, based mainly on Vygotsky (Hokanson et al, 2000). Constructivism in general is a theory in which learning is seen as an active process, one in which the pupil constructs knowledge rather than receives it. (Crowther, 1995).

Cognitive and social constructivism have some common characteristics; that knowledge is constructed through reflective abstraction where the pupil participates and is active, where they cognitively process information. The pupil rather than being passively accepting, actively constructs meaning.
The theory of cognitive constructivism indicates that;

- pupils construct their own knowledge of the world
- pupils use experiences to derive learning
- learning takes time
- pupils continually organize and reorganize, structure and restructure new experiences to fit them into existing schemata.
- knowledge and understanding are constructed by the pupil rather than imparted by the teacher.

(Cohen et al 2007).

Social constructivism advocates learning strategies that are interactive, social and cooperative (Cohen et al, 2007). It is one in which the environment plays an important role, placing topics in context. Here the teacher facilitates learning, setting up situations and prompts learning through scaffolding. This enables pupils to become independent learners, thinking for themselves and could be seen as active learning (Bonwell et al, 1991), where the responsibility for learning is on the pupils themselves. They also state that pupils are encouraged to use communication by working in pairs, using role-play or taking part in debates. The teacher provides guidance for the pupil and the amount of this varies according to the situation and the specific pupil. Here we can see that a practical intervention strategy could be the facilitation of scaffolding and group work which we will now discuss in more detail.

3.5.4.2 Scaffolding

We have already seen in the memory and communication sections above that facilitating scaffolding is an intervention strategy that addresses some of the causes of low attainment, however it is not without its potential drawbacks. (Kirschner et al 2006). Irrespective of whether scaffolding is teacher to pupil or peer to peer, if it is not done efficiently it can lead to incorrect reasoning being reinforced.

Vygotsky (1978) theorised that there was a difference between a child’s capacity to solve problems on their own and their capacity to solve them with aid. All functions and activities that a child can perform unaided are actual development levels and those in which the child needs some form of aid are called the zone of proximal development. The aid provider can be anyone who already has the knowledge to perform the task, e.g. parent, teacher, etc. We have seen in the causes of low attainment section poor working memory is a cause of low attainment as pupils find it difficult to manipulate and link pieces of information together (Staver et al, 1988). This linking of information, they say, promotes understanding and an intervention that can address this cause is the facilitation of scaffolding where the pupil manipulates pieces of information in their minds dependent on the prompts given by the teacher.

Scaffolding is an intervention strategy suggested by Dowker et al (2000) to address word problem solving questions. During scaffolding teachers must give pupils enough time to think about their answers and an intervention strategy that addresses this is to allow wait, or thinking time. (Wellington et al, 2001; Pimm, 1987; Cohen et al, 1996). This, they say, allows pupils time to manipulate the information and their thoughts. The teacher should also, when warranted, facilitate peer discussion before answering. This improves the quality of teacher pupil dialogue and allows time for understanding and assimilation by the student (Boaler et al, 2009, Dunn 2010). This is also a suggested intervention by Baker et al (2002) in their synthesised report. They state that when peers are used as guides or tutors achievement is enhanced. Dowker (2004) agrees with this premise however does state that this cannot be used as a substitution for teacher - pupil interaction.

However we have seen above that peer discussion may not always be effective. Pupils can use deflecting questions (Pimm, 1987) to lead the teacher from a topic with which they are uncomfortable or reinforce misconceptions.

With this in mind we will now look at the facilitation of group work as an intervention strategy.

3.5.4.3 Group work

Vygotsky (1978) says that an essential feature of learning is that it awakens a variety of internal development processes that are able to operate only when the child is in the action of interacting with people in its environment and in co-operation with its peers. We have also seen that Piaget (1991) believed that biological developments moved an individual from one stage to another and that concrete experiences facilitated through group work could be used to help children learn. The facilitation of group work is also an intervention strategy suggested by Haylock (1991), Watson et al (2003) and Boaler et al (2010).

Haylock (1991) advocates small group work and competition as a means of pupils practicing and consolidating their mathematics. He cites examples of scaffolding being used as a teaching strategy within these groups where prompts are used extensively at first, gradually being taken away in order that the pupils can eventually solve a greater problem unaided. This is an example of peer scaffolding and we have seen the problems and benefits of this teaching pedagogy discussed above.

A problem of allowing communication and hence group work to take place is the sacrifices teachers make in releasing control of the classroom (Pimm 1987). We have seen in the communication section that this is a problem for some teachers and that the impact that group work can have on a classroom may not always be positive.

However we have previously seen that the facilitation of group work as an intervention strategy can promote problem solving and discussion (Boaler et al, 2010). They describe an experiment that takes place in 5 schools using group work for problem solving and discussion in the classroom as a teaching pedagogy. In these 5 schools pupils were taught in mixed ability groups in Y7 and Y8, however a definition of mixed ability was not given. When working in mixed groups it was often the low ability pupils who solve the problem set and offer valuable insights when whole class discussion is facilitated. Boaler et al also describe the surprise of the teachers at the quality of the work produced by the low attainers. The result of all of the above was an increase in the attainment of the pupils in Boaler et al’s experiment of 0.9 of a level of the National Curriculum. These results should however be viewed with caution as the schools did not use the same assessment and one of the schools in the experiment was not focused on improving attainment, rather they wanted to investigate new ways of teaching. We must consider that although this experiment was conducted over a year, there was only 60 hours of group work video recording, i.e.12 hours per school.

The theory that mixed ability groups improve the cognitive ability of low attainers is re-iterated by Shayer et al (2007). However they also say that when Cognitive Accelerated Maths Education scheme (CAME) was used with low attainers no improvement was seen. They say that this is due to the fact that there are no pupils with higher thinking skills who can collaborate and communicate their ideas to the lower ability students, thus enabling the low ability student to move through the zone of proximal development. It could also be applied to groups consisting of only middle or high attaining pupils as the same principle should apply, i.e. there would be no pupils with higher order thinking skills than others in the group and hence no quickened movement through the zone. We will see a discussion on CAME later in this chapter

However if we consider Pimm (1987) when he describes ‘talking for others’ as pupils getting others to understand by passing on information. By allowing pupils to express thoughts aloud to each other Pimm says that they will clarify and organise their thoughts. It should be noted however that he does not state whether or not these pupils are mixed ability.

So what constitutes a mixed ability class? If the pupils in a class are deemed as low attainers as per the adopted definition and have a range of KS2 SATS results from a low level 3 to just under a level 4 is this a mixed ability group? Or do some pupils need to have a level 6 in the KS2 SATS and others a level 3? Neither Boaler et al or Shayer et al define what a mixed ability class is. However we must also consider that Boaler et al and Shayer et al used other interventions alongside the facilitation of the group working intervention and it is difficult to disaggregate the effect of one intervention from any other.

In the following section we will discuss assessment as a key theoretical principle and practical intervention strategy.

3.5.4.4 Assessment

We have seen in the internal causes of low attainment section that low attainers experience repeated failure. (Haylock, 1991). In order to address this Haylock suggests that clear and relevant objectives should be used within the teaching pedagogy as an intervention strategy where the pupil knows what stage they are at and how they can get to the next stage. This is particularly important when we consider the linearity of the Key Stage 3 National Strategy for Teaching Mathematics (DfEE, 2001).

This awareness of progress is also a key theoretical principle suggested by Watson et al (1998) and can improve academic attainment by .68 SD units (Baker et al, 2002). Watson et al suggest that an intervention strategy that addresses this would be the use of assessment for learning, for example the use of small white boards (Watson et al, 2003). Here pupils hold up their white boards and the teacher can assess their answers, deciding on the next question, and gradually move the pupils towards the desired outcomes or objectives. This type of assessment would be particularly useful when open questions (Watson et al 1998) are used as a teaching pedagogy as suggested in the communication section. This is an example of formative assessment and the final section of this chapter discusses this in detail.

Teachers could also use assessment to ascertain which of Piaget's stages (1991), as described above, a pupil is at and use this to inform their teaching, i.e. what resources and activities are likely to have the greatest effect on the pupil at that stage. Assessment as an intervention strategy is also suggested by Ginsberg (1977), Dowker (2004) and Boaler et al (2010) as a means of addressing the causes of difficulties in mathematics for low attainers, discussed in the previous section.

Summative assessment has been linked to rote learning in the memory section of this thesis and to the Key Stage 3 National Strategy for Teaching Mathematics vocabulary checklist in the communication section. We will also see a detailed discussion of summative assessment in the final section in this chapter.

Teachers would not efficiently be able to implement many of the interventions discussed above if a supportive environment is not facilitated and hence next we will discuss environment.

3.5.5 Environment

The interventions strategies that are dependent on a supportive environment have already been described above in the memory, communication, cognitive development and teaching pedagogy sections. Hence in this section we will only discuss the key theoretical principles relating to environment.

The key theoretical principle that the environment is an important factor is not new. Papert (1980) alludes to piagetian learning being the natural spontaneous learning of people in interaction with their environment. Mounoud (1981) also argues that the environment is an important factor in problem solving as internal representations used in the processes of problem solving should correspond in basic aspects to the external environment and have seen an example in the inspection lesson of the pilot study. Here pupils were asked to measure their desks in order to calculate a mean desk size. Some pupils gave answers in centimetres and some in metres but they did not give the units. I had then said that 1.39 is tiny and 174 is much larger. The pupils had corrected me immediately stating that 1.39 was metres. Here they had used their knowledge of the environment to make sense of the different magnitude of the numbers.

The facilitation of communication would provide an effective teaching and learning environment (Hay McBer, 2000). We have seen interventions stating that teachers should facilitate more pupil to pupil discussion (Pimm, 1987) and that pupils in general are fluent in listener oriented speech but need to practice message oriented speech (Brown, 1982). When pupils are trying to be listener oriented they find it difficult to change the historical belief that a teacher does not want pupils to 'talk' in the classroom (Luria, 1976) and this can be ameliorated if a supportive environment is facilitated.

Teachers should also promote pupil's listening skills in order that more pupil to pupil discussion can take place (Pimm, 1987) and again the environment that the teacher creates can promote this. Message oriented speech should also be encouraged (Brown, 1982) and is enhanced if a supportive environment is in place.

Boaler et al (2010) also suggest that the environment created in the classroom is important where communication should be facilitated and this can be achieved via group work. Pupils who took part in Boaler et al's experiment said that they enjoyed the group work as it allowed them to discuss problems and this gave them a better understanding of how the solution had been arrived at. The pupils also said that the discussion allowed them to understand different ways of solving problems. Here again the intervention strategies of facilitating collaboration, discussion, and peer scaffolding (Boaler et al, 2010) need a supportive environment if they are to be used effectively.

Watson et al (2003) suggest many intervention strategies that may have an impact on attainment such as allowing and facilitating pupil participation, time to think, working on memory, awareness of progress and putting maths in context. They say that when asked questions which require mathematical thinking, pupils will achieve more than their counterparts if these learning strategies are facilitated. These interventions should take place in an environment in which pupils are challenged but supported. This, they say, could address some of the difficulties in mathematics for low attainers.

We have seen examples above of how the supportive environment is intertwined with many of the intervention strategies such as memory, communication and teaching pedagogies. Examples have been given that demonstrate how the supportive environment is essential in bringing intervention strategies such as putting mathematics in context and using every day examples into the classroom.

In conclusion we have seen a discussion on causes of low attainers in mathematics from both an internal and external perspective. These ranged from poor memory and communication skills, diminished cognitive development, learning styles, physical or psychological problems to inappropriate teaching pedagogies. We have also considered key theoretical principles and practical intervention strategies that address these causes. These theories and strategies were categorised under the headings of memory, communication, cognitive development and teaching pedagogy. We have also seen that the overriding key element was the supportive environment without which these intervention strategies could not be facilitated.

In the following section we will consider why the accelerated learning pedagogy is suitable to address the causes of low attainment by discussing the key theoretical principles and practical intervention strategies that underpin this teaching pedagogy.

We will start by looking at the history of accelerated learning followed by the discussion of the theories and strategies that underpin this pedagogy. These key theoretical principles and practical intervention strategies are also examined in relation to CAME. We will discuss the rationale for categorising the key theoretical principles and practical strategies as aspects of environment, communication and memory, showing these to be the three important elements of the interventions.

3.6 Accelerated Learning

3.6.1 History of Accelerated Learning

Accelerated learning is based on the work of Bulgarian psychiatrist Georgi Lozanov who developed the theory of suggestopedia. This was the basis for what became known as accelerated learning in the USA in 1976 (Bancroft, 1978). Suggestology was developed by Lozanov in 1966 when he established the Suggestology Research Institute in Sofia where he trialled this new system of teaching. Originally suggestology was used to teach language students and is derived from the two words ‘suggestion and pedagogy’. Lozanov believed that pupils had preconceived beliefs (suggestions) that they brought into the classroom (Lozanov, 1978), rather like the fears identified by the author in the introduction chapter and addressed in the pilot study. Facilitators, in our case teachers, can help pupils move from beyond these fears by using suggestopedia. In this teaching pedagogy emphasis was placed on the quality of the learning environment. This learning environment should be challenging but supportive, one in which pupils would be stretched and engaged. Peer to peer communication and group work are encouraged.

In 1975 Dr. Donald Schuster and Dr. Charles Gritton formed the Society for Accelerative Learning and Teaching (SALT) at Iowa State University. Subsequently in 1994 SALT changed its name to the International Alliance for Learning and it was at the same time that the name of suggestopedia was changed to accelerated learning. The Accelerated Learning movement in the United States assimilated various research into teaching approaches over the years such as research into learning styles, multiple Intelligences and adult key theoretical principles (AtKisson, 1991). New discoveries in the field of neuroscience were also incorporated.

We will see in the following sections how accelerated learning is underpinned by key theoretical principles and practical strategies in the following section and how the diversity of learning activities and methodologies are brought together in a supportive environment and the 7 stages of the Accelerated Learning cycle. However we will begin by considering what the accelerated learning pedagogy consists of.

3.6.2 Accelerated Learning Pedagogy

Smith (1996) says that accelerated learning is not for a specific group of learners, age range, nor a category of perceived ability. The classroom teaching method, or pedagogy, is not about doing things faster. It is a considered generic approach drawn from disparate disciplines and tested with different age groups and different ability levels. Accelerated learning is to be accomplished, he says, via a learning cycle that consists of 7 stages that facilitate different learning styles. These 7 stages are:

- Connect to the learning
- Big picture first
- Describe the outcomes
- Input
- Activity
- Demonstrate
- Review for recall and retention.

The learning that is done in this learning cycle, he suggests, should be an active creation of knowledge not a passive absorption of information. This is inline with Hokanson et al (2000) and Vygotsky (1978) who say that cognition takes place when knowledge is constructed through reflective abstraction where the pupil participates and actively constructs meaning rather than passively accepting it.

These 7 stages are to be taught within the supportive learning environment. Smith describes the supportive learning environment as one in which the pupil is free from anxiety and stress but must be challenging. Models for building and maintaining self-esteem must be in place and the teacher communicates high expectation positively and provides constant educational feedback via summative and formative assessment (Boaler et al, 2010; Watson et al, 2003) which, as we have previously seen, are practical intervention strategies that address low attainers difficulties in mathematics. Vygotsky (1978) says that the environment can facilitate cognitive development and in accelerated learning the teacher establishes a supportive learning environment in which this can take place.

Wise (2002) also suggests that there are 7 stages to the accelerated learning pedagogy plus the learning environment and stages are taught in a cyclic fashion. He agrees that a supportive environment must be created first and that this environment must be one where the pupil feels supported but challenged. It should promote high self esteem and be stimulating. The stages Wise suggests can be seen in the diagram below.

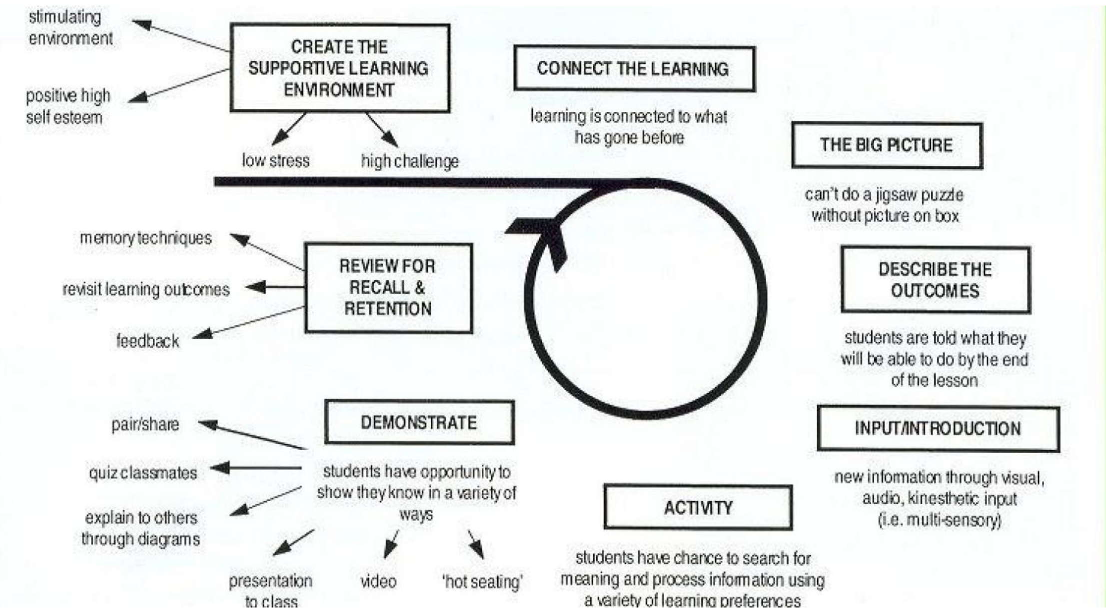


Figure 6 Accelerated Learning Cycle.

An explanation of Wise's diagram is given below:

- **Connect to the learning**

  Pupils need to be aware of how this new knowledge will affect them and be put in context. This could be achieved by drawing on the pupils' personal experiences. It maybe that this new knowledge is connected to prior knowledge.

- **The big picture**

  Pupils are informed how this new knowledge fits into the whole. This could be accomplished via mind maps or flow diagrams.

- **Describes the outcomes**

  Pupils should be told what they would accomplish by the end of the lesson or in fact by the end of the topic. This could be done by topic charts in which the pupils fill in the date on which they finished the topic, a self-assessed grade and the level at which they are working.

- **Introduction**

  New information is given via different media, e.g. visual, audio, symbolism, keyword text, modelling etc.

- **Activity**

  The teacher would use a multi-activity approach to teaching the new knowledge. This could be via a combination of:

  - employing a variety of teaching styles (facilitating for kinaesthetic, visual and auditory learners)
  - allowing communication such as peer to peer.
  - group and independent work.
  - using of assessment to inform the progress

This allows pupils to process information in a style that they prefer and to try to link information in order to get a solution.

- **Review, recall and retain**

  Memory techniques are used in order to ensure that the pupils retain the new knowledge. This could be achieved by various methods, e.g. a memory game. The outcomes are re-visited in order to gain assessment for learning feedback that can then be used to inform the next lessons objectives.

- **Demonstrate**

  Pupils are given the opportunity to feedback in an appropriate manner. This usually involves communication skills for presenting to the whole class or group, or by asking and answering questions in pairs.

This cycle is also reiterated by Jervis (2006) where again there are 7 stages to the accelerated learning cycle plus a supportive learning environment. All of the stages have similar titles to both Smith and Wise and describe the same teaching pedagogy.

Above we have seen a description of the 7 stages and supportive learning environment described by Smith (1996), Wise (2002) and Jervis (2006) that constitute accelerated learning. Next we will discuss the key theoretical principles and practical intervention strategies that underpin these 7 stages and supportive environment demonstrating its theoretical underpinning and empirical validation.

3.6.3 Key Theoretical Principles and Practical Intervention Strategies underpinning Accelerated Learning

According to Cohen et al (2004, page 164),

'there is no single blueprint for effectiveness, though there are very many characteristics of effective teaching and effective learning'.

Palmer (2005) believed that when teaching practice is informed by an understanding of how students learn it is more likely to be effective and it is with this these sentiments in mind that we will begin by looking at how the 7 stages of accelerated learning are underpinned by key theoretical principles and the practical intervention strategies that address the causes of low attainment as seen in section 3.5. The key theoretical principles can apply to several of these 7 stages, and in the following sections they are discussed under the most relevant stage and only referenced in the other stages where applicable. Practical intervention strategies demonstrating the empirical validation of the components are also discussed. A summary chart showing which of the 7 stages (and environment) the key theoretical principles and practical intervention strategies are used or facilitated in is given at the end of this section, thus summarising the theoretical underpinning and empirical validation of accelerated learning.

3.6.3.1 Environment

Watson et al (2003) and Boaler et al (2010) suggest that a supportive learning environment should be facilitated in order for effective learning to take place. In the following section we will see examples of practical intervention strategies underpinned by key theoretical principles that are facilitated by the supportive learning environment advocated by accelerated learning.

We will begin by looking at Piaget (1991) who believed in abstract symbolic reasoning, i.e. how we come to know things. He put forward the theory that younger children gave qualitatively different answers to questions than older children not because they were not as intelligent, but because they thought differently. He suggests that there are 2 processes through which we learn:

- the process of coming to know and
- the stages we go through as we acquire the new knowledge or ability.

Behaviour, Piaget theorised, is controlled through mental organisations called schemes that the individual uses to represent the world and decide on actions. He maintains that we are born with schemes that operate at birth which he calls 'reflexes'. As infants use these reflexes within their environment they change and are replaced by constructed schemes. He describes two processes that are used by individuals whilst they are growing.

The first is assimilation, whereby the individual uses or transforms the environment in order that it will fit within the pre-existing cognitive structures. The second is accommodation whereby the cognitive structures are changed in order to accommodate something from the environment. In the accommodation scheme a teacher could facilitate cognitive change for example by displaying posters on the walls of the classroom. Here if this is new information pupils would need to change their cognitive structures in order to achieve accommodation. These views on assimilation and accommodation are supported by Wadsworth (1971) as discussed earlier. So we can see that in the context of schemes the environment can play an integral role.

We have also seen above that in order for cognitive development to develop we must understand the interrelationships between thought and language (Vygotsky, 1978). Thomas (1993) also believed that that language plays a critical part in the development of thought. However we have seen from Luria (1976) that socio-historical development would have to be changed in order for this communication to be facilitated. One of the central themes of accelerated learning is the supportive learning environment that enables many types of communication (language) such as message oriented speech (Brown, 1982) and peer to peer communication (Pimm, 1987; Boaler et al, 2010) to take place. Thus, by facilitating communication, an effective teaching and learning environment can be provided (Hay McBer, 2000).

Also the theoretical ideology of Vygotsky (1978) that cognitive skills and thinking patterns are products of the social environment is facilitated within the supportive environment of accelerated learning.

We have also seen that the environment is an important factor (Papert, 1980) and Mounoud (1981) argues that in the problem solving process the environment is an important factor as internal representations used in the processes of problem solving have to correspond in basic aspects to the external environment. Examples of practical intervention strategies such as putting mathematics in context (Watson et al, 2003) and pupils' prior experiences (Driver et al, 1986) are used in the accelerated learning pedagogy in support of these key theoretical principles.

We have seen that there has been a move in education towards constructivism (Hokanson et al, 2000) where higher order thinking skills, deep and superficial learning, metacognition and cooperative learning are paramount (Cohen et al, 1997). In constructivism, amongst other things, a pupil constructs knowledge rather than receives it (Crowther, 1995) and pupils use their own experiences to derive learning (Cohen et al, 2007). In addition, Bonwell et al (1991) say that pupils should be encouraged to use communication by working in pairs, using role-play or take part in debates. We have also previously seen that teachers can use the practical intervention strategy of scaffolding (Cockcroft, 1982; Cohen et al, 2004; Boaler et al, 2010), as a means of helping pupils to construct knowledge. An important aspect of effective scaffolding is wait or thinking time (Wellington et al, 2001; Pimm, 1987; Cohen et al, 1996) as the teacher must allow pupils time to manipulate the information and their thoughts. The accelerated learning pedagogy uses scaffolding and again this practical intervention strategy can best be facilitated when a supportive environment is in place.

From the above we can see that a supportive learning environment facilitates many of the theories and practical strategies that address the causes of low attainment and that this is integral to the accelerated learning pedagogy.

Looking back at section 3.5 we can see the theories and strategies that address the causes of low attainment and now we will consider each of the 7 stages of accelerated learning in turn, identifying the key theoretical principles and practical intervention strategies that underpin them.

3.6.3.2 Connect to the learning

In this stage of accelerated learning the pupils need to be aware of how the new knowledge will affect them and be put in context.

In accelerated learning pupils are actively encouraged to bring their experiences and knowledge into the classroom and we have seen examples of this in the pilot study where the pupils designed desks in the inspection lesson. This is underpinned by the key theoretical principle that understanding is dependent on the pupils' prior experiences and knowledge (Driver et al, 1986; Kirschner et al, 2006).

A practical example that can be seen in the case studies is the puppy's playpen lesson where pupils design a run for a Dalmatian puppy underpinned by the practical intervention strategy of putting mathematics into context with pupil participation (Watson et al, 2003)

In the connect to the learning stage of accelerated learning the teacher draws on the pupils' prior experiences making the learning real for them, thus demonstrating that this stage is underpinned by Haylock's (1991) practical intervention strategy; teachers should use real life examples in which the learning could be made meaningful for the pupils. This stage also takes into account such key theoretical principles as Thom (1973) with regard to right and wrong answers. Here the answer to the car problem was only correct if the pupil has answered 2 but this assumes that the pupil has thought not only about the mathematical numerical problem, but also interpreted the result in a real life situation (the answer being a whole number of cars).

From this we can see that accelerated learning uses pupils' prior experiences and knowledge. Topics are put in context and group work is facilitated in this stage. All of these theories and practical interventions have been shown to address the causes of low attainment in mathematics in the previous section.

3.6.3.3 The Big Picture

In the big picture stage of accelerated learning pupils are informed how this new knowledge fits into their existing knowledge. We have seen that learners go through a process of assimilation and accommodation of new knowledge integrating this into their existing schemas (Wadsworth, 1971). Within this big picture pupils could use bridging techniques in which ideas and methodologies from other activities could be transferred to the current problem. Hence we can see that in the big picture stage of accelerated learning builds on the key principle of assimilation and accommodation. An intervention strategy of wait and think time can be used to facilitate this (Pimm, 1987; Cohen et el, 1996; Wellington et al, 2001).

3.6.3.4 Outcomes

In this stage pupils are informed what the learning outcomes are expected to be, either in the lesson or by the end of the topic. The practical intervention strategy that clear and relevant objectives should be used to address this (Haylock, 1991).

In order for the teacher to sensibly set these outcomes they must have a clear idea of where the pupil is in terms of attainment. A key theoretical principle is that learning is dependent on the development stage a pupil is at and learning can be accelerated dependent on this stage (Piaget, 1991). Here the teacher could use formative assessment as a practical intervention strategy (Boaler et al, 2010) to ascertain which stage the individual pupils were at in their development and use this to set the outcomes of a lesson or topic.

Assessment is a practical intervention strategy also suggested by Watson et al (2003) to address the problems low attainers have with mathematics. An example of this in the case studies is the use of the small white boards, another suggestion of a practical strategy by Watson et al (2003). Here the teacher can assess all pupils' answers as they hold up their small white boards, deciding on the next question based on these answers, gradually moving towards the desired outcomes or objectives.

3.6.3.5 Introduction

The introduction to the lesson is given via different media such as video, audio, symbolism etc as described in section 3.6.2. It is in this introduction stage that pupils formulate a plan of how to approach and solve the problem. As many types of communication are facilitated in accelerated learning pupils can use their communication skills to talk their approach through with their peers, a practical intervention strategy suggested by Watson et al (2003), Pimm (1987), and Boaler et al (2010). They could also use peer to peer scaffolding (Cohen et al, 2004) or group work (Boaler et al, 2010) in order to decide upon a suitable approach. These interventions are used mainly in the activity section and hence are discussed in more detail in that section.

This discussion may involve the use of prior knowledge and hence memory skills would be needed. We have seen many key theoretical principles and intervention strategies that address low attainers' memory problems such as scaffolding (Cockcroft, 1982; Boaler et al, 2010; Watson et al, 2003) and putting mathematics in context (Haylock, 1991). These theories and strategies could be applied to this stage of accelerated learning however key principles and intervention strategies based on memory are primarily used in the review, recall and retain stage and are discussed in more detail there.

3.6.3.6 Activity

If we consider the timeframe devoted to the 7 stages then the activity stage is thought to be the most important stage of accelerated learning. During this many of the aforementioned key theoretical principles and practical intervention strategies can be facilitated such as dis-equilibrium (Piaget, 1991).

We have also seen that a vital basis for learning is when a pupil has an incomplete understanding of what they have been shown or told (Wood, 1991). Here the pupil is in the their zone of proximal development (Vygotsky, 1978), as they can have a partial understanding of what an adult or peer has said or done and can learn from it. This can be facilitated in the activity stage where the teacher creates a learning situation where there is cognitive conflict for the pupils. Two practical intervention strategies that allow for proximal development to occur are peer provided scaffolding (Cohen et al, 2004) and group work (Haylock, 1991; Watson et al, 2003; Boaler et al, 2010).

The functions and activities that a child can perform unaided are ‘actual development levels’ and those in which the child needs some form of aid are called the ‘zone of proximal development’. In this stage the teacher or peers can be aid providers as some pupils already have the knowledge to perform the task. Again here we can see that pupils are encouraged to work in pairs or in groups thus facilitating Vygotsky’s learning theory that internal development processes operate when a child is interacting with people, their environment and peers. This is also relevant for the demonstrate stage where pupils feedback by presenting their findings to the rest of the class.

The teacher can also facilitate group work that is underpinned by concrete experiences (Piaget, 1991) and co-operating with peers (Vygotsky, 1978) within a supportive learning environment (Boaler et al, 2010). Group work was discussed as a practical intervention strategy to address the difficulties low attainers have in mathematics (Haylock, 1991; Watson et al, 2003; and Boaler et al, 2010). Although accelerated learning encourages group work in this stage, it can also be used in the connect to the learning and demonstrate stages.

We have also seen that Vygotsky (1978) believed social scaffolding takes place if pupil to pupil communication is allowed in the classroom. This peer to peer communication is a practical intervention strategy suggested by Watson et al (2003) and examples of this can be seen in both the pilot and case studies chapters. This is not only allowed in this stage of accelerated learning, but actively encouraged. Although we have seen some problems associated with peer provided scaffolding, we must also consider that peer provided scaffolding is motivating and meaningful (Cohen et al, 2004; Boaler et al, 2010) Scaffolding is a practical intervention strategy suggested by Cockcroft (1982), Cohen et al (2004) and Boaler et el (2010). Such scaffolding is underpinned by the key theoretical principle of discussion (Pimm, 1987; Chin, 2006; Boaler et al, 2010). Chin (2006) also states that understanding can come from teacher – pupil discussion and this can also be facilitated in this stage by scaffolding.

However we have seen that there is no educational benefit in merely increasing the amount of time that pupils communicate in a lesson (Brown, 1982), rather pupils need to practice message oriented speech. In this stage of accelerated learning pupils need to use such words as ‘because’ or ‘consequently’ together with naming items such as ‘perpendicular’ or ‘congruent’. Pupils in the activity stage practice message oriented speech in order to communicate ideas and knowledge to their groups and use both message and listener oriented speech in other stages. An example of a practical intervention strategy is talking for others (Pimm, 1987). Here we can see that the key theoretical principles and practical intervention strategies related to communication underpin this stage of accelerated learning, and are also pertinent for the demonstrate stage.

This stage would also allow the teacher to activate pupils’ innate knowledge discovering implicit contradictions in their own thinking (Piaget, 1991). It would also facilitate the assimilation and accommodation of this new knowledge into existing schemas (Wadsworth, 1971). The intervention practical strategy of formative assessment (Boaler et al, 2010; and Watson et al, 2003) could be used to ascertain which of Piaget's stages a pupil is at. The teacher could then use this information to inform their teaching with respect to the resources and activities that are likely to have the greatest effect on the pupil.

During assessment low attainers are given time to formulate their answers, often connecting to prior knowledge, as described in the big picture stage. In this stage, wait or thinking time of approximately 10 seconds should be given (Wellington et al, 2001; Pimm, 1987; Cohen et al, 1996).

We have seen that this activity stage is underpinned by the key theoretical principles and practical intervention strategies of dis-equilibrium, progress through Piaget's stages, wait or think time, group work, concrete experiences, communication, scaffolding, message oriented speech and a supportive learning environment in which to facilitate them.

3.6.3.7 Demonstrate

In this stage pupils have the opportunity to feedback the new knowledge they have learnt. We have seen that this is usually achieved using communication skills, presenting to the whole class or group and answering and asking questions. Consequently if we consider that communication such as listener and message oriented speech (Brown, 1982) can address the problems low attainers have in mathematics, it can be concluded that this stage could, by facilitating communication in the classroom, address these difficulties.

We have seen that a practical intervention strategy of expressing thoughts aloud in words (Pimm, 1987), can helps pupils to clarify and organise their thoughts. This could be achieved here by allowing the pupils to read questions aloud. Also in this stage pupils are encouraged to explain the new knowledge to each other as if they can do this, it is reasonable to conclude that they understand the new knowledge (Hiebert et al, 1996)

Working memory is the manipulation of pieces of information (Staver et al, 1988) and this would be required in the demonstrate stage of accelerated learning. Pupils need to link not only the facts learnt in this lesson, but also to facts from previous lessons when presenting their results to the rest of the group, class or when answering or asking questions. However working memory is primarily used in the review, recall and retain stage and hence it will be discussed in more depth in the following section.

3.6.3.8 Review. Recall, Retain

Outcomes are revisited in this stage and memory techniques are used in order that the pupils retain the new knowledge. Hence a number of the key theoretical principles and practical intervention strategies described above underpin this stage. Specifically, if we consider that low attainers have immature strategies for memorisation (Wood, 1991), then as we have seen, putting the learning in context is a practical intervention strategy to aid memorisation (Watson et al, 2003). Hence it can be used in this stage where pupils are required to demonstrate that they have retained the new knowledge.

We have seen that pupils need to be able to remember their new knowledge so that they can recall it for use in new lessons when they are utilising the key theoretical principle of working memory (Staver et al, 1988). An intervention practical strategy for doing this was previously discussed of scaffolding. (Cockcroft, 1982; Cohen et al, 2004; Boaler et al, 2010). In this stage pupils can be scaffolded either by their peers or the teacher in order to remember the new knowledge they have just learnt. Scaffolding can also use the key theoretical principle of structured questions to enable pupils to remember the new knowledge (Wertsch, 1978; Weinert et al, 1990).

Bruner (1961) suggests that a practical intervention strategy of active engagement to address the key theoretical principle of poor memory. In this stage the teacher can ascertain if the pupils have understood the new knowledge by using formative assessment (Watson et al, 2003; Boaler et al, 2010) in an interactive manner.

In this stage the original objectives of the lesson are revisited in order that the teacher can ascertain if the pupils have understood and retained the new knowledge. Summative tests can, and are, used in this stage to ascertain if pupils have done so. We have seen that some questions in summative tests can be answered using surface learning (Warburton, 2003) and a practical intervention strategy of rote learning (Warburton, 2003) was given. However formative assessment is used more frequently to assess retention of new knowledge.

When formative assessment is used we have seen that the teacher can assess not only if a pupil can remember and apply the new knowledge, but also which stage of development the pupil is in. Small white boards are an intervention practical strategy suggested by Watson et al (2003) where the teacher can assess at the end of a lesson if a pupil has understood the topic. This intervention strategy is used in the case studies in this stage.

The key theoretical principles and practical intervention strategies discussed above that underpin the environment and 7 stages of accelerated learning can be summarised in the charts below. The darker shaded squares indicate the most relevant stage with lighter shading indicating some relevance in that stage. In addition the key theoretical principles and practical intervention strategies have also been grouped together under the three headings of environment, communication and memory. The rationale for this categorisation will be discussed in section 3.9.

Key Theoretical Principles	**Accelerated Learning Environment and 7 Stages** **Practical Intervention Strategies**	**Environment**	**Connect**	**Big Picture**	**Outcome**	**Intro**	**Activity**	**Demonstrate**	**Review Recall Retain**
Environment									
Language Vygotsky (1978), Thomas (1993), Ginsberg (1977), Biggs (1985),	**Peer to peer communication** Pimm (1987), Baker et al (2002), Dowker (2004), Boaler et al (2010).								
Socio-historical development Luria (1976)	**Message Oriented speech** Brown (1982)								
Prior experience. Driver et al (1986)	**Put mathematics in context, pupil participation**. Dowker (2000), Watson et al (2003),								
Experience Kirschner et al (2006)	**Real life examples** Haylock (1991)								

Concrete experiences Piaget (1991), . Dowker (2000),	**Group work** Haylock (1991), Watson et al (2003), Boaler et al (2010). **Supportive environment** Boaler et al (2010)								
Cognitive skills and thinking patterns Vygotsky (1978)	**Environment** Vygotsky (1978**)**								
Social constructivism Cohen et al (2004)	**Working in pairs, role play, debates** Bonwell (1991) **Scaffolding** Cockcroft (1982, Dowker (2000), Cohen et al (2004), Boaler et al (2010).								
Environment Papert (1980), Mounoud (1981), Boaler et al (2010**).**	**Pupil to pupil discussion** Pimm (1987), Dunn et al (2010), Boaler et al (2010)								
Communication									
Co-operating with peers Vygotsky (1978)	**Group work** Haylock (1991), Watson et al (2003), Boaler et al (2010).								
Dis-equilibrium Piaget (1991)	**Formative assessment** Ginsberg (1977), Baker et al (2002), Watson et al (2003), Dowker (2004), Boaler et al (2010)								

Assimilation and Accommodation Wadsworth (1971)	**Wait and think time** Pimm (1987), Cohen et al (1996), Wellington et al (2001).								
Development stages Piaget (1991)	**Assessment** Ginsberg (1977), Baker et al (2002), Watson et al (2003), Dowker (2004), Boaler et al (2010) **Clear and relevant objectives** Haylock (1991)								
Zone of proximal development' Vygotsky (1978)	**Group work** Haylock (1991), Watson et al (2003), Boaler et al (2010). **Peer provided scaffolding** Cohen et al (2004)								
Discussion Pimm (1987), Dowker (2000), Chin (2006), Boaler et al (2010).	**Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010).								
Listener and message oriented speech Brown (1982)	**Talking for others** Pimm (1987)								
Right and wrong answers Thom (1973)	**Put mathematics in context**. Dowker (2000), Watson et al (2003),								

Memory									
Structured questions Wertsch (1978)	**Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010).								
Poor memory Bruner, (1961), Ginsberg (1977), Biggs (1985), Dowker (2000)	**Actively engaged** Bruner, (1961)								
Working memory Staver et al (1988)	**Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010).								
Surface learning Warburton (2003)	**Rote learning.** Biggs (1985), Dowker (2000), Warburton, (2003) **Assessment.** Watson et al (2003) Boaler et al (2010)								
Immature strategies for memorisation Wood (1991)	**Put mathematics in context.** Dowker (2000), Watson et al (2003),								
Series of structured questions Weinert et al (1990).	**Scaffolding.** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010).								

We have seen that many of the intervention theories and practical strategies shown to address the difficulties low attainers have in mathematics underpin the environment and 7 stages of accelerated learning. Infact it has been shown that many of these theories and strategies can be applied and facilitated over more than one of the 7 stages and the supportive learning environment is paramount in their facilitation. Hence it was concluded that accelerated learning is a suitable pedagogy to use in the experiment.

3.7 Differences between Accelerated Learning and CAME

Next we will look at CAME as this was used in some lessons in the case studies and the pilot study as previously described. We will begin by considering the main differences between accelerated learning and CAME.

In CAME lessons pupils work in groups for the whole lesson whereas in accelerated learning pupils may work in groups in some of the 7 stages but not necessarily all. Although at the time of the experiment CAME lessons were available for Y7 and Y8, these lessons only covered a fraction of the mathematics syllabus for those years and are designed to be taught in one lesson. However the 7 stages and supportive environment of accelerated learning are a framework in which to teach the syllabus and hence can be applied to all topics as specified in the national numeracy framework for year groups 7, 8 and 9.

It should also be noted that Shayer et al (2007) state that when CAME was used with low attainers no improvement was seen. They say that this is due to the fact that there are no pupils with higher thinking skills who can collaborate and communicate their ideas to the lower ability students, thus enabling the low ability student to move through the zone of proximal development. Hence it maybe concluded that CAME is unsuitable for use with low attainers if the goal is to improve cognitive ability. However in the case studies we can see in the analysis section that in case study 1, for example, there was a wide range of low ability pupils. Their range for the school entrance test scores was 4 to 38 and for the KS2 SATS scores was 31 to 59 (note that the two lowest scoring pupils did not have a KS2 SATS result). Thus the experimental groups could be seen as mixed ability and therefore CAME could improve the attainment of the pupils. It should also be noted that although the pupils in these groups could be seen as mixed ability, they were all classed as low attainers as they had not achieved a level 4.

However it will be shown below that the key theoretical principles and practical strategies underpinning accelerated learning also underpin CAME and that CAME can have an impact on the academic attainment. In 1991 eight schools took part in the CAME project experiment. Pupils in the experimental groups had an average increase of 34 percentile points on the CSMS norms (Shayer, 2003). The GCSE results from 1999 for the 11 schools that had taken part in the CASE experiment had, for maths, 0.95 of a grade value added. Shayer et al (2007) also report results from a further experiment that took place between 1995 and 1997. Here they say that pupils who took part in the experiment being taught using CAME showed larger gains in academic attainment than those in the control group in Y8. The same pupils also had significantly higher pass rates at GCSE.

In light of the above CAME was deemed to be a valuable resource as will be discussed below. It was used to supplement the accelerated learning lessons and Shayer et al (2006) advocate the teaching skills used in CAME lessons should be used in other mathematics lessons in order for cognitive acceleration to take place. The following section starts by looking at the history of CAME.

3.8 CAME

3.8.1 History of CAME

In the above we have seen examples of the key theoretical principles and the practical strategies underpinning the accelerated learning cycle and now a specific scheme for teaching accelerated learning, namely Cognitive Accelerated Maths Education (CAME) (Adey et al, 1994) will be discussed. This was used on occasions in the case studies to complement the accelerated learning teaching pedagogy. The actual CAME lessons are described in a narrative fashion in the pilot study chapter and in an ethnographical narrative with archival analysis fashion in the case study chapter of this thesis.

In September 1984 the British Economic and Social Research Council funded the Cognitive Acceleration through Science Education project (CASE) (Shayer, 1987). The research focused on activities that relied on thinking skills to enhance pupil's achievements in science. The project was conducted over a three year period and hoped to achieve long term enhancements to academic achievement. 32 CASE lessons were produced and these were recommended to be taught over a two year period.

Following on from the CASE project the Cognitive Accelerated Mathematics Education CAME project was developed (Adey et al, 1994), and this reflected the CASE pedagogy. CAME was developed with respect to the theoretical ideas of Piaget, helping pupils ‘jump’ from the concrete to abstract operations encourages developing thinking skills. Piaget (1991) calls these operations schemes and in CAME they were called the 5 pillars of wisdom. They can be summarised by the following:

- Concrete preparation (introduction to the topic).
- Cognitive conflict (what happens when the "facts" don't fit the explanation - pause, wonder and think again).
- Construction (of the reasoning patterns above).
- Metacognition (thinking about own thinking, i.e. clarifying how your own thinking has developed).
- Bridging (enabling the transfer of ideas and methodologies from the activity to other contexts).

3.8.2 Key Theoretical Principles and Practical Intervention Strategies underpinning CAME

Again here we will discuss key theoretical principles and practical intervention strategies in detail under the headings of the most relevant pillar of wisdom and only reference the other pillars where they are applicable, thus demonstrating the empirical validation of the 5 pillars.

3.8.2.1 Concrete Preparation

In this pillar pupils are introduced to the new topic and we have seen in the previous section that putting mathematics in context and experiences are key theoretical principle (Piaget, 1991; Driver et al, 1986; Kirschner et al, 2006) that can be used when introducing new topics. In order to facilitate these theories in the classroom we must allow pupil participation (Watson et al, 2003) and group work (Haylock, 1991; Watson et al, 2003; Boaler et al 2010) and use real life examples (Haylock, 1991) all within a supportive environment (Boaler et al, 2010). CAME uses appropriate subject matter in order to 'connect to the learning'. These principles and strategies can be seen in the Two Step Relationship CAME lesson described in the case studies where examples from nature are used and in the desk size lesson in the pilot study chapter where pupils designed desks for the new school.

The concrete preparation pillar can be exemplified through pupils describing to each other what they think the problem involves, suggesting ways in which it could be solved (Shayer et al, 2010). This is a form of collaborative learning where communication is important and is underpinned by the key theoretical principle that pupils first form their ideas as part of group thinking then go on to form these ideas as an individual (Wertsch, 1979).

3.8.2.2 Cognitive Conflict

In the cognitive conflict pillar facts do not fit the explanation (dis-equilibrium, Piaget, 1991) and pupils are encouraged to pause, wonder and think again about how and why they got their answer (Shayer et al, 2007). Pupils can either carry out assimilation or accommodation (Wadsworth, 1971; Piaget, 1991) of new facts learned; i.e. they can make the information fit into pre-existing ideas or change their ideas to accommodate the new information. In the CAME unit 'tournaments' 4 teams play matches against each other. One of the new facts that pupils learn is that a letter can stand for the score of a team. In this unit we see the beginnings of introducing algebra and pupils need to assimilate and accommodate this new concept. This process is supported by using a real life example that put the learning in context (Watson et al, 2003; Haylock, 1991).

Additionally in order for this to be effective in the classroom, the teacher facilitates wait or think time (Wellington et al, 2001; Pimm, 1987; Cohen et al, 1996) where pupils are given the time to accommodate and assimilate the new information. CAME also provides a supportive environment thus allowing both individual pupils and groups the time to think through the problem. This theory has been placed under the cognitive conflict pillar as pupils construct their own knowledge, organising and re-organising it to fit their facts into existing schemes, however it could also be considered under the construction pillar.

We have previously seen that there is not always one answer to a question but maybe several all equally correct in different contexts giving the potential for cognitive conflict. Hence the methodology used to get to the ‘correct’ answer, given the context, can be seen as important. Thom (1973) says that if a pupil cannot use the methodology described by the teacher, then the teacher must use some other means of getting the pupil to understand. Here we must also consider Watson et al (1998) who say that pupils can use different ways to solve a problem. In CAME lessons examples are given of how equally correct and in fact incorrect answers are used as a teaching pedagogy. These can be found in the case studies chapter demonstrating that it is not the answer but the method of getting there that is important.

Cognitive constructivism, as described in detail in the previous section, could be seen as one of the key theoretical principles underpinning the cognitive conflict pillar of CAME. In this theory pupils construct their own knowledge of the world, use experiences to derive learning, continually organize and reorganize, structure and restructure new experiences to fit them into existing schemata. Knowledge and understanding are constructed by the pupil rather than imparted by the teacher (Cohen et al, 2004). A practical intervention strategy that can facilitate this in the classroom is the use of active learning (Bonwell et al, 1991). Active learning is a term used to describe different models of instruction that focus the responsibility of learning on learners. We will see in CAME lessons, pupils take charge of the lesson, working in groups and communicating their results to other groups at specific points during the lesson. Group work, as we have seen, is suggested as a practical intervention strategy by Haylock (1991), Watson et al (2003) and Boaler et al (2010) to address the problems of low attainers. The teacher guides the lesson, and only takes charge if a common misconception is seen. An example of this is in the 'Two step relationship' unit where pupils often do not understand that a twig is defined by the fact that it always has 3 leaves. Here the teacher would stop the lesson and make sure that all pupils understood this definition. Then the teacher relinquishes the lesson to the pupils again, placing the responsibility for learning back onto the pupils.

Above we have seen that the teacher would provide guidance for the pupils and the amount of this varies according to the situation and the specific pupil. This could be viewed as scaffolding (Cockcroft, 1982; Cohen et al, 2004; Boaler et al, 2010) as previously described. Although scaffolding is seen as part of the construction pillar, the active learning described above can use scaffolding and hence is also viewed as underpinning the cognitive conflict pillar.

3.8.2.3 Construction

We have seen earlier in this chapter a suggestion that constructivism led to effective teaching and learning being based on higher order thinking skills, deep and superficial learning, metacognition and cooperative learning (Cohen et al, 1997) and that the constructivism theory is one in which learning is seen as an active process, where pupils construct knowledge rather than receive. (Crowther, 1995).

Of the two types of constructivism, cognitive constructivism, according to Hokanson et al (2000), was based largely on Piaget's theories, and social constructivism based mainly on Vygotsky's. These theories do have some common characteristics. They both state that knowledge is constructed through reflective abstraction where the pupil participates and is active, where they cognitively process information. Pupils actively construct meaning rather than passively accepting it. In this pillar pupils often participate through group work and discussion (Watson et al, 2003) using message oriented speech (Brown, 1982) in order to construct explanations for other pupils in their group. They may also need to present their findings to other groups and in doing so would need to cognitively process the information.

According to Cohen et al (2004), teachers will need to ensure learning is about problem solving, communication, and the ability to evaluate and apply information. They go on to state that this type of teaching goes far beyond the recitation paradigm of traditional learning and an emphasis on correct responses. So not only would the pupil have to know how to perform a calculation they need to be able to recognise how and when to apply it correctly. We will see examples in the case studies of how the method used to obtain an answer is seen to be more important than the correct response. This has been referred to in the cognitive conflict pillar section where Thom (1973) talks about the methodology used not the answer given. However this approach has its difficulties as the onus is put on the teacher correctly interpreting and communicating the problem in order that the pupil can use their problem solving skills to solve the problem. One way this can be accomplished is to draw on the pupils' prior experience or facilitate group work (Watson et al, 2003), as we have already discussed in the previous sections.

3.8.2.4 Metacognition

In this pillar pupils clarify how their thinking has developed. Vygotsky (1978) believed that teachers should be responsible for setting up a learning situation where pupils could then be helped to learn by the teacher prompting answers, a form of scaffolding, allowing movement from one zone of proximinal development to another. Scaffolding (Cockcroft, 1982; Cohen et al, 2004; Boaler et al, 2010), can be used in this pillar and an example of this is the 'Two step relations' unit. Here patterns from nature are 'transformed', with the help of the teacher, into sequences leading to an algebraic equation. According to Collis (1978) this step from number to using letters is the first step into formal thinking.

This is also true of the final step of this CAME unit where two graphs are described in terms of their different equations. These equations are of the form Y=MX + C, i.e. a straight line graph, where M represents the X co-efficient and C the constant. This graph can be drawn and subsequently the points of intersection (C the constant) and gradient M (the X co-efficient) would be 'noticed' by the pupils. The link between the equation of the graph and the point of intersection and the gradient had always been the objective of the lesson, however in CAME the teacher will use scaffolding in order that the pupils will discover these facts as they progress. This process allows pupils to understand how this concept has been developed, in effect metacognition. Many communication-oriented practical intervention strategies, as previously discussed, can also be used in this pillar.

In the above we have seen examples of collaborative learning in which pupils' cognitive development is improved (Piaget, 1991; Vygotsky, 1978; Shayer et al, 2010). However Piaget does not say how to teach, rather he says that cognitive conflict is important, whereas Vygotsky suggests that this could be accomplished through pupils helping each other through the zone of proximal development by collaboration and mediation. An example of this in CAME lessons is when group work is facilitated. Pupils can make jumps in cognitive development when they have had input into a successful outcome to a problem within their group even when it is another pupil from their group who demonstrates this successful outcome to other groups (Shayer et al, 2007).

3.8.2.5 Bridging

In this pillar pupils transfer their ideas and new knowledge to other concepts. Here we must consider working memory (Staver et al, 1988), as in order to be able to bridge from one concept to another pupils must be able to remember previous information and link it to the new information. This could be achieved by scaffolding where a series of structured questions could help with pupils locate something in their memories (Weinert's, 1990). However the teacher must also give wait and thinking time (Pimm, 1987; Cohen et al, 1996; Wellington et al, 2001) for the pupils to do the locating. In this pillar both of these practical intervention strategies for bridging can be facilitated by the teacher.

We have also seen that low ability pupils have immature strategies for memorisation (Wood, 1991) and that this can be addressed by putting mathematics in context (Watson et al, 2003) and using real life examples (Haylock, 1991). We will see examples of how this key theoretical principle is addressed by using these practical intervention strategies in the case studies with both the puppy's playpen lesson and the 'Two step relationship' unit.

The discussion of the key theoretical principles and practical strategies underpinning CAME's 5 pillars of wisdom is summarised in the following chart. It indicates where the key theoretical principles and practical intervention strategies can be implemented and again the darker shaded squares indicate the most relevant pillar as the strategies can be applicable to more than one. It should also be noted that these are classified under headings of environment, communication and memory. A case is made in the following section for these 3 elements being the important elements of the interventions.

CAME 5 Pillars of Wisdom **Key theoretical principles**	**Practical intervention strategies**	**Concrete Preparation**	**Cognitive conflict**	**Construction**	**Metacognition**	**Bridging**
Environment						
Prior experience. Driver et al (1986)	**Put mathematics in context, pupil participation.** Dowker (2000), Watson et al (2003)					
Experience Kirschner et al (2006)	**Real life examples** Haylock (1991**)**					
Concrete experiences Piaget (1991), Dowker (2000).	**Group work** Haylock (1991), Watson et al (2003), Boaler et al (2010) **Supportive environment** Boaler et al (2010)					
Collaborative learning Shayer et al (2010)	**Collective reasoning** Wertsch (1979)					
Cognitive Constructivism Cohen et al (2004).	**Active learning** Bonwell et al (1991)					

Constructivism Cohen et al (1997)	**Group work** Haylock (1991), Watson et al 2003, Boaler et al (2010)					
Construct Knowledge Crowther (1995)	**Message oriented speech** Brown (1982)					
Communication						
Right and wrong answers. Thom (1973)	**Ways to solve a problem.** Watson et al (1998)					
Zone of proximal development Vygotsky (1978)	**Mediation** Vygotsky (1978) **Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010) **Cognitive development** Vygotsky (1978), Piaget (1991), Shayer et al (2010)					
Assimilation and Accommodation Piaget (1991), Wadsworth (1971)	**Wait and think time** Wellington et al (2001), Pimm (1987) and Cohen et al (1996)					
Discussion Pimm (1987), Dowker (2000), Chin (2006), (Shayer et al (2007), Boaler et al (2010).	**Successful outcomes** Shayer et al (2010)					

Memory						
Working Memory Staver et al (1988)	**Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010)					
Immature strategies for memorisation Wood (1991)	**Put Maths in context** Dowker (2000), Watson et al (2003) **Real life examples** Haylock (1991)					
Series of structured questions Weinert et al (1990)	**Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010)					

Again here we have seen that CAME is underpinned by the key theoretical principles and practical intervention strategies shown to address the difficulties low attainers have in mathematics and it was concluded that CAME was a suitable pedagogy to supplement the accelerated learning lessons.

In the following section we will see the rationale for categorising these key theoretical principles and practical intervention strategies under the headings of environment, communication and memory.

3.9 Environment, Communication and Memory: Key Theoretical Principle and Practical Intervention Strategy Categorisation

We have seen at the beginning of this chapter suggestions of key theoretical principles and practical intervention strategies that address the problems low attainers have in mathematics from such people as Wadsworth (1971); Vygotsky (1978); Driver et al (1986); Piaget (1991); Haylock (1991); Watson et al (1998); Cohen et al (2004); and Boaler et al (2010). We have also seen the theories and strategies shown to underpin both accelerated learning and CAME. These range from the supportive environment to the range of teaching strategies and styles used, from the questioning techniques to support through scaffolding.

Next the rationale for categorising these theories and practical strategies under the 3 elements of environment, communication and memory will be discussed.

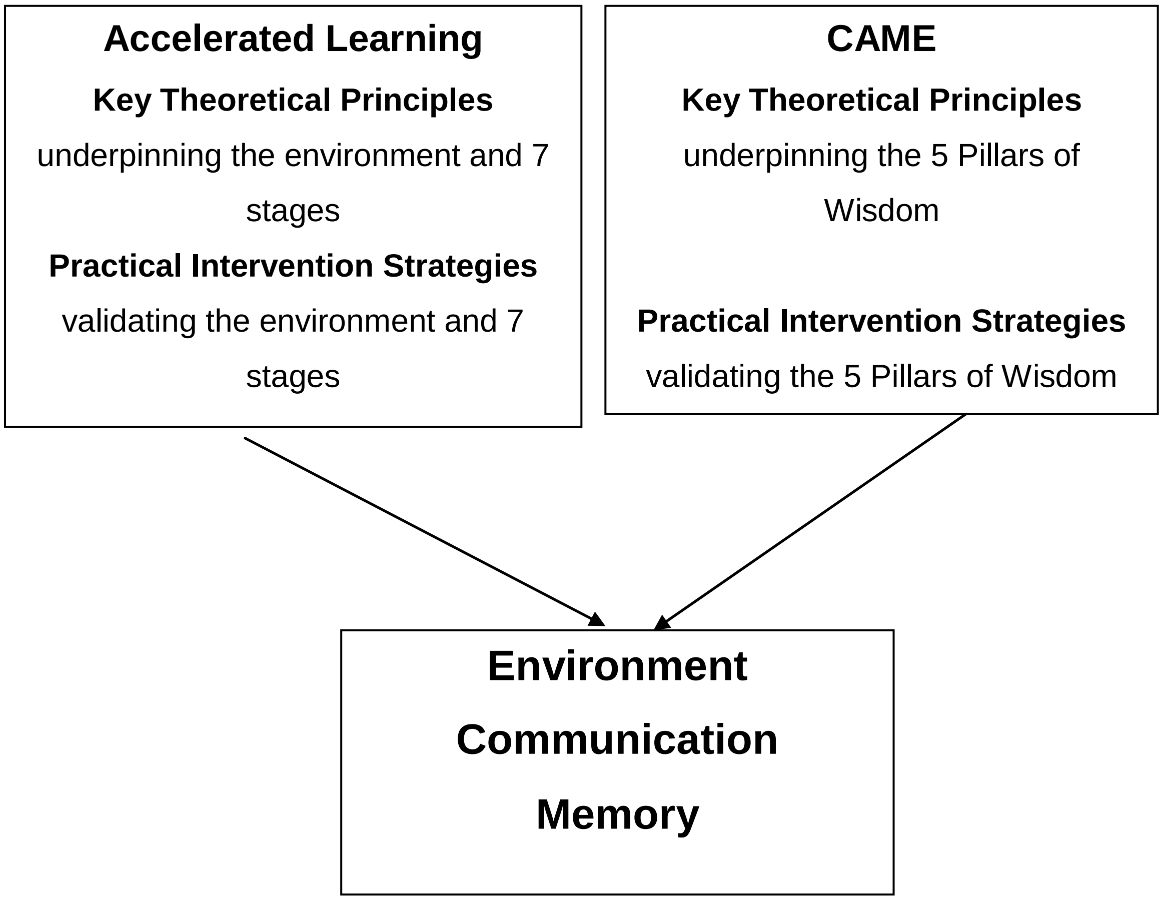


Figure 7 Theory and Practice underpinning the 3 elements.

It is however, important to understand that the 3 elements of environment, communication and memory cannot be entirely separated from each other as they are often intertwined. Hence the following section will describe the rationale for the categorisation of the key theoretical principles and practical strategies under a particular element but may also refer to the other elements on occasions. An example of this would be scaffolding (Cockcroft, 1982; Cohen et al, 2004; Boaler et al, 2010).

We have already seen that in order for effective scaffolding to take place a supportive environment should be in place. Hence scaffolding could be viewed as part of the environment element.

However scaffolding can also be viewed as communication. The teacher can prompt pupils to the correct answer using a series of structured questions as previously described. Peer scaffolding also uses communication as one pupil prompts another in a similar way to teacher scaffolding. Hence we can see that scaffolding could be categorised as an element of communication.

And finally, the teacher could use a memory strategy to help the pupil locate the answer in their memory (Weinert et al, 1990) as seen in the key theoretical principles and practical strategies chart above. Hence scaffolding could also be viewed as an element of memory.

In the following sections scaffolding has been categorised under the communication element and only referenced under the other two elements.

We will now consider the individual elements starting with environment. We have seen that a supportive environment was thought to be important by such people as Vygotsky (1978), Papert (1980), Mounoud (1981), Boaler et al (2010), and we will begin by looking at the key theoretical principles and practical intervention strategies categorised under this element.

3.9.1 Environment

The first of the key theoretical principles we will consider are experience (Piaget, 1952; Kirschner et al, 2006), prior experience (Driver et al, 1986), concrete experiences (Piaget, 1991), putting maths in context (Watson et al, 2003), and real life examples (Haylock, 1991). These components have been placed under the element of environment, as when there is a supportive environment in the classroom pupils are happy to talk about their experiences. They will give examples of their own real life experiences relevant to the problem being solved. An example of this can be seen in the pilot study where pupils described their desks, even saying that we could have metal desks or desks with beds on top. We will also see examples of this in the case studies. We have seen that putting the problem in context through personal experiences and discussing ways of approaching and solving a problem are key theoretical principles underpinning the Concrete Preparation stage of CAME lessons. These could also be seen as falling under the element of communication as the experiences can be discussed with their peers when preparing their approach to the problem.

In social constructivism (Cohen et al, 2004) we have seen that the environment plays an important role where problems are put in context. This, as we have seen above, can enable scaffolding (Cockcroft, 1982; Cohen et al, 2004; Boaler at al, 2010) and also pupil to pupil discussion (Pimm, 1987; Boaler et al 2010). Although these could both be classified under the communication element, they would not be able to take place effectively without the supportive environment.

We have seen that when considering socio-historical development (Luria, 1976) a change must be made in order to facilitate listener and message oriented speech (Brown, 1982) between pupil and teacher and a case has been argued that this could best take place if a supportive environment was provided. Also group work (Haylock, 1991; Watson et al, 2003; Boaler et al,

2010) cannot effectively take place without a supportive environment (Boaler et al 2010).

Crowther (1995) states that pupils should construct knowledge rather than receive it and Vygotsky (1978) states that cognitive skills and thinking patterns should be developed and active learning (Bonwell et al, 1991) could facilitate these. This could involve collective reasoning Wertsch (1979) where pupils practice active learning by working together in pairs, role play or debate (Bonwell et al, 1991). All of these key theoretical principles and practical intervention strategies require a supportive environment in which to take place.

In order to progress, pupils need clear and relevant objectives (Haylock, 1991). It is the supportive environment that provides the framework in which this can be facilitated allowing the pupils to know what they are expected to attain by the end of a lesson or group of lessons, however this is primarily categorised under the communication element.

Above we have seen the rationale for placing the key theoretical principles and practical intervention strategies under the element of environment and next we will consider the theories and strategies placed under the element of communication.

3.9.2 Communication

We have seen in the previous section that the use of scaffolding (Cockcroft, 1982; Cohen et al, 2004; Boaler et al, 2010) can best be facilitated if a supportive learning environment is provided. If the teacher used a series of structured questions (Wertsch, 1978), in order to effectively scaffold a pupil to the correct answer, then communication plays a key part.

When pupils are working in the zone of proximal development (Vygotsky, 1978) peer provided scaffolding (Cohen et al, 2004), can enable pupils' internal development processes to operate. Vygotsky (1978) refers to this as mediation where the teacher prompts the pupils to help each other; this can also be viewed as talking for others (Pimm, 1987). Peer provided scaffolding and mediation are enabled through the use of co-operation (Vygotsky, 1978) and communication and hence these theoretical and practical components have been categorised under the communication element.

We have also discussed dis-equilibrium (Vygotsky, 1978) and it has been suggested that formative assessment (Watson et al, 2003; Boaler et al, 2010) could be a method used to help pupils bridge their knowledge from what they expected to happen and what actually happened. This formative assessment could take the form of questioning where the teacher assesses each answer and decides what needs to be asked next in order to allow the pupil to get to the correct answer with an understanding of how they got there. It is because of this questioning and answering that this has been categorised under the element of communication although again the supportive environment would need to be present in order for the formative assessment to take place effectively.

Pimm (1987) states that words help pupils clarify and organise thoughts. The accelerated learning pedagogy is one of cognitive conflict, construction and meta-cognition where pupils are required to clarify and organise their thoughts in order to solve problems. This can be achieved by pupils' verbal communication (Vygotsky, 1978; Thomas 1993) and has been categorised under the communication element.

We have seen above how assimilation and accommodation (Wadsworth, 1971; Piaget, 1991), can be accomplished through wait and think time (Pimm, 1987; Cohen et al, 1996; Wellington et al, 2001). This could be categorised as environment, communication or memory however it is felt that it should be placed primarily under the communication element as it is through the questions and explanations given that pupils are able to assimilate and accommodate the new knowledge.

In order to facilitate discussion, communication must be allowed to take place in the classroom (Chin, 2006). Often however in classrooms, discussion is merely used to answer the question of how or why rather than be used as a teaching pedagogy. The Cockcroft (1982) report recommended that mathematics teaching at all levels should include opportunities for discussion between teacher and pupils and between pupils themselves. Shayer et al (2007) also suggest that discussion should be facilitated in the classroom and can lead to successful outcomes (Shayer et al, 2007). However one of the problems with the use of discussion as a pedagogy is that pupils can also use deflecting questions (Pimm, 1987) and the teacher needs to be aware of this when facilitating discussion. So we can see that discussion and deflecting questions should be categorised under the communication element.

Pimm (1987) also talks about the sacrifices teachers have to make in order to allow communication within the classroom by facilitating pair or group work (Haylock, 1991; Watson et al, 2003; Boaler et al, 2010). However we have seen the benefits of facilitating pair or group work as an intervention strategy and here they has been classified under the communication element.

Pimm (1987) leads us to believe that teachers should facilitate more pupil to pupil discussion in order to enhance pupil’s listening skills. The message being conveyed by the pupil who is speaking needs to be via using message oriented speech. The pupil who is speaking needs to be specific and monitor the group whom he is speaking to in order to ascertain if they have understood the message he is trying to get across. We have previously seen that Brown (1982) believes that pupils in general are fluent in listener oriented speech but need to practice message oriented speech. Hence we can see that listener and message oriented speech should be categorised under the element of communication.

We have also seen that it may not be the answer that is important, it is the methodology used to get that answer (Thom, 1973). By explaining their methodology to the rest of the class, the pupils are engaging in collaborative learning (Shayer et al, 2010) and this is used extensively in the CAME lessons.

We have previously seen that putting maths in context (Watson et al, 2003) can address the problems of right and wrong answers (Thom, 1973). Here the learning has been about communication employed as a methodology and not the answer, hence this component is placed under the communication element.

3.9.3 Memory

And finally the following section discussed the key theoretical principles and practical strategies categorised under the element of memory.

Pupils may have immature strategies for memorisation (Wood, 1991), then we have seen that rote focused learning can be a way of addressing this. This type of learning can be effective for summative assessment where facts need to be remembered for examinations. We have seen that assessment is a practical intervention strategy suggested by Watson et al (2003) and Boaler et al (2010) to improve attainment. Hence surface learning such as rote learning (Warburton, 2003) and assessment have been categorised primarily under the element of memory. However assessment is also categorised under both environment and communication as we have previously seen.

We have also seen that Watson et al (2003) suggest that putting mathematics in context and the use of real life examples Haylock (1991) help pupils to remember facts and hence these practical intervention strategies have been placed in the memory element.

Bruner (1961) believed that memory plays an important part in learning and that pupils need to be actively engaged in their learning in order to understand. We have also seen that working memory (Staver et al, 1988) can possess the capability to increase understanding. We have seen that the practical intervention strategy of scaffolding, as previously described**,** could be used to facilitate this theory. We have also seen that the use of scaffolding can support pupil's movement through the stages in Piaget's theory (1991), enabling them to master aspects of the tasks. Hence the above components of active engagement and working memory have been categorised as memory elements. However as we have seen, scaffolding can be categorised under the element of environment, communication or memory and is primarily categorised under communication.

The following table summarises the categorisation of key theoretical principles and the practical intervention strategies that address them in terms of the 3 key elements of environment, communication and memory.

Key Theoretical Principles	**Practical Intervention Strategies**
Environment	
Language Vygotsky (1978), Thomas (1993), Ginsberg (1977), Biggs (1985)	**Peer to peer communication** Pimm (1987), Baker et al (2002), Dowker (2004), Boaler et al (2010).
Socio-historical development Luria (1976)	**Message Oriented speech** Brown (1982)
Prior experience. Driver et al (1986)	**Put mathematics in context, pupil participation**. Dowker (2000), Watson et al (2003)
Experience Kirschner et al (2006)	**Real life examples** Haylock (1991)

Concrete experiences Piaget (1991), Dowker (2000)	**Group work** Haylock (1991), Watson et al (2003), Boaler et al (2010). **Supportive environment** Boaler et al (2010)
Cognitive skills and thinking patterns Vygotsky (1978)	**Environment** Vygotsky (1978**)**
Social constructivism Cohen et al (2004)	**Working in pairs, role play, debates** Bonwell (1991) **Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010).
Environment Papert (1980), Mounoud (1981), Boaler et al (2010**)**	**Pupil to pupil discussion** Pimm (1987), Dunn et al (2010), Boaler et al (2010)
Collaborative learning Shayer et al (2010)	**Collective reasoning** Wertsch (1979)
Cognitive Constructivism Cohen et al (2004).	**Active learning** Bonwell et al (1991)
Constructivism Cohen et al (1997)	**Group work** Haylock (1991), Watson et al (2003), Boaler et al (2010).
Construct Knowledge Crowther (1995)	**Message oriented speech** Brown (1982)
Communication	
Co-operating with peers Vygotsky (1978)	**Group work** Haylock (1991), Watson et al (2003), Boaler et al (2010).
Dis-equilibrium Piaget (1991)	**Formative assessment** Ginsberg (1977), Baker et al (2002), Watson et al (2003), Dowker (2004), Boaler et al (2010)
Assimilation and Accommodation Wadsworth (1971)	**Wait and think time** Pimm (1987), Cohen et al (1996), Wellington et al (2001).

Development stages Piaget (1991)	**Assessment** Ginsberg (1977), Baker et al (2002), Watson et al (2003), Dowker (2004), Boaler et al (2010) **Clear and relevant objectives** Haylock (1991)
Zone of proximal development Vygotsky (1978)	**Mediation** Vygotsky (1978) **Peer provided scaffolding** Cohen et al (2004) **Cognitive Development** Vygotsky (1978), Piaget (1991), Shayer et al (2010)
Discussion Pimm (1987), Dowker (2000), Chin (2006), Shayer et al (2007), Boaler et al (2010),	**Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010). **Successful outcomes** Shayer et al (2007)
Listener and message oriented speech Brown (1982)	**Talking for others** Pimm (1987)
Right and wrong answers Thom (1973)	**Put mathematics in context**. Dowker (2000), Watson et al (2003) **Ways to solve a problem** Watson et al (1998)
Memory	
Poor memory Bruner (1961), Ginsberg (1977), Biggs (1985), Dowker (2000)	**Actively engaged** Bruner, (1961)
Working memory Staver et al (1988)	**Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010).
Surface learning Warburton (2003)	**Rote learning.** Biggs (1985), Dowker (2000), Warburton, (2003) **Assessment.** Ginsberg (1977), Baker et al (2002), Watson et al (2003), Dowker (2004), Boaler et al (2010)

Immature strategies for memorisation Wood (1991)	**Put mathematics in context.** Dowker (2000), Watson et al (2003) **Real life experiences** Haylock (1991)
Series of structured questions Weinert et al (1990).	**Scaffolding** Cockcroft (1982), Dowker (2000), Cohen et al (2004), Boaler et al (2010).

Thus we can see that accelerated learning, based on a supportive learning environment and the 7 stages, and CAME based on the 5 pillars of wisdom, are theoretically underpinned and empirically validated. In light of this the rationale for the categorisation of the key theoretical principles and practical intervention strategies under the 3 elements of environment, communication and memory was discussed. We have also seen that many of the theories and strategies could have been categorised under any of the 3 elements, and hence that environment, communication and memory are intertwined, each dependent on the other.

3.10 Chapter Summary

In this chapter we have discussed reasons why the label low attainers is to be used in this thesis. We have seen possible definitions of low attainers with the argument put forward that the following definition be adopted of.

Pupils who have not achieved a level 4 in their KS2 SATS.

Next the theoretical causes of low attainment were discussed from both an internal and external perspective demonstrating the difficulties low attainers have in mathematics. Next an argument was given for key theoretical principles and practical intervention strategies that could be used to addressed these difficulties.

Then the history of accelerated learning is given followed by a description of the teaching pedagogy. This demonstrated that accelerated learning to be based on a supportive learning environment and the 7 stages namely:

- Connect to the learning
- The big picture
- Describes the outcomes
- Introduction
- Activity
- Demonstrate
- Review, recall and retain

Following this the key theoretical principles and practical intervention strategies that underpin the supportive environment and 7 stages were discussed. It was found that these theories and strategies could address the difficulties low attainers have in mathematics as discussed in the previous section, thus demonstrating the theoretical and empirical validation of accelerated learning as a pedagogy for low attainers.

A brief history of CAME is given followed by a description of the pedagogy showing it to consist of 5 pillars of wisdom namely:

- Concrete preparation
- Cognitive Conflict
- Construction
- Metacognition
- Bridging

and this was also followed by a discussion on the key theoretical principles and practical intervention strategies that underpin these 5 pillars. It had previously been shown that these underpinning key theoretical principles and practical intervention strategies could address the difficulties that low attainers have in mathematics, hence demonstrating the theoretical and empirical validation of CAME as a teaching pedagogy for low attainers.

Next the author’s rationale for the categorisation of the key theoretical principles and practical intervention strategies that underpin accelerated learning and CAME under 3 key elements of environment, communication and memory was discussed. It was shown that environment, communication and memory are three important elements of the intervention and are theoretically and empirically underpinned.

In summary three research questions were identified in the pilot study. The first: “Who are low attainers (the subjects of the experiment)?” was addressed in this chapter and a definition of low attainers was adopted. In this chapter we also saw a discussion on: “What are the causes of low attainment and in particular why is accelerated learning a suitable pedagogy to address these causes?” providing a theoretical underpinning. Finally the question “What is academic attainment and how can we measure improved academic attainment?” was addressed providing a mechanism for empirical validation.

Given all of the above, the next chapter will discuss the proposed methodology for the experiment.

Chapter 4 Methodology

4.1 Chapter Introduction

In this chapter we will look at several ways in which this experiment could have been carried out, deciding which of the options were the most appropriate. To put the methodology into context I will give a brief description of the experiment.

In order to ascertain whether low attainers academic attainment could be improved by using accelerated learning I conducted a pilot study as a practitioner. The pilot study consisted of one experimental group and one control group. Analysis of the data obtained from this experiment supported this premise and in order to put the experiment in a more academic light two further more rigorous case studies were undertaken as a research practitioner. The first of these case studies involved one experimental and one control group and the second had two experimental groups and one control group.

The analysis was performed by using KS2 SATs and the school's entrance test results as baseline data and these were compared with the school's internal Christmas and summer examinations following the intervention. The control groups' examination results were compared against the experimental groups' examination results in order to ascertain if the intervention had had any statistically significant effect. In the following sections we will see why the various methodological choices were made.

The chapter begins by looking at research design for data collection and it will be argued that a mixed methods approach is appropriate for the data collection for this thesis. We will see that the experiment was considered to be valid according to Campbell and Stanley's (1963) threats to internal and external validity.

We also need to consider what type of data will be collected, quantative or qualitative. Quantative data is measurable in numeric terms however as qualitative data refers to such things as the visual or verbal descriptions of human behaviour it cannot be analysed in this way, Gross et al (2000).

Cohen et al (2007) also state that a decision should be made in the methodology section as to what types of data should be acquired, who are the sample group and will data be available from anywhere else. Hence we will look at the subjects taking part in the experiment, describe them and give reasons why these pupils could be deemed as acceptable under the adopted definition of low attainers.

Cohen et al (2007) go on to say that the way in which the data will be collected (instrumentation) should also be described. Hence we will consider how data could be collected in this type of experiment and consequently how it was collected in the actual case studies. In order to put the data collection into context an introduction to the actual teaching pedagogy is given followed by why this pedagogy can be considered suitable for the experiment.

Next we will see a discussion on academic attainment and assessment, both formative and summative. As the data from the experiment needed to be measured in terms of improved attainment a method of measuring the pupils' starting and end attainment points during the experiment was needed. Methods of doing this are discussed and a method is selected for the measuring the improved attainment made in the experiment. Then we will see a discussion in which the SATS will be shown to be a standardised summative baseline from which improved attainment can be measured in the experiment.

Finally means of analysing the data are discussed namely data normalisation, correlation, ANOVA and linear regression. Suitable data analysis techniques that could be used to calculate the suggested improved attainment are decided upon.

4.2 Data collection method

We will begin by looking at different methods of data collection, discussing each methods advantages and disadvantages with respect to the experiment. According to Cohen et al (2007, page 47), methods means 'the range of approaches used in educational research to gather data which are to be used as a basis for inference and interpretation, for explanation and prediction'. They say that this is 'traditionally associated with the positivist model'. Positivism uses universal and general laws to answer predetermined questions. It tests and measures against reality by performing experiments and collecting data. It can include, participant observation, role-playing and episodes and accounts.

According to Cohen et al (2007) research design has to be fit for the purpose and it is this purpose that determines not only the research design but the methodology as well. Depending on this purpose, the main methodology of the research should be chosen such as a quantative survey, qualitative research, an ethnographical study, an experiment, a case study, a piece of action research etc.

However there are issues with using this methodology. Epistemological issues are glossed over according to Smith (1987), i.e. how we know what we know is not catered for under the positivistic approach, we merely interpret the results. In the experiment we are interested in the improvement in the academic attainment of the pupils. This, as we have seen, is to be measured using summative assessment provided by the pupils' examination results. Hence a weakness of the positivism approach is that no insight is given into how the pupils are learning, it can only demonstrate that they have improved their academic attainment.

This viewpoint is reiterated by Bryman et al (2003) who state that positivism does not facilitate the examination of the underlying causal mechanisms by the researcher. However in the experiment both summative and formative assessment are used to inform teaching and learning, aiding the teacher to assess which practical intervention strategy will have the most impact. So here we can see that a pure positivism approach would not be appropriate if the main question was asking how the pupils learn.

In the positivism approach the researcher tends to view the events from outside (Bryman, 1984) and little concern is given to the reasons for the observations. In this methodology the researcher has little interaction with the experiment and consequently it could be thought that they have cause little interference. In the case studies this is not the case as the researcher is the teacher in the classroom and does have an effect on the experiment itself and the subjects of the experiment.

However, even given the above, a mainly positivist paradigm was adopted for the research, and the research methods appropriate to this viewpoint were used. The experiment is based on a predetermined question of ‘does the academic attainment of pupils improve when accelerated learning is used as a teaching pedagogy?’. In order to answer this question we do not need to know how pupils learn and hence the epistemological issues do not have an impact in answering this question. Conversely the understanding of how the pupils learn does impact on the choice of practical intervention strategies hence a purely positivist approach cannot be adopted. However the research question itself can be measured against reality by performing experiments and collecting data, i.e. the case studies that encapsulate the experiment and the data collected was the pupils’ KS2 SATS and internal examination results.

Next we will consider what data collection methods is the most appropriate for this purpose by discussing:

- Surveys
- Questionnaires and Interviews
- Case studies (including mixed methods)

4.2.1 Surveys

Surveys are the most common technique of data collection, O'Leary (2003) and according to Yin (2009) can be used if the research question being asked is 'how many' or 'How much'. The research question of the thesis could be configured as how much have the low attainers improved by using accelerated learning as the teaching pedagogy and this would fit with Yin's suggestion of when to use a survey.

Surveys collect data in a structured manner where collecting information about individuals or groups who share the same variables or characteristics. The intention of a survey, according to O'Leary (2003), is to generalise from a sample to a population. Flick (2009) also talks about random samples of populations being surveyed and how inferences for the whole population are made from the data analysis. In the experiment a sample of pupils could take part in a survey however as the premise is that the pupils had improved in their academic attainment, there would be little point in asking them if they thought that they had done better as this is subjective and empirical data can be obtained from their actual test results.

Academic surveys are used to explain theoretical concerns (O'Leary, 2003). Here the theoretical concerns can be viewed as the environment, communication and memory elements of the accelerated learning pedagogy and the pupils could be asked if they thought that they had attained more academically as a result of these elements. However, as stated above, there is empirical evidence in the data collection techniques being employed and hence surveys would not be the most suitable method for the experiment. Also we would have to consider the reliability of the responses given that we are working with low attainers.

So we can conclude that surveys are not an appropriate methodology for the experiment.

4.2.2 Questionnaires and Interviews

Questionnaires are an inexpensive way of producing a quick but adequate and efficient assessment of peoples' attitudes according to Gross et al (2000). Questionnaires can contain both open and closed questions, allowing the respondent to enter into a dialogue in the open questions or give specific answers in the closed questions.

Scaling can be used for answering closed questions where for instance, the respondent would answer on a scale of 1 – 5, 1 being the highest rating and 5 being the lowest rating. This could be used to ask pupils how well they think they have done on a particular topic or question but is subjective and again could be seen as unreliable. However it should be noted here that this system of scaling is used in the formative assessment part of accelerated learning for example where the pupil is asked to grade their work using the 'traffic light' system, i.e. if you found the work easy put your book in the green pile, if you had some difficulties put it in the amber pile and if you found the work hard put it in the red pile. Also the hypothesis asks the question has pupils' attainment improved not do they think they have and this is another reason why this type of scaling would not be appropriate.

The fixed choice response can be seen as having the advantage of being quantifiable however this must be tempered with the fact that this only allows for the answers given by the researcher and the respondents could not elaborate on them. In the thesis a question such as how well do you think you did on that topic rating yourself from 1 – 5, 1 being the lowest and 5 being the highest could be used. However, it could be thought that as low attainers may have low self esteem, they may rate themselves at the bottom of the scale and a questionnaire with closed questions, would not allow them to give any reason why they think this or what specific problems they had. The topic of confidence of low attainers is dealt with in depth in the case studies chapter.

In order to address the problem of lack of narrative or explanatory feedback, an interview could be used after a questionnaire has been completed. In fact Witzel (2000) suggests that a short questionnaire followed by an interview would be 'fruitful'.

There are three main types of interviews, according to Leonard (2003), structured, semi structured and unstructured. These differ in the amount of structuring contained within each type; Structured are like questionnaires using predetermined questions, semi structured where the researcher would decide on the broad topics in advance and unstructured where the interviewee could determine the topics for discussion.

Some of the advantages of interviews, Leonard says, are that they are flexible and have a high response rate. A researcher could prompt the interviewee for a response or probe for more information leading to clarification. This could be seen as message and listener oriented communication as discussed in the literature review chapter and again this type of questioning technique is used in the formative assessment that informs the teaching and learning during the accelerated learning lessons.

The disadvantages, she says, are that interviews are time consuming and costly. They lack reliability and anonymity. Unstructured and semi-structured interviews are not standardised and hence cannot compared like with like. A problem for the thesis could be the unreliability of the responses given, as we have seen in the literature review that pupils are not confident in message oriented speech which would be required for the responses in the unstructured and semi structured interviews.

Overall it has been shown that interviews and questionnaires are not a suitable method of collecting data for the thesis as the research question asked can be answered by analysing empirical and not subjective data. However the narrative and discussion does need to be considered as part of the data collection and hence, we will now consider case studies.

4.2.3 Case studies

The aim of a case study, according to Ragin et al (1992), is to produce a precise description or reconstruction of a case. This precise description is important in the replication of this teaching pedagogy for other teachers. The subject of a case can be varied; such as an institution, person or community and the problem, according to Flick (2009), is in identifying a case which is significant for the research question, to clarify what else belongs to the case and to know what methodological approach would be needed in order to re-construct the case. In this thesis the pilot study was treated as a case study in which the research questions were identified. The subsequent two case studies are also treated as case studies and were deemed as significant for the research question. The subjects of the case studies were the pupils in the chosen mathematics sets and the teaching pedagogy and details of these pupils are given in the subjects in the case studies section below.

Flick (2009) agrees with Ragin et al (1992) in that case studies can capture the process under study in a very detailed way, and as the thesis seeks to inform other teachers, this is a way of transferring knowledge to enable other teachers to teach using this pedagogy. Shepard et al (2003) reiterate this view where they say that a case study is an intensive study of a single group, incident, or community and it is because of this intense study aspect that case studies are suitable for the experiment.

Flick (2009) also says that concentrating on one case can lead to problems of generalisation. Although this thesis details one pilot study followed by 2 case studies the issue of generalisation is still a problem hence we should be careful about drawing generalisations from these case studies. However case studies can counteract the potential problem seen in comparative studies in that the whole of the mathematics set is chosen to be in either an experimental or test group. The pupils in the groups are similar in terms of their mathematical attainment by virtue of being placed in that set from their SATs and entrance test results.

Yin (2009) states that case studies are relevant when the question being asked requires an extensive and in-depth description of some social phenomenon, similar to the sentiments of Flick (2009). A case study is an empirical inquiry having critical features, Yin says, that:

- investigates a contemporary phenomenon in depth within its real life context, especially when,
- the boundaries between phenomenon and context are not clearly evident.

That is, case studies can be used when you want to understand a real-life phenomenon but this understanding is encompassed by important contextual conditions because they are highly pertinent to the phenomenon of the study (Yin et al 2007). In the proposed case studies we are trying to understand if or how or why the low attainers academic attainment is increased as a result of using accelerated learning. The contextual conditions can be viewed as:

- the accelerated learning pedagogy
- the classroom environment
- the school environment
- the socio-economic background of the pupils'

Yin et al (2007) go on to say that in real life situations it is difficult to distinguish between the phenomenon and the context and hence other aspects such as data collection and analysis techniques need to be considered as part of the case study definition.

When evidence is collected using different methods from different sources all within a single case study as suggested above, the triangulation of a mixed methods approach should be adopted (Brewer et al, 1989).

4.2.4 Mixed Methods Approach

The mixed method approach is one in which the methods used have non overlapping weaknesses and complementary strengths, then joint findings that are in agreement are much more reliable (Brewer et al, 1989).

Brewer et al (1989) suggest that taking the agreeing joint findings without actual empirical investigation can lead to contradictions. They consider a survey on traffic offences where the data comes from members of the public. Here people are not aware of each other's traffic offences and we do not get a true picture of actual traffic offences. If however a trained person observed traffic offences then a truer picture of the offences would be given. This could then be compared to police data and it is suggested that more reliable findings would result. In the case studies the teacher observes the pupils and formatively assesses their learning. The empirical data is the pupils' KS2 SATS results and the internal examination results, when combined with these observations, provides more reliable findings, e.g. a good examination result backed up by teacher observation would then be considered a more reliable reflection of the pupils' true ability.

As well as collecting data from different sources we must also explicitly identify the data, the sequence of data collected and data collection procedures to be used (Tashakkori, 2009), in order for the empirical investigation to be robust. In the case studies KS2 SATS data is collected before the experiment and the internal examination results are collected during and at the end of the experiment hence we can consider the data collection process robust.

The following Convergence of Evidence diagram (Yin, 2009) shows six different types of evidence that can be used in a single case study. It should be noted that not all six types of evidence are needed for the case study to be robust (Yin, 2009). He suggests that in some case studies only one maybe needed and it maybe that in collecting all possible data some of this data maybe superfluous. Hence what data is captured needs to be carefully thought out and so we will consider Yin's (2009) in respect of the data collection for the thesis.

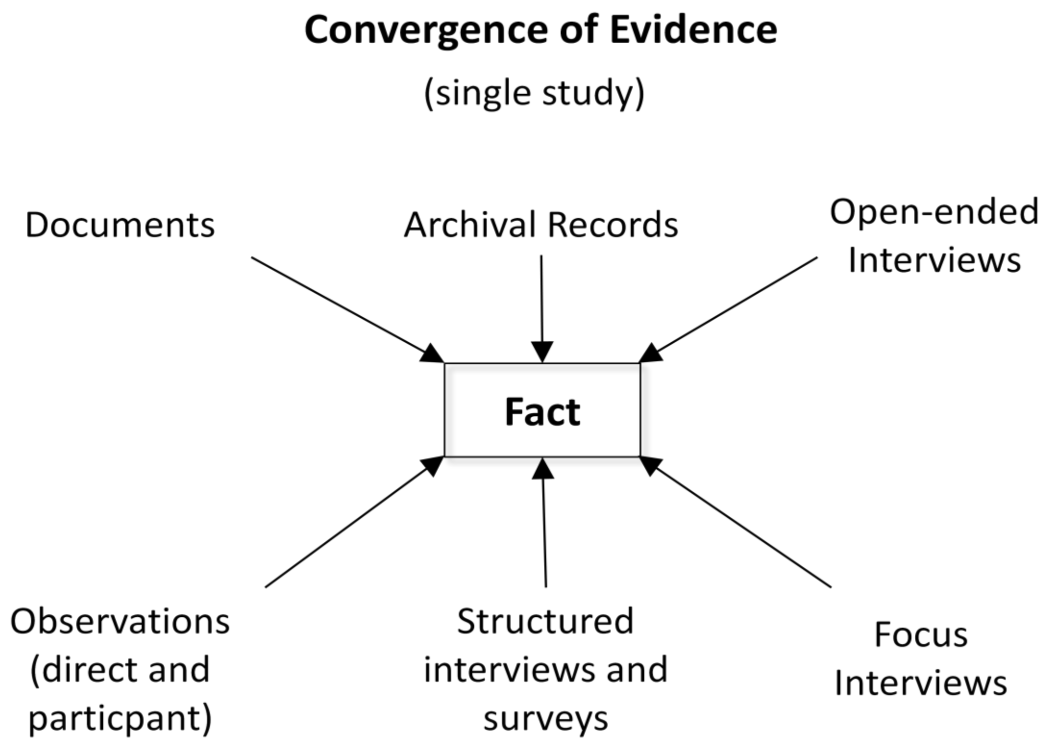


Figure 8: Convergence of multiple sources of evidence

The diagram illustrates triangulation of data where different types of evidence are brought to bear on the research question. Here we can see that documents, archival records, open-ended interviews, observations, structured interviews and surveys and focus interviews can be used. However we have seen in the previous section that questionnaires and interviews are not suitable for this experiment; hence neither questionnaires nor interviews were used as evidence. However observations, documents and archival records were used, providing sufficient triangulation for the case studies to be robust with no superfluous data.

Yin et al (2007) also state that the inquiry:

- copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as one result
- relies on multiple sources of evidence, with data needing to converge in a triangulation fashion, and as another result
- benefits from the prior development of theoretical propositions to guide data collection and analysis.

The case studies provide a wealth of possible data points to collect however in order to address the research question only a subset of these are required. In order to enhance the robustness of the findings additional sources of evidence are collected for triangulation; observations, documents and archival analysis. This is guided by the key theoretical principles and practical intervention strategies that have previously been identified in the literature review chapter.

Next we will look at the three types of evidence collected as part of the mixed method case studies: observations, documents and archival analysis.

Observations

We have seen in the literature review suggestions of key theories and intervention strategies for low attainers that could improve the academic attainment of these pupils. With this in-mind and given Regan et al's (1992) description of a case study being a precise description of a case, a narrative approach will be used based on lesson observations. This will not be the traditional interview narrative, as described in the interview section above, but more an ethnographical narrative.

According to Goetz et al (1984) ethnographies recreate the subjects' beliefs, practices and behaviours. This is inline with Merriam (1988), who states that an ethnographic case study is a socio-cultural interpretation of the data and in the case studies in the experiment no such interpretation is undertaken. The research question being addressed here is based on causes of low attainment and intervention strategies that address these causes leading to improved attainment and not socio-cultral interpretations and hence could be considered not an ethnographical approach.

However Brewer (2003) defines ethnography as a study of people in naturally occurring settings or 'fields' by means of methods which capture their social meanings and ordinary activities involving the researcher directly in the setting. In the experiment the field is the classroom the teacher is the researcher in the setting. The data capture does not seek to capture the social meanings but does seek to answer what effects the intervention strategies have on the pupils' ordinary activities during their mathematics lessons.

Brewer (2003) also says that if participant observation is used in data collection, ethnography can involve introspection, whereby the researcher's own experiences and attitude changes while sharing the field become part of the data. In the case studies formative assessment was used to inform the teaching and learning and this could be viewed as introspection.

So here we can see that although the case studies were not ethnographical in some of the elements described above, they do have some ethnographical elements in them. The main aim of the vignettes used as a data collection method is to highlight the intervention strategies and not to describe socio-cultural scenarios. Thus they would provide a precise description of the interventions in such a manner that other teachers would be able to replicate the case.

Archival Analysis

In order to produce numerical data some archival analysis was performed. This involved the KS2 SATS results, the school's entrance test and the internal examinations.

When archival evidence is seen as relevant the investigator must, according to Yin (2003), look at the accuracy and the conditions under which the data was produced. He states that as most archival data is produced for a specific purpose it may not be as relevant for the case study and is usually quantative.

The drawbacks of archival records are that the data is usually subject to privacy rules however in the case studies the data was owned by the school and as such was made available for the research with the proviso that the findings were reported anonymously.

The KS2 SATS data is used in the statistical analysis section as a benchmark against which potential improvement in attainment is measured. It is considered that the KS2 SATS results are accurate and the conditions under which they are produced is standardised. A case has already been made for the use of these SATS in the case study and this will be further discussed later in this chapter.

The case studies also use the school's entrance test as a baseline against which to measure improved attainment. Again although these tests are were not specifically designed for the case study they are considered standardised as discussed in the attainment section below.

The final archival analysis used the internal examinations from Christmas 2005, summer 2006 and Christmas 2006. We will see that these were based on the KS3 SATS past papers and hence could also be considered as standardised. An analysis of the questions used in these internal examination papers was undertaken and the proportion of the marks associated with each of the environment, communication and memory elements is shown. These examination papers were created specifically for the case studies. From the graphs in appendix 2 we can see that the papers test the 3 key elements of environment, communication and memory. These thelements have been shown to be underpinned by the key theoretical principles and practical intervention strategies that address the causes of low attainment.

Documents

According to Yin (2003) documentary evidence is usually relevant in every case study. Documents can be letters, e-mails, minutes of meetings, administration documents such as progress reports to name but a few. These documents may not be accurate or unbiased and Yin suggests that they should not be taken at face value for example the ‘verbatim’ transcripts of official US congress hearings are infact edited. However documents can be used to supplement and support evidence from other sources such as the observations and archival analysis used in the case studies.

In the case studies several documents were used; class registers, SEN registers, Individual Action Plans (IEPs), lesson plans, school files and minutes of mathematics meetings.

In my experience it is common in schools for teachers to mark in their written register the names of the pupils who were on the SEN register. This marking usually differs according to the pupils’ particular learning difficulty for example a pupil who suffered from dyslexia may have an asterisk next to their name and dyspraxia many be signalled by a cross etc. This was the situation in the case studies where it was the school policy for teachers to mark pupils on the SEN register in their own written registers.

The SEN department in schools also usually produce written documents such as Individual Action Plans (IEPs) for pupils on the SEN register. These IEPs include the learning difficulty the pupil has and suggest teaching and learning strategies that may help the pupil. There may also be suggestions for the teacher to help the pupil such as writing words the pupil has difficulty with in their diary. This type of document was available at the school in the case study and was used by the teachers in both the experimental and control groups.

These statements could also be referenced in lesson plans and individual pupils on the SEN register would be identified. Lesson plans are another type of document used in the case studies. It gives details of the lesson objectives, resources needed, timings, and the topics together with the teaching pedagogy to be used in the different parts of the lesson. These lesson plans would also be used to inform the next lesson and were used in the case studies by all teachers in the experiment. It should be noted that there were no pupils on the SEN register in the control group.

Another type of document that could be utilised in case studies is the school's pupil files. These files not only contain the parents' names and contact details but also in the case study, details of bursaries and if the pupil boards, i.e. socio-economic background. Although reported this has not been considered in the case studies it has been noted that this maybe a topic that warrants further research.

Minutes of meetings can also be used as documents according to Yin (2003) and in the case studies mathematics meetings were held fortnightly. At these meetings SEN was always on the agenda and individual pupils were discussed as appropriate. The information from these meetings could then be fed into the teaching where applicable.

So we can conclude that case studies, using a mixed methods approach, is suitable for contextualising the experiment in order that other teachers can replicate the study. In the literature review the key principles and intervention strategies that address the causes of low attainment have been discussed and the adoption of the narrative approach allows the main intervention strategies to be highlighted. According to Merriam (1988) this implies that improvement in the academic attainment of the low attainers could be attributed to these interventions as they are underpinned by the theoretical principles discussed in the literature review chapter and any improvement can be seen as providing additional support for these theoretical principles. We will see from the analysis section in the case study chapter that there is an improvement. Consequently the implications for teaching and learning chapter will suggest specific recommendations based on these intervention strategies described in the case studies.

4.3 Subjects in the Case Studies

In this section I will discuss socio-economic and cultural status and how this relates to the pupils in the experiment. I will go on to give details of the schools and the teaching sets involved.

Subjects' socio-economic status

Thinking and learning styles can be affected by a number of factors including socio-economic status, Zhang (2002b), age, gender and parenting styles Sternburg (1997), and personality traits, Zhang (2002a). The pupils in the pilot study had a similar demographic and social background and attended a state secondary school. In the case studies the pupils attended an independent school where some pupils were paying full fees and some held full scholarships via HM forces grants, some pupils were part funded as their parents were employed by the school, and some held school bursaries. There was also a mix of boarders and day pupils in each group and the tables below show a breakdown of the types of pupils in the case studies. None of the pupils held an academic sponsorship and hence it was decided that the experimental and control groups were of a similar makeup. It is however, outside the realms of this thesis to comment extensively on how socio-economic factors might influence the testing of the hypothesis but details have been given in the following section on the socio-economic status of pupils' who attended the independent school, in order that the reader might have a more complete picture of the subjects taking part in the experiment.

Case Study 1.

Case study 1 Experimental Group.

	Full Fee Paying	**Part Fee Paying**	**Fully Sponsored**
Day	11	1	
Boarder	1	1	

Table 5 Case Study 1. Experimental Group by Type and Sponsorship.

Case study 1 Control Group.

	Full Fee Paying	Part Fee Paying	Fully Sponsored
Day	13	1	
Boarder	2		

Table 6 Case Study 1. Control Group by Type and Sponsorship.

Case Study 2.

Experimental Group 1.

	Full Fee Paying	Part Fee Paying	Fully Sponsored
Day	6		
Boarder	1	2	

Table 7 Case Study 2. Experimental Group 1 by Type and Sponsorship.

Experimental Group 2.

	Full Fee Paying	Part Fee Paying	Fully Sponsored
Day	15		
Boarder	1		

Table 8 Case Study 2. Experimental Group 2 by Type and Sponsorship.

Control Group.

	Full Fee Paying	Part Fee Paying	Fully Sponsored
Day	13	1	
Boarder			

Table 9 Case Study 2. Control Group by Type and Sponsorship.

Subjects' Cultural differences

The main aim of this thesis is to explore improvement in academic attainment and in order to do this tests were used both as a benchmark at the start of the experiment and as a final assessment at the end of the experiment. Greenfield (1997) says testers use tests developed for certain cultures and the testees may not have the cultural knowledge to interpret the question in the correct setting. They may not understand the values, knowledge and communication implicitly assumed by the test. The tests would be appropriate to the culture for which they were written but become ethnocentric when adopted into a new culture. However this factor is not considered an issue in the thesis as there were no pupils who came from a different culture hence all were equally disadvantaged or advantaged should a culture knowledge based question arise.

4.3.1 School in Case Studies 1 and 2

Both case study 1 and case study 2 were conducted at School 2, an independent school in County Durham, U.K. The school had approximately 650 pupils in Y7 – Y11 plus a sixth form and a preparatory school. Case study 1 started in the autumn term of 2005 and finished in the summer term 2006. Case study 2 started in the autumn term of 2006 and finished in December 2006.

4.3.2 Pupils in case study 1 and 2

In case study 1 there was one experimental group and one control group. A control group is necessary and pupils should be randomly assigned to both the control and experimental group in order to eliminate alternative explanations

(Bryman, 2001). In the experiment control groups have been set up for both of the case studies however there is no opportunity for the random assignation of pupils to the groups. This is negated to some extent by the fact that the adopted definition of low attainer for the experiment. In case study 2 there were two experimental groups in order that the teacher factor could be addressed. This point is further discussed in the threats to internal and external validity later in this chapter.

At the beginning of the academic year 2005, there were 14 pupils in the experimental group and 16 pupils in the control group, each group having one teacher. The experimental group was set 4 of 4 and the control group was set 2 of 4. Again from this we can see that the pupils in the experimental group for case study 1 all fell within the chosen definition for the thesis of low attaining pupils by virtue of the fact that they were in the lowest set, however none of the pupils in the control group could be classed as low attainers. If set 3 of 4 had been chosen as the control group, some of the pupils would have been within the definition of low attainers and some would not. It was decided that this split in academic ability could have affected the experiment and hence the set 2 of 4 were chosen as the control group.

All pupils were in Y7, i.e. 11 – 12 years old with the exception of one pupil who was 12 years old at the start of the case study and 13 years old at the end. This pupil was in Y7 due to a low academic attainment. It should be noted that there was also one epileptic pupil in this group whose memory was severely affected.

School 2	Experimental Group	Control Group
	14	16

Table 10 Case Study 1. Number of pupils in the experimental and control groups.

From the summer of 2006 to the Christmas of that year case study 2 was instigated in order to try to take the teacher influence out of the experiment. In case study 2 there were two experimental groups and one control group. Experimental group 1 had 9 pupils in and was set 4 of 4, experimental group 2 had 16 pupils and was set 3 of 4 and the control group had 14 pupils and was set 2 of 4. All sets had different teachers with no classroom assistant. Again all of the pupils in experimental group 1 fell within the chosen definition of low attainers and some of the pupils in experimental group 2. The point of the second case study was to address the possibility that it was the teacher rather than the pedagogy that had made the difference. It should be noted that all the groups were taught by different teachers.

School 2	Experimental Group 1	Experimental Group 2	Control group
	9	16	14

Table 11 Case Study 2. Number of pupils in the experimental and control groups.

4.4 The Experiment: Collecting the data

In order to put the experiment into context, I will now give an overview of the teaching pedagogy used in the experiment followed by a discussion on the theory of internal and external threats of the research design. An argument is then put forward for the use of accelerated learning in the classroom and a proposal of how the elements of environment, communication and memory identified in the literature review can be linked with this.

Teaching Pedagogy for the Case Studies

Accelerated learning pedagogy was used in the case studies together with both CAME and the Gatsby Fellowship units to teach the experimental group and no specific intentional accelerated learning techniques were taught or used with the control group.

In case study 1 there are 5 lessons of 40 minutes per week and for experimental group 1, accelerated learning pedagogy was used in nearly every lesson throughout the year. There would be a 5 – 10 minute starter followed by 2 or 3 different activities in the main part. The lesson would end with a 5 minute plenary. Details of these lessons can be found in the following section. This established the structure for the rest of the year and it began by having different starters and plenaries. These were primarily:

- 5 – 10 questions on any topic studied between Y4 – Y7
- Memory techniques
- Communication games
- Communication and lateral thinking puzzles

Although not all of these activities were mathematically focused, multiple approaches to activities were used and revised as and when appropriate, in a formative manner, during the case studies. More details on these activities can be found later on in this chapter and detailed descriptions of how they were used in the classroom in the case study chapter.

As with case study 1, there were 5 lessons of 40 minutes per week for all of the groups in case study 2. At the start of the summer term 2006, an INSET was given by myself to the mathematics department on accelerated learning and the teacher of the second experimental group was given further training and adopted this pedagogy for the term leading up to Christmas 2006 examinations. Again no intentional accelerated learning was used with the control group although the teacher taking this group had been at the INSET training. I asked this teacher to confirm that no accelerated learning had taken place in his lessons and he stated that he had not intentionally taught using the accelerated learning pedagogy. However we must consider the fact that teachers do use communication, different teaching styles, evaluate pupils knowledge and create a supportive environment during lessons as this is the nature of teaching. Hence it can not be categorically stated that he did not use some of the elements and stages of accelerated learning however it can be said that he did not use the whole learning cycle together with the supportive learning environment as previously described as the teaching pedagogy to be used in the case studies, in his lessons. The main part of the lesson was essentially the same for both of the experimental groups.

So we have seen the makeup of the groups and lessons however a rigorous research design for the case studies was needed. Hence I looked at Campbell et al (1963) threats to internal and external validity.

Theoretical Research Design applied to the Experiment Research Design

Campbell et al (1963, page 34) state that quasi-experimental designs are ones in which the author can 'introduce something like experimental design into his scheduling of data collection procedures (e.g. when and whom to measure) even though he lacks the full control over the scheduling of experimental stimuli (the when and whom are exposed and the ability to randomise exposures)'. In this respect the case studies can be viewed as quasi-experimental designs as the author had control over who and when to collect data but could not randomise the pupils' exposure.

In these cases where full experimental control is lacking the author must, they say, be aware of the specific variables that the design fails to control. They suggest that their framework of threats to internal and external validity of experiments is appropriate to assess the reliability and validity of the research.

The following section discusses these threats in the context of the case studies. The threats are described and then later analysed in a table with arguments why the threats do not invalidate the experiment.

The threats to internal validity in the case studies

History: Following the KS2 SATs and the school entrance tests the pupils had a break for the summer holidays prior to entry into secondary school. There may have been a negative effect on the pupils' general level of attainment as they have six weeks in the summer with no education. This would, of course, be the same for both the control and the experimental groups.

Maturation: The peer groups of the pupils may have changed between leaving junior school or during the first three months of secondary school and this could impact on both the experiment and control groups.

Instability: The pre tests (School 2 entrance tests) were standardised in that all of the pupils sat the same test and was considered reliable. There was some fluctuation in the groups as when the pupils were admitted into the secondary school there were some timetable conflicts. Pupils who had not taken the entrance test at the end of Year 6 had to be allocated a group based on junior school teachers' judgement, however these pupils were not then counted as part of the statistical analysis group. Some of these pupils could have been moved from the groups as their secondary teacher became more aware of their mathematical ability. This was not the case for any pupil in either the experimental group or the control group in either case study but the possibility had been there should it have been needed.

Testing: There was only 3 months between testing and no other tests were administered during this period. The pupils' raw scores from their KS2 SATs and entrance tests at the end of Year 6 were used as starting benchmarks to judge academic attainment. Within the inputs there could be some discrepancies, as the pupils will have been subjected to different teaching styles and approaches with their junior schools. In the prep school at School 2 the pupils would have had access to the previous years entrance tests. This can enhance the pupils' entrance tests results hence, the raw score starting data may be higher than would normally be expected as opposed to the pupils who did not have access to the test. This could skew the baseline for both the experimental and control groups however this is accounted for in the analysis methodology suggested below.

Instrumentation: The teachers did not change during the experiment. It could be argued that as the scorers for the post test were the teachers who actually taught the groups, the test results could be affected when comparing the experimental groups' results to the control group's results. This however, should not be the case as the post tests used were based on previous years SATs questions and the answer booklet provided by the DfES gives rigorous examples and expected answers. It could also be argued here that as the tests are marked with the names of the pupils' on and not anonymously then the test scores may not be true. Again this should not be true in the case studies as the teachers are professionally trained in marking examination papers.

Regression artefacts: In case study 2 neither of the experimental groups nor the control group had any outlying pupils at the beginning of the experiment. However in case study 1 there were 2 outliers in the experimental group. The subsequent analysis was performed with all pupils within both groups and then without the outliers. However it should be noted that the experimental group in case study 1 was only using pupils who have low KS2 SATs and entrance test scores and hence have the most potential for improvement. This point is addressed further in the analysis section of this chapter. In case study 2 there were two experimental groups, one is set 4 of 4 and one being set 3 of 4. The control group was set 2 of 4. Setting was done from 1 to 4, set 1 having achieved the highest entrance test results.

Selection: Again this was avoided by selecting on raw score entrance test results and KS2 SATs results. The pupils were grouped accordingly and this fits within the definition adopted in this thesis for low attainers.

Experimental mortality: The control and experimental groups were not equal in academic ability as described in regression artefacts above but were deemed to be equal to the experimental group both socially and ethnically as previously described.

Selection-maturation interaction. The selection of pupils for the experiment and control groups did not appear to result in different rates of maturation.

The threats to external validity in the case studies.

Interaction effects of testing: All but two pupils took the School 2 entrance test and hence this would not make the pupils more responsive or sensitive to the experiment. They were not exposed to any accelerated learning tests at the start of the experiment.

Interaction of selection and experimental treatment: All of the pupils in the experimental groups demonstrated a response to the experiment in both case studies.

Reactive effects of experimental arrangements: The experimental environment was the same as any other environment in which the experiment could have been carried out for all groups.

Multiple treatment interference: Neither the control groups nor the experimental groups were exposed to other experiments.

Irrelevant responsiveness of measures: In order to assess whether the teacher element was making the difference or the accelerated learning pedagogy, a second case study was implemented in which there were 2 experimental groups. A different teacher taught the second experimental group. Other than this no effects were attributed to anything other than the experiment itself.

Irrelevant replication of treatments: The experiment was replicated in case study 2 for the reasons stated above.

Finally a comparison of the threats of both experiments is shown.

	Case study 1	Case study 2
History	X	X
Maturation	X	X
Instability	*	*
Testing	*	*
Instrumentation	√	√
Regression artefacts	*	*
Selection	√	√
Experimental mortality	*	*
Selection-maturation interaction	√	√
Interaction effects of testing	√	√
Interact of selection and exp treatment	√	√
Reactive effects of exp arrangements	√	√
Multiple-treatment interference	√	√
Irrelevant response of measures	√	√
Irrelevant replicability of treatments	*	√

Table 12 Case study threat analysis.

Key to the table.

X = evidence of the threat.

* = some evidence of the threat.

√ = no evidence of the threat.

From the table above we can see that the history and maturation in both case studies could give cause for concern. The main issue is the KS2 SATs and the entrance test are taken prior to the summer holidays. This break in exposure to learning can have unpredictable effects on the pupils, however this should be comparable in both the experimental and control groups.

Another major area is the issues around the pupils' academic background as they enter the secondary school in Year 6 from different junior schools., e.g. some pupils have had access to prior years tests and for this experiment they are in effect pre testing for the pre test as the entrance test results have been used as the starting baseline for the experimental data analysis.

The peer bonding that the pupils have had in their junior schools may change on entry to the secondary schools and this in turn can affect the pupils' academic attainment. Again, this would affect both the experiment and control groups.

So we can see that although there were some threats to the experiment none of them were sufficiently strong as to invalidate the experiment and now we will look at why accelerated learning was chosen to be the teaching pedagogy used in the case studies.

4.4.1 Why is the accelerated learning suitable for the experiment?

We have seen a detailed discussion in the literature review chapter of the theoretical causes of difficulties in mathematics for low attainers. This included theories from an internal viewpoint such as poor memory and communication skills, poor cognitive development, and physical or psychological problems and from an external viewpoint causes such as poor communication skills and incorrect teaching pedagogies. It was suggested that the causes were often a result of the teaching and teaching-learning environment (Barnes, 2005).

Subsequently the key theoretical principles and practical intervention strategies that were shown to address these causes were discussed and summarised in a chart. It includes theories such as discussion (Pimm, 1987; Dowker, 2000; Chin, 2006; Boaler et al, 2010) and intervention strategies, e.g. scaffolding (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010).

It was then shown that accelerated learning was underpinned by these key theoretical principles and that the practical intervention strategies could be facilitated within the supportive environment and 7 stages of the pedagogy.

Hence we can conclude that accelerated learning is a suitable teaching pedagogy for the experiment.

4.4.2 Accelerated learning stages and the 3 key elements of Environment, Communication and Memory

In the pilot study chapter narrative of the classroom activities is given under the headings of the environment and 7 stages. In the literature review chapter it was suggested that environment, communication and memory are three important elements of the intervention and were shown to be underpinned by the key theoretical principles and practical intervention strategies that address the causes of low attainment in mathematics. Below we will see where these elements could be used in the 7 stages and later, in the case studies chapter, how they were actually used. It should however, be noted that there is a case for all of the elements to be used in all of the stages of accelerated learning and the table below details where they were most frequently used in the case studies.

Elements \ Stages	Connect	Big Picture	Outcomes	Intro	Activity	Demon-strate	Review Recall Retain
Environment	(shaded)				(shaded)		
Communication	(shaded)	(shaded)	(shaded)		(shaded)	(shaded)	
Memory							(shaded)

Table 13 The 3 Elements v The 7 Stages

4.4.2.1 Environment

The supportive learning environment (Papert, 1980; Mounoud, 1981; Boaler et al, 2010) plays an important part in the accelerated learning pedagogy and this environment was created in the classroom for the experiment. This was achieved in a variety of ways, some brief details of which are given below. Detailed examples of ways in which the environment was used in the experiment are given in the case study chapter.

Classroom discussion has to take place on neutral ground, Johnson et al (1996), and the teacher in the experiment enabled this through the environment created in the classroom. Examples will be given of environments in which the not only the pupils were made to feel safe and confident as if a pupil feels safe and confident then they will be much more willing to go out on a limb and try new things (Haylock, 1991).

Accepted behaviours were described, deadlines set and made clear, active listening skills practiced and methods of praise were all set out at the beginning of the experiment as part of the supportive learning environment.

As we have seen in the literature review, internal and external environments can influence learning and both are used in the teaching pedagogy for the experiment. The teacher has most influence over the internal environment in the experiment, but examples of how both of these environments have influenced the pupils' cognitive development are described in the case study chapter.

4.4.2.2 Communication

We have seen that pupils need to be confident in two types of speech, listener and message oriented speech (Brown, 1982), both of which are used in the experiment. This was facilitated by the teacher allowing the following types of communication to take place:

- Pupil to pupil (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Dunn et al, 2010; Boaler et al, 2010)
- Pupil to teacher (Luria, 1976)
- Group discussion (Haylock, 1991; Watson et al, 2003; Boaler et al, 2010)

- Presentation of results (Shayer et al, 2007)

as part of the teaching pedagogy. Detailed instances of this can be found in the case study chapter.

Scaffolding (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010) has been shown to allow pupils to move from stage to stage and hence enhance their cognitive ability. This was achieved in the experiment by the pupil to teacher communication as, according to Chin (2006), this type of communication can be seen as a form of scaffolding.

Pupil to pupil communication was used in the experiment and as Hiebert et al (1996) state, pupils develop greater understanding, retain more information, are more competent and make quicker progress through topics when peer explanation of problems are facilitated. Examples of pupil to pupil communication are detailed in the case study chapter.

Communication and lateral thinking puzzles were used to encourage listening skills and enhanced pupils' communication skills and although some of these puzzles are not directly mathematics related, the generic skills of listening and communicating feed cyclically back into the pupils' mathematics lessons.

4.4.2.3 Memory

In the literature review chapter Wertsch (1978) states that by asking a series of structured questions of a pupil, the pupil will be able to remember the answer to a question. He refers to this as the metacognitive process. In the experiment memory techniques are used to enhance the metacognitive process by scaffolding as described above where the teacher prompts the pupil in order to help them remember facts needed to solve the problem.

Working memory, because of its ability to manipulate and link numerous pieces of information, can increase understanding (Staver et al, 1988). This can be facilitated in the accelerated learning by the communication that the teacher allows to take place in the classroom.

Summative assessment (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al, 2010) promotes memorisation by the pupils and as summative tests were used as baselines for the attainment levels of the pupils at both the start and end of the experiment it was felt that memory techniques should be taught as part of the experiment. Details of how attainment was measured are described in the next section.

So we can see from the literature review and from the above that accelerated learning is a suitable pedagogy for the experiment and next we will consider the final research question identified in the pilot study chapter of does the academic attainment improve. Hence the next section will discuss academic attainment and how any improvement can be measured.

4.5 Academic Attainment

We will start by looking at academic attainment by discussing testing techniques. Summative and formative methods of assessing if improved attainment had taken place will then be considered.

4.5.1 Testing

A test is a summary based on evidence collected from the responses a testee makes to the topic or topics being tested (Thissen et al, 2001). There are many ways of testing such as multiple choice, free response or a general aptitude test such as the SATs. This is an example of a summative assessment where the resulting test score is a snapshot of a pupil's attainment at a specific point in time. Topping (1998) describes another type of testing namely formative assessment. This type of assessment can take place several times in one lesson and the feedback from the assessment can impact on and improve learning as an ongoing process during the academic year. Both formative and summative assessment are discussed in detail below.

As feedback can impact on teaching and learning we must also look at the marking of assessments. According to Newstead (1996), work should achieve the same mark regardless of who marks it and Oakes (1989) says that in many states in the United States of America, the only accountability systems are outcome indicators and these are usually test scores. So if we are using tests to measure the attainment of the testees the test marking must be standardised.

The use of tests as indicators is mirrored in the United Kingdom where, as we have previously seen, the government uses the SATs, based on the national curriculum, as a key performance indicator published in the UK league tables. The programmes of study and achievement targets for the National Curriculum are set down in section 3 of the 1988 Education Reform Act and details of these targets can also be found in the section above.

We have previously seen that the SATs are to be used as indicators then we must look at the potential effect on teaching. According to Shepard (1990), high pressure tests focused more instructional time and attention on tested objectives. To demonstrate this she describes the situation in the United States of America where state directors of testing were asked for their comments on testing. They had two totally different opinions as to the effect on teaching in response to the tests. Some of the directors of testing believed that pupils would learn more as the tests forced the pupils to focus on skills that they were not as competent in or had not been exposed to sufficiently previously. Other directors of testing believed that the teaching to the test could somehow reshape the curriculum. The tests would focus pupils' work on the topics used in the examinations from the previous years and as this may not cover the whole curriculum. Some topics are not used every year in the examinations and hence could be missed out of the programmes of study by using this method.

In the U.K. the curriculum for KS3, which is set up by the secretary of state, is tested via the SATs. The question of whether the SATs are skill based or are an example of 'teaching to the test' is discussed in detail in the next section. Shepard (1991) says that in order to evaluate testing effects one must have an integral knowledge of learning theory and hence we will now look at two main types of assessment, formative and summative which can feed into teaching and learning.

4.5.2 Assessment

Assessment can be defined as the process of obtaining data about how pupils think, achieve or make progress, Crooks (2001). As this thesis' hypothesis tests does the academic attainment of low attainers improve when accelerated learning is used as a teaching pedagogy in the classroom, the following section will discuss types of assessment and how this could provide benchmarks for the analysis section.

4.5.2.1 Formative assessment

An example of Formative assessment is when feedback from learning activities is used to inform and adapt subsequent teaching. See Cowie et al (1999) for an explanation in a science context, Black et al (1998) for a more general overview.

Woods et al (2001) refer to misalignment with emphasis being on academic achievement at the expense of personal and social education. They state that national policies focus on the academic achievement at the expense of the personal and social aspects of a pupils life. This emphasis on academic achievement does not allow pupils to be creative, and in order for children to grow into healthy, well adjusted adults they must be allowed to play (Pellegrini, 2001). Fein (1979) reiterated this when he states that it is through symbolic play children come to organize meaning in language and thought.

In Topping's work (1998) he describes formative assessment and how it aims to impact on and improve learning as an ongoing process during the academic year. Students, he says, will be able to gain immediately from their successes rather than only know that the have failed at the end of the topic. This is inline with Ginsberg (1977) and Biggs (1985) who also state that with mathematical success comes confidence and enjoyment. In this type of assessment students can identify their strengths and weaknesses and plan their own way forward. This would mean that pupils learn from their mistakes at a point where they are in a position to rectify them rather than it being too late for them to do so. He describes peer assessment as having great benefits to the students and suggests that even simple quantative feedback cannot only improve the assessment results of the students, but improves the students' perception of the subject. It can also improve the student's overall confidence and has been seen to have a positive effect on presentation and appraisal skills.

Formative assessment can easily be applied to accelerated learning in the same vein as Topping (1998) describes, assessing frequently and using the results to inform the pupils of their strengths and weaknesses and hence allowing the teacher to made a more informed decision for each individual pupil as to how they should progress.

Messick (1995) states that when assessing a pupils' work inferences can be made from the students' portfolio about the quality, knowledge, skills and other attributes. However with the SATs there is no opportunity for the students to demonstrate these characteristics as they do not present any portfolios to the examiners and in mathematics they merely take two written tests and one mental test. Their performance indicator is based solely on these assessments. He goes on to say that assessments can be either too narrow or too broad. There maybe extraneous clues in the question that make some pupils respond correctly to the ‘extra’ information but incorrectly to the actual question being asked. It is so embedded that it is not obvious to some pupils what the ‘real’ question actually is. From this we can conclude that summative assessment of a portfolio as a snapshot of the pupils’ ability for that year without the formative assessment of teacher judgement would not give a true reflection of that pupils’ actual ability.

Inferences made from pupils’ responses have to be valid according to Messick (1995). Coursework and teacher judgement could be used to counteract any invalidity posed from these inferences and the DfES (2003) themselves state that teacher assessment of pupil performance should be more highly thought of.

According to Pellegrini (2001) if high stakes assessment is to be used then we should use a variety of assessment methods. He goes on to say that when assessing young children observations about play can be used as a form of assessment and he uses Vygotsky’s (1978) theory of symbolic play as it links specifically to assessment. Young children are not always motivated to demonstrate their highest levels of competence in test situations and hence, he says, a child’s real competence level cannot be assessed. He goes on to say that role play and assessment through all types of play provide higher data reliability. Many types of data should be used when assessing a pupil progress such as information from parents, teachers and peers (Pellegrini et al, 2000).

Child centred learning must also play a large part in assessment through the curriculum and Pellegrini (2001) says that children must play if they are to develop into healthy and socially competent adults. This attribute is very important when we consider life-long learning. Fein (1979) links play to academic achievement when he says that through symbolic play children come to organise meaning in language and thought.

It can be seen that formative assessment has much in common with the accelerated learning paradigm and examples of how formative assessment is used to feed back into planning and learning will be looked at in more detail in the case studies. However in terms of measuring improved attainment, using formative assessment would not be standardised and therefore not appropriate or indeed viable given the frequency of testing that would be required. Hence a different approach is needed.

4.5.2.2 Summative Assessment

Summative assessment is when assessment is used after a particular period of time and summarises the learning of the pupil up to that specific point.

Whilst there is a wealth of work on summative assessment, e.g. Glickman et al. (2003), for this thesis the important aspect is that the definition of low attainers and the methodology used in the case studies relies on standardised summative assessment. Specifically the Standard Assessment Tests (KS2 SATs) give a baseline for the studies, and a further summative assessment, the schools entrance tests, from which the value added attainment can be measured.

We have seen that one of the major events in the United Kingdom to influence testing was the introduction of the SATs in 1991 by the Conservative government as part of their commitment to raising standards. They were a statutory requirement and assess pupils according to the National Curriculum programme of study. An in-depth discussion on the benefits and detriments of the SATS can be found in the previous chapter and only the main points will be re-iterated below.

Originally the SATS were based on the teachers' observations but this became too time consuming and consequently a paper based test was introduced in 1995. The tests focused initially on Mathematics and English and gave a performance indicator that could be reported to the Department for Education and Science (DfES). Parents were also given access to this information not only about their own child but, through the publication of performance tables, to schools throughout the country.

We have seen views from the DfEE (1999) stating that there should be a return to school / teacher assessment. We have also seen that Shepard (1990) says tests focus pupils' time and attention on the test objectives and this influences teaching pedagogy to teach only to the test. Some of the directors of testing in the United States of America see this as potentially changing the curriculum to only cover aspects which are to be included in the test and this appears to what has happened in the U.K. in the teaching of secondary pupils when we consider the SATs.

The SATS were based on National Curriculum Programme that prescribed the order in which pupils would be taught topics and INSET via the ‘Guide to teacher assessment’ was used to train teachers in how to teach the curriculum. Thus it was a very prescriptive pedagogy and left little room for interpretation by the teacher.

The SATs were used to provide authoritative data on the effectiveness of schools however we have seen that value added had little value in this and where pupils had made greater progress, but at lower level than their peers, they were seen to be failing by the government. This can have a negative effect on the pupils who has ‘only’ achieved a level 4 and yet has greater value added than the level 5 pupil.

We have seen in the formative section above that inferences made from pupils’ responses have to be valid according to Messick (1995). Coursework and teacher judgement could be used to counteract any invalidity posed from these inferences and the DfES themselves state that teacher assessment of pupil performance should be more highly thought of. This is not however, something that is used in the SATs and in fact in 2009 the KS3 SATs were withdrawn by the government.

However the SATs could be used as a benchmark from which to measure improved attainment as they are standardised and next we will see a discussion of why the SATS were considered a suitable starting benchmark.

4.6 Measuring improved attainment

In order to answer the third research question posed in the pilot study it was necessary to calculate improvement in academic attainment. To do this we will look at indicator systems such as the SATs which, as we have seen, are an example of summative assessment tests. It will be shown how they can be used as a benchmark both at the start and end of the experiment. Then how the starting attainment and final attainment of pupils in the case studies was calculated will be demonstrated and finally an analysis of the internal examination papers is shown in order to demonstrate the link between the 3 elements and the measurement of attainment.

Why were the SATs used as a starting point?

When looking at how to analyse the improvement made by the low attainers we need to consider what Fitz-Gibbon et al (2002) stated re indicator systems, i.e. they should be viewed as ‘top down’ and are usually state or local authority controlled. Also Campbell et al (1969) states that only certain implementations would be allowed where the government has already decided what it wants the outcomes to be. We have seen that the government implemented the SATs and had a rigid framework of expected attainment levels as outcomes. Also Oakes (1989) says that in many states in the United States of America, the only accountability systems are outcome indicators and these are usually test scores.

This is mirrored in the United Kingdom where the government uses the statutory test results as an indicator, testing in Year 2, Year 7 and Year 9. The outcome is a key performance indicator, e.g. in Year 9, a level 5 in the KS3

SATs is seen as acceptable by the government and schools work towards this goal. This level in Year 9 is one of the key performance indicators published in the UK league tables and used by many parents to assess the quality of the school. A detailed description of SATs levels can be found in the literature review chapter.

Although the examination results that are to be used come from a top down system, i.e. the are government regulated SATs, the accelerated learning methodology used is a bottom up one in that it is implemented by the schools and teachers who have direct contact with the pupils. So we can see that although the SATs results used as key performance indicator benchmarks are top down, the approach is bottom up so the teaching pedagogy could have an influence on the outcome of these tests.

Regardless of who marks examination scripts, according to Newstead (1996), the work should achieve the same mark it. In the case of the SATs they are marked by trained markers from different parts of the country with a percentage being ‘double marked’ to ensure reliability. He also says that different standards apply in different institutions however in the experiment all of the tests were marked by teachers from the participating school using the detailed SATs mark scheme.

Coursework elements could however cause problems as this could be viewed as a subjective form of marking. Schools do try to standardize marking of coursework and use exemplar materials provided by the examination boards. The SATs have no coursework element and as shown above there is no teacher assessment hence again the SATs could be viewed as a good summative assessment for the experiment.

Testing is also linked to cultural issues according to Greenfield (1997) where tests are developed for certain cultures. The pupils need the cultural knowledge in order to interpret the question in the correct setting and may assume implicit knowledge.

The SATs do for example, use multi-racial names and examples in questions but as we have seen above there was no difference in cultural backgrounds of the pupils in the experiment and hence all of the pupils would be equally affected. We must also consider that the SATs are an example of a summative assessment where the resulting test score is a snapshot of a pupil's attainment at a specific point in time.

So although we have seen some weaknesses in the SATs they are a pervasive summative standardised test. We can conclude that from an attainment point of view the SATS have been well thought out and allow for most of Newstead's (1996) characteristics of a 'good' assessment system.

All of the pupils who came to the school in the two case studies from different junior schools had aKS2 SATS examination mark that was standardised and consequently could be compared. The examinations taken by the pupils during and at the end of the case studies were in fact based on previous KS3 SATs papers and would also give a standardised examination mark. So although the SATs have been shown to have some weaknesses, they have also been shown to be a standardised summative benchmark from which improved attainment can be measured and hence can be used in the experiment.

The other benchmark used in the case studies was the schools entrance test and again it can be seen above that different methods of testing are important. All pupils in the case studies took the entrance test and hence it could be considered standardised in this respect, but not all pupils' SATs results in the case studies were known. Hence as the entrance test was considered a summative standardised test, it was an important benchmark as it gave another baseline for use in the analysis for all pupils in the case studies. The methodology for analysing these attainments is detailed in the analysis section later in this chapter.

This following part of this section describes the research design view of the data collection for the case studies.

Case study 1 and 2 Design View.

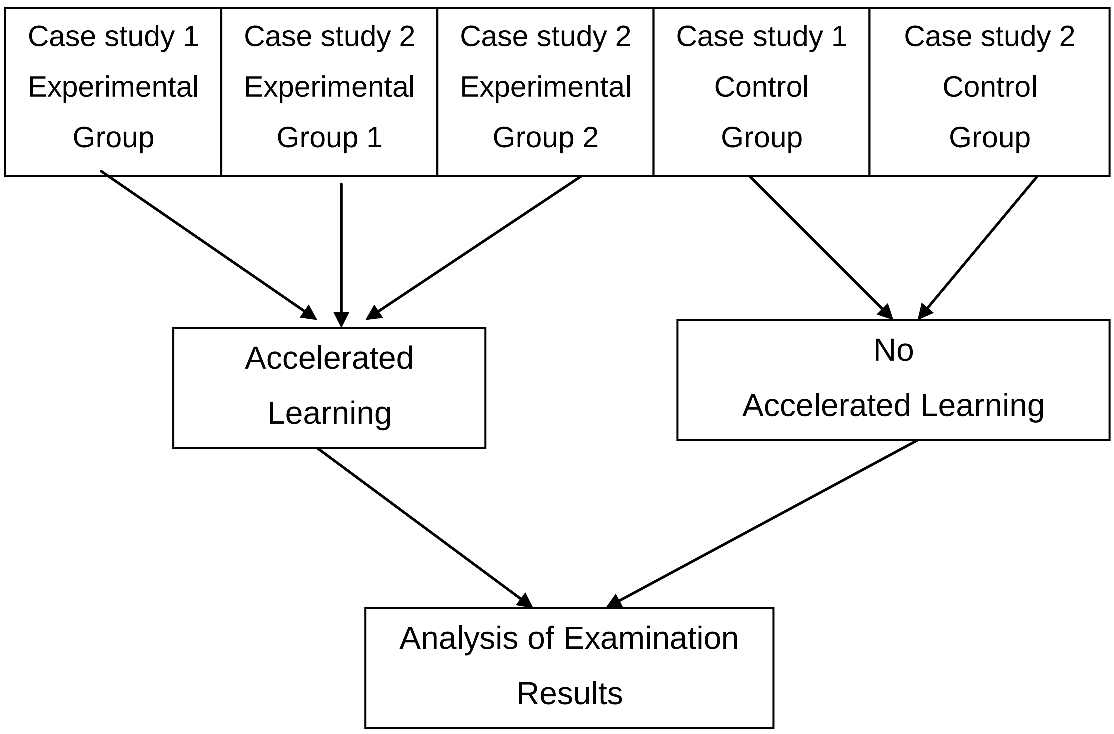


Figure 9 Case Studies Design View.

In case studies 1 and 2 the pupils' academic achievement in the KS2 SATs and the School 2 entrance test were used as a starting benchmark. At the end of one academic term (i.e. Christmas 2005 in case study 1 and Christmas 2006 in case study 2) the pupils sat internal examinations. These examinations were based on the KS3 SATs questions and consisted of two papers, one calculator and one non-calculator plus a mental test. In case study 2 this process was repeated at the end of the summer term 2006. Again these examinations were based on the KS3 SATs. Predictions based on the control group pupils' KS2 SATs results were then made for the experimental groups Christmas and summer examinations. These were used to measure value added in terms of improved academic attainment for the experimental groups. More details of this can be found in the analysis section below.

4.6.1 Starting attainment in the case studies

Case study 1.

- School 2 from 2005 – 2006. (Case study 1)

School	Experimental group	Control group
School 2	14	16
School 2 (number used)	13	15

Table 14 Case Study 1. Number of Pupils taking part in the Experiment.

As previously stated the experimental group consisted of year 7 pupils in set 4 of 4, i.e. the lowest attaining group. At the beginning of the academic year 2005, there were 14 pupils in the group, 6 girls and 8 boys. They were all working at National Curriculum levels 2-4, some with attention disorders and some with behaviour difficulties. Of these 14 pupils, 9 had been to the schools preparatory school and 5 came from the surrounding area's primary sector. None of the pupils held any type of scholarship other than from HM forces.

As mentioned above, case study 1 had one pupil who was 12 years old at the start of the case study and 13 years old at the end. This pupil was in Y7 due to a low academic attainment***.*** There was also one epileptic pupil in this group whose memory was severely impaired. These two pupils were shown to be outliers when the statistical analysis was performed. The charts below show the test results with all pupils and without these 2 outlier pupils results however, the case study chapter only contains statistical analysis for the whole of the experimental group. The statistical analysis for the experimental group excluding the outliers can be found in appendix 3.

Pupils had already have sat their KS 2 SATs in the previous summer and a common School 2 entrance test. These were both used as a starting baseline of academic achievement. Pupils in the experimental group had an average of 29.54 on the entrance examination compared to 44.16 average in the control group. Of the KS2 SATs results known, the experimental group had an average of 41.83 and the control group and average of 59.31. In the control group as one pupil did not have a KS2 SATs result. These results are detailed below.

Case study 1 KS2 SATs results

All pupils

	Experiment	Control
Mean	41.83	59.31
STDEV	10.17	7.52

Table 15 Case Study 1. Mean and Standard Deviation KS2 SATs. All Pupils.

As the 2 outliers did not have KS2 SATs results the data was the same for both groups.

Case study 1 Entrance tests.

All pupils:

	Experiment	Control
Mean	29.54	44.16
STDEV	10.63	5.13

Table 16 Case Study 1. Mean and Standard Deviation Entrance Test. All Pupils.

Without the outliers:

	Experiment	Control
	Pre-Test	Pre-Test
Mean	33.55	44.16
STDEV	4.27	5.13

Table 17 Case Study 1. Mean and Standard Deviation Entrance Test. Excluding Outliers.

As with case study 1, some pupils at School 2 in case study 2 did not have an entrance test result (or a SATs result) and hence were not used in the analysis. The charts below show how many pupils' data was used in the analysis stage.

- School 2 from 2006 – 2007. (Case study 2)

School	Experimental group 1	Control group 1	Experimental group 2
School 2	9	14	16
School 2 (Numbers used)	9	13	15

Table 18 Case Study 2. Number of Pupils taking part in the Experiment.

Case study 2

Again the pupils' entrance test results and their SATs results were used as a benchmark against the pupils' Christmas examination results for all of the groups in case study 2.

Case study 2 Entrance test Results:

	Experiment 1	Experiment 2	Control
Mean	37.56	59.27	72.46
STDEV	11.60	7.25	7.07

Table 19 Case Study 2. Mean and Standard Deviation Entrance Test.

Case study 2 KS2 SATs results:

	Experiment 1	Experiment 2	Control
Mean	39.00	60.38	75.29
STDEV	9.20	4.60	4.89

Table 20 Case Study 2. Mean and Standard Deviation KS2 SATS.

4.6.2 Final attainment in the case studies

At the end of one academic term (i.e. Christmas) the pupils in both case studies were examined and re-setted based on their internal examination results. These examinations consisted of 2 papers, one calculator and one non-calculator plus a mental test. These examinations were based on the KS3 SATs questions. This process was repeated at the end of the summer term and re-setting was then carried out based on their internal examinations results and teacher recommendation for the following academic year. Again these examinations were based on the KS3 SATs. The only re-setting which affected the experiment took place after the Christmas 2005 examinations for case study 1

Analysis of the examination questions in terms of the 3 Elements

Next we will look at the composition of the internal examination. As we have seen in the literature review, the accelerated learning cycle has 7 stages and these are used extensively throughout the teaching pedagogy used in the case studies. For the reasons discussed in the literature review communication, environment and memory can be seen as 3 critical elements of accelerated learning and in order to demonstrate a link the attainment with the elements the internal examination papers were broken down into the elements of accelerated learning. An example of the analysis of a question on the Christmas 2005 calculator paper can be found below:

Marks	Question Number	Environment	Communication	Memory	Other	Primary topics
2	1		X			Co-ordinates logic puzzles - complete the square on a grid

Table 21 Examination Paper Analysis by Element.

The marks allocated for each question are in column 1, the question number in column 2. If the element of environment, communication or memory had been used in the teaching pedagogy to teach that particular topic, columns 3 – 5 contain a X. Finally the primary topic that the question was based on is in column 7. These topics are discussed in detail in the case studies chapter. So here we can see that question 1 was based on the co-ordinates topic and was worth 2 marks. The complete breakdown for both the calculator and non-calculator papers for each case study can be found in appendix 1.

A detailed graphical analysis of the questions on the examination papers in which the proportion of marks from questions associated with each of the 3 elements is shown as percentages of the overall total can be found in appendix 2. An example of the Christmas 2005 calculator examination is shown below.

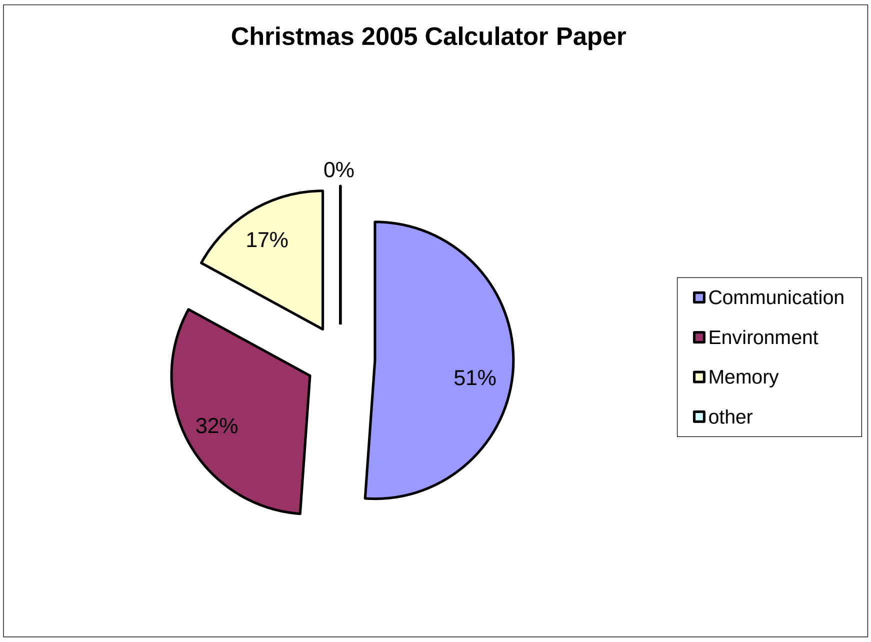


Figure 10 Examination Paper Analysis. Pie Chart.

So we can see that the environment, communication and memory were used extensively in the teaching pedagogy and were reflected in the internal examination papers.

4.7 Analysing the data

The following section details possible methods of analysing the data collected in order to address the thesis' hypothesis. We will start by considering the spread of the data by looking at mean and standard deviations. Next we will consider visual representations via scatter graphs and finally linear regression for a numerical way of representing a predicted examination result.

4.7.1 Mean and Standard Deviation

I began by looking at the mean and standard deviation as it is statistically useful, Gross et al. (2000) This gives a good estimate of the variation of the population from which the sample was drawn, i.e. the standard deviation measures the dispersion of the data set. In a low standard deviation the examination marks would predominantly be around the mean and for a high standard deviation they would be spread out over a large range of values.

4.7.2 Scatter Graphs

Next scatter graphs will be used in order that the reader can gain a pictoral view of the results. In the experiment the KS2 SATs were used as the starting benchmark and were compared to the:

- Christmas 2005, (Case study 1)
- Summer 2006 (Case study 1)
- Christmas 2006 (Case study 2)

internal examination results. This was repeated with the school's entrance test as the starting benchmark.

4.7.3 ANOVA

In order to compare the performance of the experimental and control groups, given that these groups have a normal distribution as described above, an appropriate analysis to test the equality of the improvement of the groups should be used. According to Kinnear et al (1999), in traditional significance testing it is not the experimental hypothesis that is directly tested but its negation, known as the null hypothesis and they suggest ANOVA for this. If the significance, or p-value, of the ANOVA is less than 0.05 (Kinnear et al 1999), then the null hypothesis can be rejected and hence a difference is shown. The lower the significance, the stronger the evidence against the null hypothesis that is to say that the difference is unlikely to have arisen by pure chance. Hence it is proposed to use ANOVA to test the equality of the improvement of the group's examination results in the experiment.

4.7.4 Linear Regression

We have seen above that scatter graphs give a visual representation of the comparison of the groups results, and trends can clearly be seen when considering the lines of best fit. ANOVA could then be used to tell us whether the difference in the groups is statistically significant and is not down to pure chance. Although linear regression is mathematically identical to ANOVA and contains all of the information that is in ANOVA (Cohen, 1968), it allows the size of the difference between the groups, the effect size, to be estimated after controlling for covariates. In the case studies the covariates are the KS2 SATS results, the entrance test and a combination of the KS2 SATS results with the entrance test. It allows us to estimate the precision of this effect size by calculating the standard error and hence gives us a confidence level, i.e. it makes a good estimate of outcome based on the starting point (Kinnear et al, 1999).

According to Fitz-Gibbon (1984), it is the magnitude of effect and the interpretation of how educationally significant this was that is the most important information arising from an experiment. She states that a statistical significance of 0.05 is normally quoted as being noteworthy. Fitz-Gibbon goes on to justify this by describing an example in which two groups of pupils were given a pre test. After 3 weeks they were again tested and only managed to achieve one more item correct. This would not logically be viewed as noteworthy even though there maybe a statistical significance of 0.05 or more. If however, the lowest pupils had almost achieved the same grades as the top pupils, this would be seen as educationally significant despite not being statistically significant. She concludes this point by saying that the educational difference between two groups should be interpreted in terms of a matrix against which the outcomes could be judged. Statistical significance, she says, relies too heavily on sample size where a small sample size can skew the results.

This is reiterated by Thompson (1986), who states that when ANOVA is used it tends to overestimate the effect particularly for small groups, whereas linear regression is more accurate making it a suitable method for the experiment where the group sizes are small. As the group sizes in the experiment are small this method was considered appropriate.

Hence we can see that the use of linear regression is an approach argued for by Fitz-Gibbon (1984), Thompson (1986) and Coe (2002) in the use of effect sizes, but this is not a common use of linear regression in educational research. However, it is widely used for other purposes such as meta-analysis where different studies are compared and combined (Coe, 2002). According to Vidal (1997), ANOVA is preferred by many researchers as they see it as simpler method of providing all of the information they need. She goes on to say that researchers prefer ANOVA as they see it as being simple to calculate. However in order to maximise and provide more relevant research findings, linear regression should be performed (Cohen, 1968). This, he says, will give us the optimal prediction. The American Psychological Society have officially been encouraging researchers to report effect sizes since 1994 (Coe, 2002) and with the progress in technology many computer packages, such as SPSS, facilitate the easy calculation of linear regression and hence it can readily be used.

A linear regression uses the fact that there is an association between 2 variables to predict the value of one of the variables (the dependent variable) against another variable (the independent variable). The dependent variable here was the Christmas or summer exam marks. The independent variable is the KS2 SATS, the entrance test and the combination of the KS2 SATS and entrance tests made an option for a third independent variable. This will show the estimated effect size for the experimental and control groups for the Christmas and summer exams after controlling the covariates of the starting attainment baselines.

Hence in this thesis ANOVA will be used to tell us if the difference in the improvement in the academic attainment of the groups is statistically significant, that is has not just arisen by pure chance. The linear regression will be used to estimate this difference (effect size) and the precision of this effect, i.e. will give us a numerical estimation of the results of the internal examinations at Christmas and summer given the KS2 SATs and entrance test results as the baseline together with a precision of this estimate in the confidence interval via its standard error. It should however be noted that a linear regression does not imply any causal connection between the relationships (Tabachnick et al, 2001).

The following section details how linear regression is undertaken.

Linear Regression

Linear regression is based on a straight line slope of the form $Y' = MX + C$

Where:

Y' is the estimated value of Y (say the Christmas examinations)

M is the slope (known as the regression co-efficient)

C is the intercept (known as the regression constant)

In the case study 1 there were two groups being considered, namely the experimental group and the control group and in case study 2 there were three groups, two experimental groups and one control group. This meant that in both cases a multiple regression had to be performed; but the M values form partial regression co-efficients, i.e.

$$Y' = C + M1X1 + M2X2 + M3X3 \ldots\ldots MPXP$$

So for example in the analysis for case study 1 the:

Y' is the Christmas or summer examinations.

C value is shown as the constant (Regression constant)

M_1 is the multiplier for the SATs or entrance test examinations.

(Regression co-efficient)

M_2 is the multiplier for the group number (2^{nd} regression co-efficient)

Hence the

$Y' = M_1$ X SATs or entrance test + M_2 X group number + C

i.e. Predicted Christmas examination result (Y') = M_1 X SATs or entrance test + M_2 X group number constant (C)

The details of how this was done in practice and the predicted results for the Christmas and summer examinations can be found in the case studies chapter.

Next we will look at the data assumptions that must be considered when using linear regression.

Assumptions / Violations

Before any linear regression is performed, assumptions about the data must be examined. According to Tabachnick et al (2001) et al, Osborne et al (2002) and Johnson et al (2007), there are several assumptions that must be checked before the use of linear regression can be considered valid and whilst described in differing terms, these assumptions may be summarised as follows:

- absence of outliers
- variables are measured without error
- normal distribution of errors
- linearity
- homoscedasticity

Some of these are robust to violation, according to Osborne et al (2002). These are dealt with within the design section of the methodology chapter, e.g. analysis is to be performed with and without the outliers in case study 1. Similarly, the KS2 SATs results used as a starting baseline have a standardised marking scheme as does the internal examination used at Christmas and summer as these were based on the KS3 SATs thus minimising as far as possible the possibility for marking errors (variables measured without error). However the entrance test did not have as robust a marking scheme and hence does not give as reliable a baseline under this assumption.

So in this section we will focus on the 3 remaining assumptions that are not as robust to violation and hence could threaten the validity of using linear regression.

Normal distribution of errors

One of the assumptions is that the errors from the predicted to actual examination results should have a normal distribution. The assumption is that the errors are normally distributed. If there is a normal distribution, linearity is, according to Tabachnick et al (2001), enhanced.

Linearity

The linear regression must show linearity if the results of the regression are to be an accurate estimate. In order to screen for linearity a scatter graph of the residuals v the predicted values can be generated. Visual examination of this scatter graph will reveal if there are either curvilinear or linear relationships. This residual test can also test for normality and homoscedasticity.

Homoscedasticity

Here we are looking to see if the variance in the errors is equally distributed. If this is not so the results will not be invalidated, only weakened (Tabachnick et al, 2001),

From the above we can see that normal distribution of errors, linearity and homoscedasticity should be tested for in order to ascertain the robustness of the linear regression results. Although linear regression was used in the pilot study, the assumptions were not addressed. However the statistical analysis section of the case studies chapter does contain data that has been tested against these assumptions.

4.8 Related Work

We have seen above how linear regression is to be used and we must remember here what Tabachnick et al (2001), says in that linear regression reveals relationships among variables and do not imply that the relationships are causal. This issue is addressed by looking at other related case studies in aspects of accelerated learning and suggests that if these case studies determine that academic attainment has been improved then it is reasonable to conclude that the improvement in the case studied of this thesis is also due to the teaching pedagogy.

We have seen in this chapter what was involved in the teaching pedagogy in the experiment and that after the pilot study, two case studies were instigated in order to see if the results were replicable. However, Fitz-Gibbon (1984) states that if you examine the magnitude of effect of an experiment statistical significance is much less important in the ‘one off’ experiment due to the smallness of the sample size. The results may not reliably replicate and she implies that the way forward is by actual replication. More reliable results can be found when experiments are conducted in several classrooms and the outcomes are combined.

We must also consider that the qualitative case studies in this thesis are based on small number of pupils and hence we cannot conclude that the experiment was successful when such small numbers were involved and have been analysed. Brown (2003) states that small qualitative studies give an insight and this can be tested on a wider scale. Case studies can be used to explore patterns seen in larger scale studies.

Taking both of the above into account, although actual replication of the experiment was not possible in the time frame, we can look at other larger studies performed in this area and look at their results and conclusions. If these studies demonstrated an improvement in the academic attainment of the pupils, then it would be reasonable to conclude that any improvement in the thesis' experiment could be as a result of the teaching pedagogy used.

In the following section I will describe some larger scale case studies. These case studies are described using sections headed with the 3 elements of environment, communication and memory however it should be noted that, as we have seen in the literature review chapter how the 3 elements are intertwined. This is most evident with environment, and it is difficult to separate one element from another when describing the accelerated learning pedagogy. Hence the descriptions could be applied to all three, two or an individual element.

Environment

In order for communication and memory strategies to take place, a supportive environment must be provided. The supportive environment is the element that facilitates the other two elements identified in this thesis and although no specific examples of environment are given here, the sections on communication and memory show the intertwining, e.g. in the memory section working memory will be shown to impact on attainment through the use of:

- Posters
- Objects at the beginning of the lesson

However, these are both examples of how the environment impacts on attainment.

The same is true of the communication section in that, according to the Cockcroft report (1982), opportunities for discussion in mathematics teaching should be facilitated at all levels and this can be achieved through the environment facilitated in the classroom.

Communication

We have previously seen in the literature review communication can be facilitated by:

- Work in pairs, using role-play or take part in debates. Bonwell et al (1991)
- Collaborative learning Cohen et al (2004) teacher will need to ‘ensure learning is about problem solving, communication, and the ability to evaluate and apply information’
- The Activity stage of accelerated learning
    - Communication such as peer to peer
    - Group and independent work
- CAME lessons where students work in groups and pairs facilitating communication.

With this in mind we will now look at other case studies conducted on group work which, we have seen, enables communication to take place. The results of these studies in respect of improved academic attainment will shown.

Kutnick et al (2008) performed a case study using primary school children aged between 5 and 7 years. The study used a quasi-experimental design in which pupils in the experimental group were subjected to strategies to improve the effectiveness of group working over a school year. The experiment involved 980 pupils in 17 experimental and 21 control groups. Over a school year, pupils in the experimental groups improved more than the pupils in the control groups with considering to academic attainment, and they showed, according to Kutnick et al, high levels of communicative interaction with partners. It was concluded by Kutnick et al that young children are capable of engaging in effective group work and this promotes academic achievement.

Blatchford et al (2005) initiated the SPRinG (Social Pedagogic Research into Group work) project. This project ran over 4 years and aimed to show how group work impacted on communication and joint problem-solving skills leading to improved attainment. Pupils were assessed in terms of four outcomes:

- Academic learning.
- Motivational attitude.
- Classroom behaviour.
- Classroom rating scale.

The experiment involved KS1, 2 and 3 pupils and 30 – 60 teachers over the time period. The results concluded that for KS1 experimental pupils scores were initially lower than the control group at the pre test and significantly higher for the post test.

At KS2 the results showed the experimental group had progressed more over the school year than the control group but these results were for science. At KS3 the differences between the groups was topic dependent. It is suggested that for topics that required higher order thinking skills, the experimental groups showed significant gains against the control groups.

This project was extended on in Scotland (ScotSPRinG). Here group work in primary schools, focusing on science, was investigated. Altogether 21 secondary schools took part with pupils starting their first year in the school, i.e. the equivalent of Y7 pupils in the UK. The objectives were the same as the UK project in that the project looked at improved attainment resulting from group work. The authors conclude that there was evidence that the intervention results in a gain in science attainment (Topping, 2007).

So we can conclude that group work that is enabled via communication, can improve academic attainment. Next we will look at case studies conducted to see if memory strategies can improve academic attainment.

Memory

We have previously seen in the literature review chapter many examples of the importance of memory within the classroom such as Staver et al (1988) who describe working memory as an ability to manipulate several pieces of information, link them and fitting them together within your mind. He suggests that this could increase understanding. The experiment in the thesis enables this linking of information in the experiment via scaffolding as detailed in the pilot study, literature review, and case studies chapters, linking the theoretical to the practical.

Weinert et al (1990) say that prompts to help the pupil locate the answer should be used and many examples of this are given in the pilot and case studies chapters. But in order to attribute any improvement in academic attainment to the teaching pedagogy we will now look at other work in the field of memory leading to improved attainment.

Gathercole et al (2004 a, page 5) conducted tests on pupils between the ages of 5 and 15 looking at their working memory. The tests showed that performance improves from 5 years until the teenage years. They suggested that pupils working memory abilities are closely related to their performance in Key stage assessments of the national curriculum. In their paper they describe, the use of external memory aids such as number lines and the implications for teaching. In this thesis pilot and case studies chapters' external aids such as this are describes, e.g. posters on the walls. Here we have a connection not only with memory for improved attainment but also with the environment.

Gathercole et al (2004 b) also stated that working memory skills were excellent predictors of KS3 mathematics results, i.e. low working memory skills gave low KS3 mathematics attainment. In the pilot and case studies memory techniques have been described as used in the classroom and the improvement in attainment can be seen in the analysis section of these chapters.

Pickering et al (2001) conducted a similar experiment on 750 pupils between the ages of 4 and 15. Approximately 100 of these pupils were special educational needs (SEN) as recognised by the school. The SEN pupils who had a specific learning difficulty attributed to language (communication) had low scores on the working memory test and these were '43 times more common than in the comparison sample' (Pickering et al, 2001, page 10). Here we can see the connection with memory and communication.

According to Towse et al (2003) working memory can be measured by looking at span scores. This is where a number of items need to be remembered. A strategy to improve working memory used in the case studies of this thesis was where pupils were asked to memorise connecting items (approx 15) such as 180 degrees, triangle and so on, at the beginning of a lesson. At the end of the lesson they had to write these items down. Further details of this can be found in the pilot and case studies chapters. Towse et al say that this would strengthen the working memory. In their experiment they measured the memory and recall of 130 pupils aged 8 – 10 years. They concluded that working memory was a strong associate of a children's ability.

The above studies provide quantative data from which it would be reasonable to conclude that communication via group work and memory can improve attainment. A supportive environment has to be provided for these elements to have this effect.

The qualitative data in the case studies of this thesis will be statistically analysed as described. If it is shown from this analysis that the experimental groups did improve their academic attainment when compared to the control group, then it can be concluded that this improvement was due to the teaching pedagogy adopted for the experiment.

4.9 Chapter Summary

So we can see from the above that although there are several ways in which this experiment could have been carried out. In order that others could replicate the study a mixed methods approach was shown to be an appropriate methodology for conceptualising the experiment.

Socio-economic and cultural differences of the pupils in the experiment were discussed. The pupils in the pilot were shown to be of a similar background. In the case studies, although there were mixtures of day pupils and borders, some of whom were partly sponsored, none of these sponsorships was for academic achievement and hence the experimental and control groups were deemed to be similar. The schools that were taking part in the experiment were also described in order to give an overall background to the case studies.

The pupils in the case studies had not achieved a level 4 or above in the KS2 SATs and hence could be defined as low attainers as per the adopted definition suggested in the literature review.

An overview of the experiment describing the case studies was given and after Campbell and Stanley's threats to both internal and external validity had been explored the experiment was shown to be valid. It was then shown from both a theoretical and practical point of view that accelerated learning was a suitable teaching pedagogy to be used in the experiment. Examples of how this could be achieved using the 3 key elements of environment, communication and memory were described.

In the attainment section formative and summative assessment were discussed. It was shown that formative assessment could take place during accelerated learning lessons and this assessment could be used to inform the teacher and feed into the planning for the next lesson. This type of assessment is not however, suitable for ascertaining if improved attainment has taken place as it is not standardised and teachers of control groups and experimental groups would not be applying the same assessment techniques. Hence it could not be used to produce standardised data for analysis.

An example of a summative assessment is the SATs and these provide a standardised assessment for all pupils regardless of which primary school they had attended. They were purported to provide authoritative data on the effectiveness of schools and the government targets for KS2 and KS3 to achieve this effectiveness were detailed. A pupil who was in Y7 should attain a level 4 on the national curriculum according to the government and a pupil in Y9 should attain a level 5. This gave a numeric value to the level to be used as the observed outcome described above from which a pupil would be deemed a low attainer at Y7. Hence it was decided that although flawed in some ways, SATs provided a summative standardised assessment that could be used as a benchmark from which improved attainment could be measured.

In the case studies a second benchmark was used; the schools entrance test, as again this was considered a summative standardised assessment as all pupils in the case studies completed.

Next we saw that the internal examination papers that were used as the final baseline were based on the SATs, and it was shown how the 3 key elements of environment, communication and memory related to each of the questions in the examination papers.

In the data analysis section it was shown how the mean and standard deviation for the data would be calculated. This will show the spread of the data from the groups. Scatter graphs will be used to give the reader a visual representation of the results and linear regression lines will be imposed. We have seen above that scatter graphs give a visual representation of the comparison of the groups results, and trends can clearly be seen when considering the lines of best fit. ANOVA could then be used to establish, or refute, the equality of the improvement in the examination results of the groups in the experiment.

Before any linear regression is performed, assumptions about the data must be examined. According to Tabachnick et al (2001) et al, Osborne et al (2002) and Johnson et al (2007), there are several assumptions that must be checked before the use of linear regression can be considered valid. Linear regression is used to make quite a good estimate of outcome based on the starting point, Kinnear et al (1999). The linear regression would give a numerical estimation of the results of the internal examinations given the KS2 SATs and entrance test results as the baseline. It was noted that according to Fitz-Gibbon results can be seen as educationally significant despite not being statistically significant and that statistical significance relies too heavily on sample size where a small sample size can skew the results. It was also noted that a linear regression does not imply any causal connection between the relationships, Tabachnick et al (2001).

Finally examples of large scale studies performed by other researchers were discussed. These focused on environment, communication and memory and demonstrated that these elements have been shown to improve academic attainment. These elements have, in the literature review chapter, been linked to the accelerated learning pedagogy to be used in the experiment. Hence if the statistical analysis shows that pupils in the experiment have made improved attainment, it could reasonably be concluded that this was due to the teaching pedagogy.

We have identified the low attainers who are the subjects of the experiment, the teaching pedagogy to be used and how to measure any potential improved attainment. Next we will see how these were used in practice in the case study chapter.

Chapter 5 The Case Studies

5.1 Chapter Introduction

We have read a narrative description of the pilot study in the pilot study chapter and seen statistical evidence that the low attainers in the experimental group did improve their academic attainment..

In the literature review chapter accelerated learning and CAME were shown to be suitable teaching pedagogies to be used to address the causes of low attainment. They are underpinned by key theoretical principles and validated with practical intervention strategies. From this three important elements; environment, communication and memory, were identified.

A more robust, academic framework was to be used for the case studies and with this in mind the experiment was shown to be valid with respect to Campbell and Stanley's internal and external threats, as described in the methodology chapter. The adopted definition for low attainers as per the literature review chapter was used and in order to measure value added attainment, the standardised summative assessment (SATs) was selected as the most appropriate starting attainment benchmark.

The above detailed the parameters under which the case studies were conducted and in the methodology chapter we saw that a mixed methods approach is to be used in the case studies. Hence the case studies will be described in detail firstly using ethnographical narrative and archival analysis under the headings of the 3 important elements of communication, environment and memory. The statistical analysis of the quantative data will follow this detailing the mean and standard deviation, scatter graphs of the KS2 SATs results plotted against the pupil's internal examination results, ANOVA is performed to establish or refute the equality of the improvement of the examination results of the groups and finally a linear regression is performed.

5.2 The Ethnographic Study

To set the scene I would remind the reader that both case study 1 and case study 2 were conducted at an independent school in County Durham. There were approximately 650 pupils in Y7 – Y11 plus a sixth form and a preparatory school. Case study 1 started in the autumn term of 2005 and finished in the summer term 2006.

There was one experimental group and one control group in case study 1 with 14 pupils in the experimental group and 16 pupils in the control group. Each group had one teacher and no classroom assistant. The experimental group was set 4 of 4 and the control group was set 2 of 4 .

Case study 2 started in the summer of 2006 and ended at Christmas that year. It was instigated not only to assess the replicability of the experiment but also to address the question of whether it was the teacher or the intervention that produced the results. There were two experimental groups and one control group. Experimental group 1 had 9 pupils in and was set 4 of 4, experimental group 2 had 16 pupils and was set 3 of 4 and the control group had 14 pupils and was set 2 of 4. From the adopted definition of low attainers, all pupils in experimental group 1, some of experimental group 2, and none of the control group were classed as low attainers. All sets had different teachers with no classroom assistant.

There were five 40-minute lessons and, as in the pilot study, 5 – 10 minute starter followed by a main part of the lesson and a 5-minute plenary. The main lesson consisted of 2 – 3 activities and accelerated learning pedagogy was used in nearly every lesson throughout the year.

In this section we must also take into consideration the key theoretical principles and practical intervention strategies identified in the literature review. For example when we consider communication in the classroom, it has been suggested in the literature review that the teacher should facilitate listener and message oriented speech (Brown, 1982). Pupils need to become more confident in this type of speech that enables them to effectively communicate with others. This can lead to difficulties as many teachers do not see the benefit of discussion in mathematics or even that discussion could possibly take place (Pimm, 1987). However Hiebert et al (1996), state that through peer explanation pupils develop understanding leading to greater retention, competence and more rapid progress through topics.

Now I will describe the case studies in detail by using ethnographical narrative, identifying the key theoretical principles and practical intervention strategies relevant to the vignettes. These principles and strategies have been shown in the literature review to address the causes of low attainment in mathematics.

The narratives are presented under the headings of the previously identified important elements of the interventions namely environment, communication and memory.

5.2.1 Environment

Johnson et al (1996) advocate a neutral arena in which learning can be facilitated, one in which pupils feel safe and secure. We have previously seen that the environment plays an important part in the accelerated learning life cycle and with this in mind the following sections demonstrate how this was achieved in the case studies with respect to both the internal and external environments.

5.2.1.1 Internal environment

Creating a safe environment

Creating a safe environment is a very important aspect of accelerated learning and so when introducing a subject I would use the small whiteboards (Watson et al 2003), for pupils to write their answers on. I would ask all pupils to hold up their answers, asking only the ones who had the correct answer to shout it out. If a pupil was particularly weak I would wait until they had the correct answer to a question and then deliberately choose them. This is using formative assessment (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al 2010) as a practical intervention strategy. At first pupils were reluctant to do this as they had been told many times that they could not do mathematics. Once they felt comfortable in the classroom they were happy with this method. (Supportive environment; Papert, 1980; Mounoud, 1981; Johnson et al, 1996; Boaler et al, 2010).

Case study 1

An example of this would be when the pupils were studying substitution. The white boards were used extensively, whole lessons being taught in the manner. When they had ‘succeeded’ enough times they sometimes, not always, did an exercise in their books. The fact that they do not have a record in their exercise books of the incorrect answers could be viewed as not re-enforcing the wrong answers, i.e. if a pupil sees the incorrect answers repeatedly they ‘picture’ this in their minds. Then they recall these incorrect answers. In order to partly address this posters, as described below, were placed around the classroom in order that the pupils picture correct facts and answers in order to address the key theoretical principle of poor memory (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000).

When the pupils studied a new topic they would often be asked to produce a poster about some aspect. These were very simple posters, for example if they had just studied algebra they might produce a poster to say ‘touching means times’, i.e. 3A means 3 X A as there is no sign between the 3 and the A they are touching. Another poster could say ‘If A = 5 then 3A = 3 X 5’. These were displayed around the classroom and the pupils could refer to them during the lesson as with the starter questions.

When these were taken down for formal examinations the pupils would still look for them in the place that they used to be visualising the information and using it to answer questions. In the learning life cycle this would be the reinforcing of knowledge and were used to address the key theoretical principle of low attainers having immature strategies for memorisation (Wood, 1991). It appeared to work as when invigilating the mathematics examinations I could see pupils looking at the walls where the posters used to be.

Case study 2

A safe environment was created in this case study in the first instance again by the use of small white boards. As in case study 1, I asked the pupils to write their answers on the boards, asking only the ones who had the correct answers to explain to the rest of the group how they had arrived at their answer. Within the first two weeks the pupils became confident with the use of the white boards often asking if they could use them to write their answers down for the starter questions.

Again here we can see that the practical intervention strategies of a supportive environment (Papert, 1980; Mounoud, 1981; Johnson et al, 1996; Boaler et al, 2010), the use of small white boards (Watson et al, 2003) and formative assessment (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al 2010) were all used.

Fear of failure

Case study 1

Haylock (1991) suggests that one of the common stumbling blocks to learning is fear of failure. With this in mind the lessons were often started with 5 – 10 questions. These were answered in the back of the pupils' exercise books and at first came from myself taking random topics from KS2. Later I would choose a pupil who would then choose a page from the textbook at random. I would then ask a question from this page. The class would then answer either in the back of their exercise books or on the small white boards (Watson et al, 2003). Then the next pupil would choose a page. Later in the year the pupils started to choose pages that they enjoyed the topics from, often choosing the same page as another pupil in order to get another question on the same topic. This obviously worked in reverse if they choose a topic that they did not like. Mainly all pupils found the same topics easy or difficult. On occasions I would choose a topic with which I knew a particular pupil excelled in, in order to give that pupil a confidence boost.

At first the pupils thought that it was important to get 5 out of 5 or 10 out of 10 as they saw these questions as the ‘mental test’ which is part of the KS2 SATs they had just taken. Even though I explained that I did not want to take in the marks they got for these tests, they were very suspicious. After the first month they realised that I really did not want to record their results although I did walk around the classroom noting which pupils had problems with which topics. Hence this could be classed as formative assessment (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al 2010). The pupils’ answers were used to feed back into the teaching and learning.

Changing the negative to the positive / confidence

There are several pupils in the case studies that have been repeatedly told that they ‘Will never achieve’ or that they ‘Will never be able to do maths’. This causes a problem because as soon as you introduce a topic they automatically say ‘I can’t do that’. It is almost a habit that they cannot get out of and, according to Haylock (1991), a cause of low attainment. I have tried several approaches in an attempt to change this negative perception.

Case study 1

One was just to mark in red pen so that it could be easily seen, only correct answers. The incorrect ones were left and the pupil asked how they got this answer. After they had explained they would look at these answers again to see if they could get the correct answer. Often by explaining they realised their mistake whilst talking to either me or another pupil. Here peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010) and scaffolding to the correct answer (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010) were facilitated.

Case study 2

This was mainly addressed in the same way as in the previous case studies by building the pupil's confidence. This was achieved in several ways; by choosing the pupils who had the correct answer to explain their method (Different ways to solve a problem; Watson et al, 1998), by marking in red pen all of the correct answers and by putting pupils into groups (Haylock, 1991; Watson et al, 2003; Boaler et al, 2010) where the group would answer. In this case the groups were contrived to contain pupils who could work well together. This is an example of successful outcomes as advocated by Shayer et al (2007).

Teachers being able to take different routes as and when needed

When teaching the puppy's playpen investigation the pupils came up with the idea of square numbers. This was not scheduled on the syllabus to be taught at this time, but it was an obvious point at which to talk about this topic. The pupils had noticed that they needed to use the same number times by itself in order to obtain the largest area. They could see a pattern but did not know that these numbers produced were square numbers. In theory they did not need to know that these were ‘special’ numbers as it would not have made their investigation any easier but they would need to use square numbers in the future.

However they had discovered these numbers and could see that there was something special about them so now was the appropriate time to talk about them and so we did allowing the pupils to assimilated and accommodated (Wadsworth, 1971) the new knowledge.

Square numbers are only a level 4 topic and as such a teachers’ knowledge would not be stretched however when a teacher is teaching higher level topics, this may not always be so straight forward for the teacher. With teaching using accelerated learning pedagogies the teacher has to be both willing and able to go down different routes of investigation knowing that this will lead to the use of topics that have not necessarily previously been the prime topic of study. However as accelerated learning uses investigation techniques, many topics were used in order to construct the knowledge (Crowther, 1995) needed to address one investigation. Scaffolding (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010), was a way to allow the pupils to jump from one of these topics to another in order to obtain a fuller understanding of the problem. They need to be comfortable with the idea that an individual pupil or group of pupils may think outside the box to the extent that they are actually going on to other topics which may not have been taught in the conventional way yet.

This also leads on to the problem of when should topics be taught, i.e. when they occur in the numeracy framework or when there is the need for them in order to solve a problem despite the topic not being on the syllabus for that term or in fact, on some occasions, that academic year.

When to teach topics

Case study 1

So the timing of topics can be seen as a problem not only for the pupils but also for teachers. This happened in one lesson on estimation. The pupils were trying to estimate distances and decided to measure how long one metre was by putting a metre ruler on the floor and then taking a 'big' step. This step could then be used to pace out distances. This is an example of the practical intervention strategy of active learning (Bonwell et al, 1991). This worked well until I asked how far away the chapel was. They could not pace this out so they had to break the distance down by estimating how far to the school entrance, then across the river finally onto the chapel. This put the problem in context (Dowker, 2000; Watson et al, 2003) and the pupils decided on a suitable distance. However one pupil asked 'but how would we estimate the distance to the moon'. Each pupil had a guess but eventually we had to look it up on the Internet. It was 384403000 metres and this led onto a discussion about very large numbers and consequently standard form.

The main problem of estimating distance was a real life problem (Haylock, 1991) and breaking the distances down had helped scaffold the pupils to a solution. The pupils had been eager to use their estimating skills but came unstuck on the distance to the moon however this was used as a teaching opportunity, even though the topic was not related to the main topic being taught. The pupils did not see any problem with the teacher not knowing how far away the moon was and happily found the information. Here the teachers had to be confident that this lack of knowledge would not be a problem in respect of their own confidence.

In this case I had decided to teach the topic as it was needed and not when it occurred in the framework. In this particular problem the topics needed were used in context, a practical intervention strategy suggested by Dowker (2000) and Watson et al (2003), that helped the pupils understand and visualise the results in a meaningful way. In the above vignette pupil – teacher discussion (Chin, 2006), is facilitated. This can be viewed as a form of scaffolding (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010) that allows students to improve their problem solving skills by making sense of new topics and experiences. Open-ended questions (Watson et al, 1998), which enable pupils to become more successful at higher order thinking skills, are also used.

Case study 2

In this case study I used the CAME unit two step relations. The unit starts by putting the learning in context (Dowker, 2000; Watson et al, 2003), and using a real life example (Haylock, 1991) by asking the pupils to calculate the actual number of leaves on a branch of a tree. Each branch has twigs on it and they always have 3 leaves. There are always 2 extra leaves at the bottom of each branch.

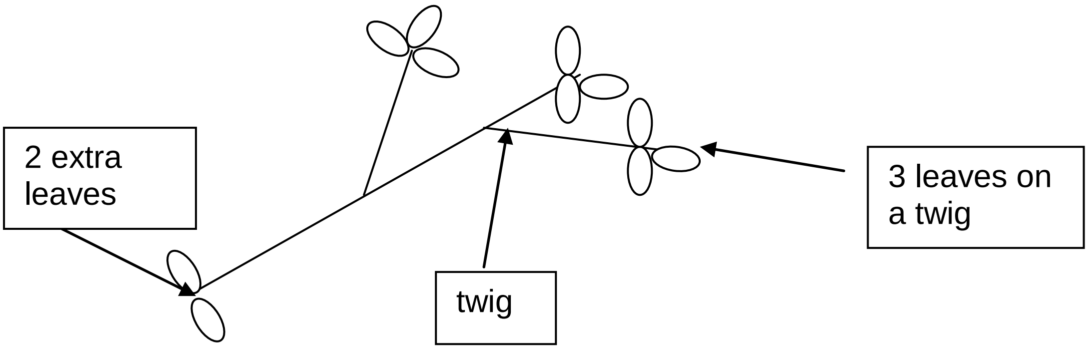


Figure 11 Two Step Relations 1.

The problem is to find out how many leaves on a branch with 5 twigs, remembering the 2 leaves at the bottom of the branch, then how many on a branch with 10 twigs etc. Eventually the pupils are asked to calculate the how many leaves on a branch with 100 twigs.

The pupils were working in groups of three or four and at first and started to count the leaves individually in order to perform the calculation. When they came to the 100 twig question some pupils in a group started to draw them. One of the other pupils said that they could not tell which was a leaf as there were so many. I asked them to explain to me how they could calculate the number of leaves on the 5 twig branch without drawing all of the leaves. They looked puzzled so I asked how many leaves on one twig. They all answered 3. So I asked how many on 2 twigs, again a unanimous 6. How did you work it out? By adding 3 and 3. I asked if they could do a different calculation to get the answer. One of the pupils said 2 lots of 3. So we can multiply? I asked. Yes. What about 5 then? 5 lots of 3 is 15 was the reply. What about the 2 at the bottom of the branch? That makes 17 one pupil said. So now we had a method of how to work out the 100 twigs. How are you going to do that? By

100 lots of 3 that's 300, plus the 2 at the bottom another pupil said. So that is 302.

The problem then goes on to ask the pupils to fill in the sentence;

The number of leaves = -------- times the number of twigs + -------

The pupils happily filled this in and then had to use

L = number of leaves, t = number of twigs.

They came up with;

L=3 x t + 2

Some pupils remembered from our algebra topic that 3 X t could be written without the x. So I explained that both L = 3t + 2 would be the best way of writing the answer as L = 3 x t + 2 you would need to remember BODMAS rules as the multiplication has to come before the addition. Here the pupil had used the BODMAS poster that had been put on the wall as a memory aide. The displaying of posters addresses, as we have seen, the key theoretical principles of poor memory (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000) and immature strategies for memorisation (Wood, 1991).

Now the pupils had to do the same for a series of tiles. For every 1 white tile you need 2 black tiles plus 1 black tile for the end of the pattern. The pupils had to calculate how many tiles would be needed for 2 white tiles then 3 white tiles then 20 white tiles ending with 100 white tiles.

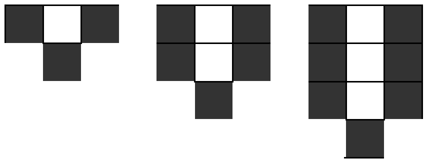


Figure 12 Two Step Relations 2.

The pupils realised that they needed to perform a similar calculation as before but add 1 on. They then had to write this algebraically as before they were given a sentence to fill in.

The number of black tiles = -------- x white tiles + ------

They were given b = the number of black tiles, w = the number of white tiles.

They quickly filled this in to be:

b = w x 2 + 1 again changing this to b = 2w + 1.

Now they were given graph charts to fill in for both of the equations and had to plot the graphs on the same axis. The pupils then looked at the graphs and the corresponding equations on the interactive whiteboard trying to find some connection. One pupil noticed that the graph of the twigs went up faster. I asked could we call this steeper. Yes. So we looked at the equation and they realised that the number in front of the letter was bigger in the twigs equation. I explained that this was the co-efficient and it tells us the gradient or steepness of the graph. Then we looked at where the graphs went through the y axis. The tiles graph goes through at 1 one pupil said and the twigs at 2. How does this relate to the equations? It's the bit at the end. That is called the constant because it never changes. We call it the point of intersection. Throughout the exercise the teacher scaffolds information (Cockcroft, 1982; Dowker, 2000;

Cohen et al, 2004; Boaler et al, 2010), in order to allow the pupils to access the new topics.

We then discussed how to work out the steepness by moving 1 unit in from the point of intersection and the co-efficient number of that graph units up. The pupils then sketched more graphs using point of intersection and gradients. This is again an example of teaching topics as they are needed and not as they occur in the national framework.

The practical intervention strategies used here were group work (Haylock, 1991; Watson et al, 2003; Boaler et al, 2010), collective reasoning (Wertsch, 1979), peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), message oriented speech (Brown, 1982), mediation (Vygotsky, 1978), actively engaged (Bruner, 1961) and talking for others (Pimm, 1987).

Formative assessment

Formative assessment is a practical intervention strategy suggested by Ginsberg (1977), Baker et al (2002), Watson et al (2003), Dowker (2004) and Boaler et al (2010) to address causes of low attainment and in the following vignettes we will see how this was facilitated in the case studies.

Case study 1

Often with accelerated learning pedagogies there is little recording in exercise books. This could be perceived as a problem as the pupils did not have lots of work to refer back to when it comes to revision or for assessment. The revision aspect is no real problem as there are many publications that have far better notes than these pupils would make but how would I assess the pupils' work? This had to be done on a continuous basis either by visual observation of the answers the pupil hold up on their whiteboard or by walking around the classroom noting what had been written down.

One pupil always had a problem with angles in a triangle when given one external angle and one internal one. She could not work out the two step procedure to firstly use the external angle to calculate the associated internal angle, then go on to use the two internal angles now known to calculate the third internal angle. I became aware of this in one lesson and hence observed her answers during the next three starters to the lessons. I choose the pupil to answer this question each time and to explain what steps she had completed to get to her answer. At one point the pupil sat next to her started pointing at the board and then down at her own whiteboard, explaining the steps she should have taken. Throughout the above example communication skills were used including working in pairs (Bonwell, 1991), peer provided scaffolding (Cohen et al, 2004), peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010) and message oriented speech (Brown, 1982).

However formative assessment can create a problem for the teacher who needs to make sure that they are aware of every pupil's cognitive development (Vygotsky, 1978; Piaget, 1991; Shayer et al, 2010) and ability to accommodate and assimilate new facts (Wadsworth, 1971). I approached this problem by marking with a coloured dot in my mark book, the pupils who were struggling with a certain topic. At the end of each chapter in the text book the pupils took a test. I reviewed all of the pupils' marks obviously noting any high flyers or pupils who did not do so well. I would then ask questions in the starter 5 – 10 questions which went over the topics that some pupils had struggled with. Again I would choose a pupil who I knew had had difficulty with a topic to answer the question on that topic.

One could argue that this is a way of producing Individual Education Plans where each individual pupil has an action plan specifically designed to build on their strengths and improve their weaknesses. It also addresses the key theoretical principle that low attainers have poor memory skills (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000) in that when 5 – 10 questions starters are used, topics are kept fresh in the pupils' memories.

When using formative assessment (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al, 2010), the teacher must provide a supportive environment (Papert, 1980; Mounoud, 1981; Boaler et al, 2010) where they can ascertain which of Piaget's development stage (1991) the pupils are at and use this to inform their teaching as discussed above.

Case study 2

As the pupils used the small white boards for the starter questions there was no recording of their achievement. This could be seen as a problem as the teacher needs to be very aware of what problem topics each individual pupil has. As low attainer classes are normally much smaller than the middle or top groups this is less of a problem and the teacher should not have any difficulty with this.

In case study 2 the pupils take short tests at the end of each topic and the results were recorded. These results were then used to decide which questions would be asked in the starter 10 questions. I would ask a particular pupil to answer a question that I knew they had struggled with in the test. This is an example of formative assessment feeding back into the teaching and learning within the accelerated learning pedagogy.

The key theoretical principles and practical intervention strategies as used in case study 1 were also facilitated here.

Reward system

The merit system also had an effect on the environment in that it created competition between the pupils as the merits counted not only towards their individual totals but also towards the house total for the term. It was noted that pupils in the boarding houses were especially keen to work for merits. This may have been due to the fact that they had a greater sense of identity with their houses as they were not able to talk about their achievement to other members of their family.

The system of getting 3 As at any point was also implemented in the case studies and the pupils seemed to work harder to get their third A in order to get their merit. The pupils who scored highest on a test or had the greatest improvement also gained a merit. I decided to not only make this for the highest score but also for the most improved result as this gave all of the pupils something to aim for.

5.2.1.2 External environment

There were also external environmental factors that influenced the achievements of the pupils. In the main these were due to parental influences.

Learnt behaviour from parents

Case study 1

As we have already seen pupils often learn fear of mathematics from their parents (Haylock, 1991). At parents evenings some parents confess that they could not do mathematics at school and that they were no good at it, especially algebra. This is then conveyed verbally or implicitly to the pupils and hence when it came to teach topics such as algebra I decided not to tell the pupils what topic we were starting. They had not come across algebra before, as it is not on the curriculum at KS2 and therefore did not recognise this topic as being algebra. From previous experience I have noted that the mere mention of algebra gets the automatic comment of ‘I can’t do that, it’s too hard’.

The teaching pedagogy here is one of efficiency, however I tell the pupils it is a lazy method, where I explain that mathematicians do not want to write more than they have to. For instance if I wanted to write the cost of 2 apples, I would just write 2A, where A is the cost of an apple. The pupils used the small whiteboards (Watson et al, 2003) to write down lazily (efficiently) the cost of 2 apples and 3 bananas, i.e. 2A + 3B. I asked why they had used the + sign. They responded that this is shorter than writing ‘and’ and it is also mathematics whereas ‘and’ is English. This was instinctive for them and led onto the substitution lessons. Here we can see an example of the socio- historical beliefs (Luria, 1976) being broken down and allowing pupils to suggest their opinions with pupils using message oriented speech (Brown, 1982).

The lessons progress to introduce substitution and was put in context (Dowker, 2000; Watson et al, 2003) by saying we are going to the shops to buying apples, bananas etc for say 10 pence each. So if we had 3 apples we would write 3A to represent the cost of the 3 apples. Then if an apple cost 10 pence the total cost would be 30 pence. The pupils often want to put the p for pence into the expression but again I explain that as we are working in pence there is no need to put pence and this would be more efficient. Again in English lessons they would not say that an item had a price tag of four pounds and fifty pence, they would merely say four pounds fifty. We then discussed the 3A = 30, i.e. 3 times the cost of an apple (A) costs (=) 30 pence. The pupils knew that the apples cost 10 pence each and looked for a connection between 3A, 30 and 10. They decided that 3 x 10 = 30 so 3A must mean 3 x A. Again I explained that through efficiency we could just write 3A and that if a letter and a number were touching, i.e. there is no mathematical symbol such as +, -, x, ÷ then it meant that they were multiplying each other. In order to address the key theoretical principle of poor memory (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000), and immature strategies for memorisation (Wood, 1991) the pupils made posters saying ‘Touching means Times’ as previously described.

The pupils then wrote sentences such as: there were some ducks on a pond. 3 more ducks joined them. How many ducks are on the pond now? They swapped these sentences with each other and wrote the ‘lazy’ version, i.e. D +

3 where D is the original number of ducks on the pond. Here the suggested practical intervention strategy of successful outcomes (Shayer et al, 2007), was facilitated and this initial success alleviated their sense of fear and failure with this topic. After about 2 weeks the pupils asked if this was algebra and could not understand what the problem was with this topic. I introduced other subtopic of algebra over the year but the lessons never started with ‘I can’t do algebra miss’.

In the above we can see that the practical intervention strategies of peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), using real life examples (Haylock, 1991) were facilitated. Wait and think time (Pimm, 1987; Cohen et al, 1996; Wellington et al, 2001) was also allowed in all of the lessons.

Linking the abstract with the concrete

Case study 1

As we have seen, pupils are more likely to understand a concept when they experience it for themselves or, in accelerated learning we must link the abstract to the concrete. This is a practical intervention strategy suggested by Dowker (2004). As we have seen in the pilot study, this happened in the best size desk CAME lesson when the pupils were discussing what type of desk they should have. One pupil suggested steel desks as no one could scratch their initials in it miss. This was a brilliant idea I suggested but they would cost too much. The pupil informed me that he had one at home and it was only £100. Here we can see again a problem being set in context with pupil participation (Dowker, 2000; Watson et al, 2003) using a real life example

(Haylock, 1991). I then asked much would it cost for the whole class? About £2000 was the reply. I realised the pupil had used estimating skills to come to this answer but I wanted them to explain to the rest of the class so I asked how they had arrived at this answer. I was told about 20 desks and about £100 each. 20 x 100 is 2 x 1 with 3 zeros, I was informed. Now I said that I wanted to know exactly how much for the desks in our classroom. The class then counted the number of desks and multiplied by 100. They then mentally did the multiplication and answered £2200 by multiplying the 22 x 1 and adding 2 zeros. So already the pupils had estimated and multiplied by 100.

At this point I gave out the small whiteboards and asked some multiplication questions such as 21 x 2,000, 340 x 1,000 up to 23,000 x 2,000,000. I choose numbers that would multiply easily as I was trying to get the pupils to understand multiplying by units of 10, not long multiplication. The pupils were very pleased that they could multiply by 2 million. This was primarily done to give pupils more confidence, a key theoretical principle suggested by Haylock (1991) to address causes of low attainment.

We did have a suggestion that we could have desks with beds on top so that I (and only me!) could stay later at school and on some nights need not go home at all. I did not pursue this idea!.

Case study 2

Both of the experiment groups did the puppy's playpen exercise at the same time. This helped the pupils to put the mathematics that they had learnt into context (Dowker, 2004; Watson et al, 2003), using real life situations (Haylock,

1991) hence linking the abstract with the concrete (Dowker, 2004). This exercise has been described extensively in case study 1.

We have previously seen that the key elements of environment, communication and memory are intertwined. Although the key theoretical principles and practical intervention strategies of communication can be seen in the vignettes above, the following vignettes have communication as their core element.

5.2.2 Communication

Case study 1

During lessons various questioning techniques were used. These included straight forward question and answer sessions as say in the plenary, single questions and answers to individual pupils or during group work I would ask for group answers.

At first closed questions were mainly used. This was primarily done with the help of the small white boards, a practical intervention strategy suggested by Watson et al (2003). I would often begin a lesson by asking short questions such as ‘What is the probability that you would get an even number when you roll a 6 sided die’. The pupils would put their hands up and I would choose someone to answer. They would usually answer with 3/6 or 3 out of 6. The pupils would than be asked to explain how they got their answer to the rest of the class, an example of peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010). They would say there are 3 even numbers out of six numbers all together. I would explain that in their examinations they would be expected to answer as a fraction and not 3 out of 6. This is an annotated answer in the SATs answer booklets provided by the DfEE that states that a mark cannot be given for 3 out of 6. I asked if anyone had a different answer. One pupil had thought the answer was 2/4 as they did not know that there were 3 even numbers. We then discussed what made a number even and decided that it was something that could be divided by 2. Another pupil had 1/2 as his answer. The pupils then had to decide if 3/6 and 1/2 were the same, or as I suggested, equivalent. I drew a pie shape on the board and divided one into 6 pieces and the other into 2 pieces. The pupil who had 1/2 as an answer coloured the 1/2 on one shape and a pupil who had 3/6 as her answer coloured 3/6 on the other shape. This was a real life example (Haylock, 1991) approach to the problem and the pupils could all see that these two fractions (pie slices) were indeed equivalent.

In the vignette above we can also see examples of practical intervention strategies such as message oriented speech (Brown, 1982), pupils to pupil discussion (Pimm, 1987; Dunn et al, 2010; Boaler et al, 2010) and collective reasoning (Bonwell et al, 1991) being used.

It could be said that this one question took too long when teachers are considering what they need to cover in the curriculum however, when the topic of equivalent fractions came up the pupils had already been introduced to it and thus saved time later.

As time went on, traditional closed questioning was used less as they do not encourage thinking skills (Cognitive constructivism; Cohen et al, 2004) and often the pupil can generate the correct answer without any real understanding of the topic, as in rote learning (Biggs, 1985; Dowker, 2000; Warburton, 2003). An example of open ended questions was when the topic of data handling was covered. The pupils already knew how to construct pictograms and bar charts and knew what a pie chart looked like. They now needed to understand which type of chart to draw in which circumstance and how to interpret the data displayed in these charts.

I asked a question for which I knew they would have to discuss, analyse and interpret the answer. Which month had the most days of sunshine and how many did it have? I then presented them with one pictogram, one bar chart and one pie chart. The pictogram had a sunshine picture = 2 days, the bar chart had days on the y axis in sections of 5 day multiples and the pie chart had no markings except for the names of the months. Here the learning has been put in context as suggested by Dowker (2000) and Watson et al (2003).

The pupils found the first part of the question easy to answer from all sources. They explained it is the one on the bar chart that is the highest, on the pictogram it goes out the furthest and on the pie chart it has the biggest bit.

When it came to the exact number of days the pupils found this far harder. They drew lines across the bar chart to see where this came to on the y axis. The line crossed above the 15 but before the 20. One pupil then put a line half way between the 15 and 20 but could not then decide what number this should be. The pupil sitting next to them suggested that as there were 5 numbers apart they should put the other numbers in at equal intervals. They both did this and came up with the answer of 17 (Correctly) and example of the successful outcomes practical intervention strategy (Shayer et al, 2007). They came to the front of the class and explained to the other pupils how they had decided on their answers. Again here we have an example of peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010).

They then went on to the pictogram. Most pupils stayed seated and chanted in twos to get the answer. I asked what they were going to do with the half sun and they explained that this meant that there was another one to add on, giving 17 as the answer.

The pie chart posed much more of a problem. The pupils tried dividing it into sections. They ‘cut’ it into 2 then 4. They knew that there was a total of 100 days sunshine throughout the year and came up with the idea that each of the 4 sections must represent 25 days as they had halved the 100 and then halved it again, just as they had halved the pie chart then halved it again, but could go no further.

A number of pupils explained why the pie chart was not as suitable as either the bar chart or the pictogram for this particular problem with the information that they had been given. They focused on the fact that you could see easily which month had the most sunshine and explained that the pictogram was easiest for counting how many days of sunshine rather than the bar chart. I asked if the sections on the y axis of the bar chart had been marked differently and the pictogram symbols represented say 3 days of sunshine, would they have found the bar chart best. They unanimously said no. This may have been due to the fact that they could not picture the graphs with the new axes / or representations.

Again wait or thinking time (Pimm, 1987; Cohen et al, 1996; Wellington et al 2001) was allowed in order that the pupil had enough time to order and manipulate the information. The group and peer discussion as advocated by Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010, appeared to improve the pupil to teacher communication (Chin 2006) as the pupils actually discussed their answers with me more as time went on. This could be seen as the negation of Luria's (1976) key theoretical principle of socio-historical development described in the literature review. This discussion time also allowed the pupils time for assimilation and accommodation of information (Wadsworth 1971), as they did not have the pressure on them to answer quickly in front of the whole class.

Above we can also see the key theoretical principles and practical intervention strategies of co-operating with peers (Vygotsky, 1987), discussion (Pimm, 1987; Dowker, 2000; Chin, 2006; Shayer et al, 2007; Boaler et al, 2010), using every day examples (Haylock, 1991) and collaborative learning (Shayer et al, 2010).

The main game that we frequently played was when a pupil comes to the whiteboard at the front of the classroom. They turn their back to the board and a name of either a person or a mathematics term is written above their head. They are then given 20 questions to ask the other pupils who can only answer yes or no. Here the pupils need to use their cognitive skills and thinking patterns (Vygotsky, 1978) in order to form their question and interpret the answer in order to decide upon the next question.

We have also played a version of taboo, see http://en.wikipedia.org/wiki/Taboo_(game), where the pupil at the front are given an object or phrase to communicate to the other pupils. They are not allowed to say the word (if they have been given a single word to communicate) or use any of the words in the phrase they are trying to communicate. They are given a time frame in which the other pupils have to guess the object, word or phrase. An example of this was when a pupil was given the phrase 180 degrees in a triangle. They actually said ‘Darts score’ and demonstrated the action of throwing a dart, followed by ‘Dairy Lea cheese shape’. This could be seen as strange as dairy lea cheese is actually a sector of a circle and does not have three straight sides so obviously does not have angles that add up to 180 degrees. I challenged this afterwards asking what shape a piece of dairy lea cheese is. The unanimous answer was a triangle. This was peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010) and the other pupils instinctively ‘knew’ that the dairy lee shape was a triangle. This maybe because they do not know what a sector is and the shape is closest to a triangle. Here it is the pupils who have used real life examples (Haylock, 1991), put the maths in context (Dowker, 2000; Watson et al, 2003) and used their prior experience (Driver et al, 1986) in order to solve the problem.

Case study 2

In the autumn term of this case study several questioning techniques were used including questions requiring a response from a single pupil and questions requiring a group answer. Both open and closed questions were, as in case study 1, used throughout the term.

Again the term started with the use of closed questions in the starters. This included such things as ‘How many degrees are there in a triangle?’ or ‘If I put a chicken in the oven at 3.30pm and left it to cook for 75 minutes, when should I take if out, on the 24 hour clock?’. We then discussed the answers. Sometimes there were several different ways of getting the answer (Watson et al, 1998) and each pupil was encouraged to come to the front of the classroom and show in any way they could, how they arrived at their answer. An example of this was when I asked the oven question above. One pupil split the minutes into 1 hour and 15 minutes then put the two times underneath each other rather like an addition sum.

$$\begin{array}{r} 3.30 \\ \underline{1.15} \\ 4.45 \end{array}$$

The pupil then explained how you add on 12 to the hours to use the 24 hour clock giving 16.45 as an answer.

Another pupil explained how when he needed to use the 24 hour clock and hence add on 12 hours, he always added on the 10 to get 14 in the hours column then add another 2 on to get 16.

In order to encourage verbal skills I also asked the pupils to sit in twos back to back. One pupil draws a shape on their white board and then described this shape to the other pupil who then tries to draw the shape from the description. This is an example of working in pairs as advocated by Bonwell (1991) as a practical intervention strategy to address the causes of low attainment. The pupil describing the shape needed to be very precise in their instructions and many weird and wonderful shapes were produced. The pupils then changed around and the person who was drawing now gave the instructions. The results made the pupils think very clearly of the properties of the shape they were describing and how to be exact in their instructions of how big or how many degrees to use in the shapes. Here pupils were co-operating with their peers (Vygotsky, 1978), using message oriented speech (Brown, 1982) and were actively engaged (Bruner, 1961).

5.2.2.1 Peer explanations

Again in this case study I wanted to test Hiebert et al (1996) theory that pupils retain and are more competent in topics which they have explained to others in their group. Hence I would ask a question. The pupils would answer on their whiteboards (Watson et al, 2003). If there was an incorrect answer I would ask 2 pupils either sitting next to each other or sometimes sitting across the room, to compare their answers and explain to each other how they arrived at their solution. This teaching pedagogy can also provide formative assessment (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al, 2010) to inform teaching and learning.

Group work (Haylock, 1991; Watson et al, 2003; Boaler et al 2010) was another practical intervention strategy that was facilitated and the following describes a lesson in which the pupils worked in groups.

Case study 1

In this lesson the pupils are set the task of designing a dog run for my son's new Dalmatian puppy, one of the Gatsby teacher fellowship units that I had developed. I put a photo of the puppy on the board as we have seen that connecting the learning to real life is a practical intervention strategy suggested by Haylock (1991). They have say 16 m of mesh fencing and have to design the largest run possible with that amount of fencing, i.e. the largest area. They were put into groups of 4 and asked to nominate a spokesperson. Although the spokesperson will give an explanation of the results the other groups can question any of their group on any aspect hence all of the group need to have a full understanding of exactly how the shape of the dog run has been decided upon. Here the intervention strategy of talking for others (Pimm, 1987) was facilitated and this can lead to successful outcomes as described by Shayer et al (2007).

The pupils were given small white boards as this makes it easier for them to rub out any mistakes. They would often jump in and draw any shape, quickly seeing that they had not used all of the fencing or too much fencing and the white boards made it easier for the pupils to remedy this by rubbing out their drawings and starting again. One pupil held up their white board and immediately put it down when another pupil commented that the puppy would be able to escape as the fencing did not go all of the way around the dog run.

This was another example of the pupils connecting the learning that is they had processed the maximum area problem with the fact that practically their solution would not work. They are also given ‘hint sheets’ that give the important steps including a table to be filled in. This formed the scaffold (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010) that the pupils needed at first. Once the majority of groups had finished their first task one group is asked to come to the front and present their results. I choose the group by walking around the classroom and asking open ended questions that I knew would be asked of them by other groups. This could be seen as formative assessment (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al, 2010). When I came across a group that I thought would be able to talk about how they got their results logically, I asked them to do so. Here the supportive environment (Papert, 1980; Mounoud, 1981; Boaler et al, 2010) needed to be in place in order that the pupils would feel confident enough to do so. The main objective at this stage was to be systematic with the results and to assimilate and accommodate them (Wadsworth, 1971). When they had presented their results, I gave a new problem.

You now have 25 m of fencing. The crib sheet I now gave out had fewer hints in it. The pupils started to work together in the groups, each taking one rectangle and working out the result. One pupil then put these results into a table. Again a group was selected who could give a good explanation of how they had got to their conclusion.

36m and 49 m lengths were then given, one after another. Eventually the pupils put their results together and realised that on the largest areas, the length and the width were the same. They then predicted the length, width and area of the playpen when they were given 64m of fencing. One group, when presenting their results at the front of the class came out with the idea of square numbers. They did not, or could not, justify their answers at this point. This however, brought up the problem of when does the teacher teach topics, as and when they are required, or when the framework suggests. But as we have seen in the previous section, topics should usually be taught as and when they are brought up by the pupils.

We can see from the above vignette that pupils to pupil to pupil discussion (Pimm, 1987; Dunn et al, 2010; Boaler et al, 2010), peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), Collaborative learning (Shayer et al, 2010), and the construction of knowledge (Crowther, 1995) are key theoretical principles and practical intervention strategies that can be facilitated in the classroom.

Case study 2

When the Taboo game, as previously described above, was played in case study 2 the pupil was again given the word triangle. The 5 words that they could not use when describing the word were angle, straight lines, 3, right-angled, pyramid. Strangely as in case study 1 the pupil used the dairy lee cheese shape to describe a triangle. Infact I was often surprised at the words pupils used to describe different objects / phrases which reinforced the idea that teachers have very different thought patterns to pupils.

This lead me to believe that on occasions peer to peer explanations (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), and peer provided scaffolding (Cohen et al, 2004) could be more beneficial than my explanations and this strategy was incorporated into my teaching pedagogy.

5.2.2.2 Questioning techniques / peer help.

This was used extensively throughout the 2 years that I conducted this experiment. The basic premise is: although I am interested in what your answer is, I am more interested in how you got it. Here I was addressing, amongst others, the key theoretical principle of cognitive skills and thinking patterns (Vygotsky, 1978).

Case study 1

It took about 1 month before the pupils actually believed that I really was only interested in the process and not the answer and were reluctant to answer questions to the group. The fostering of the safe environment (Papert, 1980; Mounoud, 1981; Johnson et al, 1996; Boaler et al 2010) as described above made this possible. Now that the pupils did not have any problem with answering either to the whole class or to the group in which they are working. They now actually want to come to the front and write their answers on the board. If they are incorrect they do not have a problem with being told so. It is rare that I have to do this as the other pupils usually do so. The pupils seem to see this rather as an adult would see constructive criticism, i.e. as a learning tool. They know that it is the process and method that is important. An example would be when one pupil said to another ‘No you don’t do it like that, watch me’. They would then demonstrate their new knowledge using message oriented speech (Brown, 1982). An example of this was when the pupils were learning to multiply by 11. The question was to multiply 6743 by 11. They had previously learned that to multiply by 10 you just add a zero onto the end of the number. One pupil came out to the main white board at the front of the classroom and wrote:

```
     6 7 4 3
       X 1 1
    --------
   6 7 4 3 0
   6 7 4 3
-----------
 1 3 4 8 6 0
```

Figure 13 Place Values 1.

This pupil had connected their prior learning of X by 10 (but had forgotten about place values, i.e. the second 3 should have been in the units column. Here we can see that the pupil had locate the appropriate arithmetical principle (Dowker et al, 2000) they need in their memory for the multiplication by 10 but had not applied the place value principle correctly. A second pupil then took over, writing hundreds, tens and units underneath the columns, explaining as they did so that you cannot move a unit into the tens and leave a gap with nothing in it.

```
    6 7 4 3
    X   1 1
   --------
  6 7 4 3 0
    6 7 4 3
-----------
  7 4 1 7 3

  T T H T U
  E H U E N
  N O N N I
  T U D S T
  H S R   S
  O A E
  U N D
  S D S
  A S
  N
  D
  S
```

Figure 14 Place Values 2.

This is an example where message oriented speech (Brown, 1982), peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), mediation (Vygotsky, 1987) are used within a supportive environment (Papert; 1980, Mounoud, 1981; Johnson et al, 1996; Boaler et al, 2010).

Case study 2

As in case study 1, peer explanations (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010) were used extensively throughout the term. This was mainly done on the small white boards, an intervention strategy suggested by Watson et al (2003), with pupils holding up their answers and then explaining how they arrived at them. An example of this was when the pupils were studying substitution. I would put an expression on the main white board with the values to be used for the letters. Pupils would do their working out on the small white boards in order that I could see how they had arrived at their answers. I would then ask them to hold up their white boards with the answers on. I would then choose a pupil and hold up their board for the rest of the class to see. (Assessment Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al 2010) I would then ask the pupil to explain how they had arrived at their answer. At first they would direct their explanation at me but with a little prompting, they started to look at the rest of the class and explain. I also encouraged them to answer questions that arose from the rest of the class about their answer. It only took about 4 or 5 lessons before the pupils were actually asking to explain their answers to the rest of the class.

Here we can see the practical intervention strategies of successful outcomes (Shayer et al, 2007), message oriented speech (Brown, 1982) being facilitated again within a supportive environment (Papert; 1980, Mounoud, 1981; Johnson et al, 1996; Boaler et al, 2010).

5.2.2.3 Leaders / spokesperson explanations

Case study 1

As in the pilot study, I introduced CAME lessons by asking how much time they spent in each lesson talking as individuals to me. Again their first reaction was similar to the pilot study pupils in that they said 35 minutes, the lessons being 40 minutes long. After much discussion it was decided that in reality it was more like 2 minutes. I then asked how long they talked to their friends during a day. They all said, all the time. So they said that they spend far more time talking to each other than they do to teachers. Also as in the pilot study, they also agreed that their friends understood almost everything they said and explained. In mathematics lessons, they agreed that they could explain things to each other and get their friends to understand. This is an example of co-operating with peers (Vygotsky, 1978), discussion (Pimm, 1987; Dowker, 2000; Chin, 2006; Shayer et al, 2007; Boaler et al, 2010) and talking for others (Pimm, 1987). The pupils then thought that this was a good idea and I used peer explanations (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010) in subsequent lessons.

The class was divided into groups and each group had to nominate a spokesperson for their CAME lessons. The group would work on their investigation as a whole, each pupil understanding all aspects of the work but the spokesperson was to present their findings. The other members of the group would also come to the front of the classroom for the presentation and members of the other groups could ask a question of them. Group work is a practical intervention strategy suggested by Haylock (1991), Watson et al (2003) and Boaler et al (2010).

These pedagogies gave the pupils some ownership of their lessons and helped to promote communication skills such as pupil to pupil discussion (Pimm, 1987; Dunn et al, 2010; Boaler et al, 2010) and, as we will see in the examples of actual CAME lessons given later in this section, peer provided scaffolding (Cohen et al, 2004) and successful outcomes (Shayer et al, 2007).

Case study 2

When using the CAME lessons in case study 2, each group elected a spokesperson to deliver their results as in case study 1. Again the groups would present their findings via the spokesperson but all pupils would be expected to explain the method and answer questions put forward by other groups. This is an example of successful outcomes (Shayer et al, 2007) being facilitated within the group presentations.

5.2.2.4 Communication and Lateral thinking puzzles

Case study 1

In case study 1 I also used communication and lateral thinking puzzles. They benefited the pupils by enhancing and encouraging listening and communication skills as described in the pilot study. The puzzles described in the pilot study were used but others described below were also used.

Examples of the communication and lateral thinking puzzles used in case study 1 were:

- 20 sick sheep in a field
- Twin brothers
- Black magic
- 2 brothers marry each other.
- Sums and Products

The first two of these are communication puzzles were primarily to enhance listening skills. They are;

“There are 20 sick sheep in a field” (the pupils hear 26 sheep). “2 of them die. How many are left?” Well obviously the answer is 18 if you have heard what was actually said but invariably as this is a mathematics lesson ‘20 sick’ commute to 26. This relates back to the algebra shorthand and how in English we say different things in mathematics, i.e. here the only possible thing to have heard is 26 as this is a mathematics lesson and we only deal with numbers. Here we can see that close attention has to be paid to what exactly is said however this also makes the pupils think of different ways in which the puzzle could be solved.

In twin brothers, one is 20 and the other is 20 too (the pupils hear 22). How is this possible? The pupils answer with such things as: they are twins born on different days (one a minute before midnight and one a minute after). They are twins to different mothers, etc. This is again a listening / communication skills puzzle and again is dependent on this being a mathematics lesson where we only deal with numbers. This could be seen as an example of dis-equilibrium (Piaget, 1991) where the expected answer, due to the fact that this is a mathematics lesson, is not the correct answer. Pupils now have to reassess their answer and think outside the box of the mathematics lesson.

Black magic is a puzzle where one person is sent outside the classroom whilst a pupil chooses one item within the classroom. The teacher, by telepathy I tell the pupils, has to send brain waves to the person who has been outside the classroom when the item was chosen, in order to tell that other person what the item was. I have agreed earlier with the pupil who was sent out of the room that I will chose something that is black in colour as the item prior to the one that the pupils has chosen. An example of one time this was used went something like this. A pupil was chosen to leave the classroom and another pupil then chose a pencil case as the item. The pupil re-entered the classroom. I asked if the item was a chair (which was grey). No was the reply. I asked if the item was the folder (which was yellow). No again. I asked if the item was a blazer (which was black). No again, but the pupil knew that this was the signal that the next item was the chosen one as the blazer was black. I then asked if the chosen item was a pencil case. Yes the pupil said.

Now this had been done in 4 guesses so the other pupils thought that I had arranged for the chosen item to be the fourth thing suggested. The pupil went outside again and another item was chosen. This time it took 7 suggestions before the correct one was identified.

The pupils thought that it was the way in which I said items, e.g. I would say 'Is it the …..' for items which were incorrect and 'Is it this' for the chosen item. Again the pupil was sent outside and another item was selected. I would say exactly the same thing each time to dispel the above reasoning.

Next the pupils thought that I hesitated just before the selected item. Another item would be selected and the process repeated with me saying 'Is it this' very to a rhythm.

One of the common answers is that the item chosen was the last one which I suggest, i.e. If the pupil has chosen a book, I would ask is it this pencil, No, Is it this chair, No, Is it this blazer, No Is it this book, Yes., i.e. the last item. The pupils could not reason that of course it had to be the last item otherwise the pupil choosing would not guess the correct item. In order to dismiss this I asked the pupil who went outside not to say which item it was until I had said all items. I would still choose a black item before the chosen item but would go on to say other items after. The pupil would not choose until the end of the list.

On one occasion a pupil chose a poster. I asked the pupil who was guessing it the item was: a pencil (red), a book (blue), a shoe (black), a poster (multi coloured), the whiteboard (white), or the door (green). He chose the poster as this came straight after the black shoe.

This happened over two weeks, the pupils guessing each lesson another strategy. They even ask other teachers if they can do black magic. The pupil who is sent outside has to keep the secret of how this is done and they always did. When the pupils said it was connected to a black item white magic is performed, changing the penultimate item to a white one, then green magic likewise.

One pupil eventually understood but would not tell the rest of the group. This seemed to give then a great sense of achievement, but they did finally tell the group how black magic was performed. This could seem like just a party trick however the pupils have to work out the relevant and linking facts in order to solve the puzzle. This addresses the key theoretical principle of working memory, the ability to manipulate several pieces of information at one time and find links between them that help to fit them together (Weinert et al, 1990). This, he says, can lead to increased understanding.

If we also analyse this vignette in terms of communication we can see that discussion (Pimm, 1987; Dowker, 2000; Chin, 2006; Shayer et al, 2007; Boaler et al, 2010), wait and think time (Pimm, 1987; Wellington et al, 2001) and assimilation and accommodation (Wadsworth, 1971) are facilitated. It also brings a slight role reversal in that the teacher is entering into the pupils' world of listener oriented speech and the pupils are using message oriented speech (Brown, 1982).

When 2 brothers marry each other the pupils do not understand how is this possible. Pupils ask if they are gay, or are they brothers to each other? The actual answer is that they are both priests and they officiate over the marriage ceremony for each other. In order to solve this puzzle the pupils need to understand themselves and be able to communicate in such a way that others understand their solutions and why they might think of that as a solution (Listener and message oriented speech; Brown, 1982). Eventually they and others analyse the incorrect solutions and the reasons why they are incorrect (Dis-equilibrium; Piaget, 1991, Assimilation and Accommodation; Wadsworth, 1971). They eventually agree on the correct solution and understand how this particular solution fits all of the criteria for being correct.

All of these were used either at the start or as the plenary to the lessons.

Case study 2

Many of the communication and lateral thinking puzzles used in both the pilot study and case study 1 were used with this group. The black magic puzzle again caused the pupils to listen and think very hard as to how this worked. Pupils came up with similar solutions as case study 1 pupils such as; you always say the 5th object, or it is the inflection in your voice, or it is the way you point at the object. The reaction to the two brothers marrying each other was also the same as in the previous case study.

As with case study 1 the practical intervention strategies of collective reasoning (Wertsch, 1979), real life examples (Haylock, 1991) and wait and think time (Pimm, 1987; Cohen et al, 1996; Wellington, 2001). Again we have seen examples of the key element of memory being used in the above vignettes however the following section describes scenarios where memory is the core element.

5.2.3 Memory

The SATs are summative assessments that are a mixture of questions that require analysis of some questions, as described previously, and some which require memory skills. In surface learning such as rote learning, pupils merely memorise answers to questions. Hence rote learning (Biggs, 1985; Dowker, 2000; Warburton, 2003), when used as a practical intervention strategy, can improve the academic attainment of low attainers. If we look at the analysis of the internal examination papers used in the case studies, in the methodology chapter, we can see that memory skills could have been used to answer between 20% and 35% of the questions.

I often use actions to reinforce facts and the darts player is a classic example of one that stuck in the pupils' memory. Here, by using the fact that the maximum dart score is 180 and the angles in a triangle add up to 180, we are connecting the learning with a real life example (Haylock, 1991). This could also be seen as memory techniques that use visual learning and action learning (Bonwell, 1991) in order for the pupil to commit the facts to memory.

In order to capitalise on the above I decided to employ a number of memory techniques throughout the case studies.

Memory games.

Case study 1 and 2

In order to improve the pupils' memory skills I started by putting 10 random objects on the board, gave the pupils 2 minutes to memorise them then taught the main lesson for about 30 minutes. At the end of the lesson the pupils would write down however many objects they could remember. I asked them how they did this. Some made up a story, some wrote the words down a number of times and some tried to link the objects in some way. With the latter in mind over the next few months I put groups of objects on the board. At first these groups were from any subject but I progressed to mathematical groups such as triangle, 3 sides, 180 degrees, straight line and so on. By the end of the autumn term most pupils could memorise all 15 objects and some could do this in order.

Story	Write down words	Link words
4	7	2

Table 22 Case Study 1. Pupils' Memorisation Techniques.

I also played the game 'on the way to market', the memory game of placing objects on a tray, and other games such as 'Simon says', http://en.wikipedia.org/wiki/Simon_says with the pupils as described in the pilot study chapter. These memory techniques were facilitated in order to address the key theoretical principles that low attainers have immature strategies for memorisation (Wood, 1991) and that they have poor memory skills (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker 2000).

5.2.3.1 Active Learning

Case study 1 and 2

It has also been stated in the literature review chapter that in order to address poor memory skills as a cause of low attainment (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000) active learning (Bruner, 1961) should be facilitated. Hence I put the following chart on the board. The pupils have to say the colour in which the word is written not what the word spells.

Green	Yellow	Black	Blue
Black	Green	Blue	Yellow
Yellow	Black	Blue	Green
Green	Blue	Yellow	Black

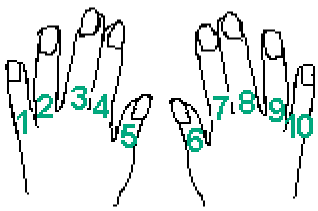
Figure 15 Colour v Word.

I choose pupils at random and timed them at the beginning of the lesson. We then did the main lesson and the pupils were timed at the end of the lesson. If a pupil made a mistake and did not realise they had a half second penalty for each occurrence. This meant that not only did the pupils have to time each other but had to work out how much was to be added on and do this calculation. This was done by writing the timings on the board for each individual pupil. Then as a group the pupils worked out how much should be added and did the calculations, discussing any different answers that they had and coming to a joint decision on the actual answer. In every case the pupils improved their timing. There was one occasion where one of the pupils was colour blind so I had to change the colours to accommodate this. The pupils not only benefited from the exercise but also from the group calculation work (Haylock, 1991; Watson et al, 2003; Boaler et al, 2010). This activity also facilitates the practical intervention strategies of discussion (Pimm, 1987; Dunn et al, 2010; Boaler et al, 2010), collective reasoning (Wertsch, 1979) and successful outcomes (Shayer et al, 2007).

When teaching the nine times table the pupils would hold up both hands with fingers outstretched, palms down, another example of active learning (Bonwell et al, 1991) to remember the 9 X table. For 1 x 9, the little finger on the left hand would be put down leaving 9 fingers representing the number 9. For 18, the ring finger on the left hand would be put down, giving one finger then a gap, then 8 fingersi.e.18 etc. See diagram below.

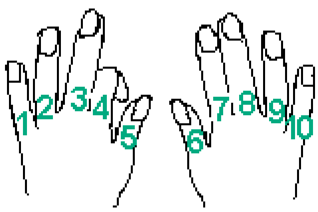
Use Your Fingers to Multiply by 9

1st: Number the digits of your hands from left to right.



2nd: Bend the finger named by the number you wish to multiply.

Example: Multiply 4 x 9. The forth finger must be bent.

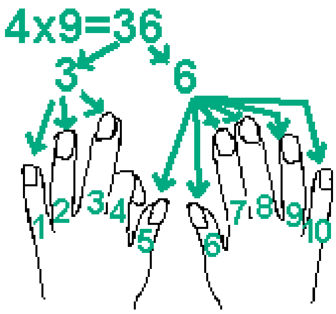


3rd: Count the digits to the left of the bent finger.

Count the digits to the right of the bent finger.

These are the digits of the product.

Example: 3 then 6, so, 4 x 9 = 36.



Source:

http://www.mathnstuff.com/math/spoken/here/2class/60/fingers.htm

Figure 16 9 Times Table. Fingers Method.

We have seen that accelerated learning allows for and encourages different ways to solve a problem (Watson et al, 1998), as seen in the literature review. In order to address this I used several approaches to teaching long multiplication. The first method could be seen as the traditional method of using columns.

	2	6	7
x		2	3
5	3	4	0
	8	0	1
6	1	4	1

Figure 17 Place Value 4.

I have also tried techniques such as Napier's bones and splitting the numbers into units of tens shown below in order to complete long multiplication questions.

200	**60**	**7**	**x**
4000	1200	140	**20**
600	180	21	**3**

Figure 18 Multiplication Table Method.

In both of these examples we can see that the pupils have located in their memory the appropriate arithmetical principle (Dowker et al, 2000), for multiplication however they have not remembered how to apply the place value principle correctly. The Napier's Bones method does 'force' the use of place value however approximately 90% of the pupils preferred the first method of aligning the numbers in columns saying that Napier's Bones had too many steps for them to remember.

Some pupils had difficulty when the topic of 'collecting like terms' was introduced so I would use one colour for each different letter. So

3A + 2B + 4A – 6B

becomes

3A + 2B + 4A – 6B

Figure 19 Collecting Like Terms. Colour Method.

Then the pupils would just have to collect the term of the same colour together. Here I was giving the pupils a strategy to remember how to collect like terms thus addressing the key theoretical principle that pupils have immature strategies for memorisation (Wood, 1991). When the pupils had to do an exercise on this topic some actually wrote the question down in different colours in the same way that I had and some wrote the questions out in pen but underlined the letters that were the same in the same colours. One problem with this that I had not foreseen was that the pupils did not also write or underline the sign that went with the letters. In one lesson a question was: 3A + 2B + 4A – 6B. When I walked around the classroom I noticed that there were 2 answers. One was 7A – 4B, the correct one, and the other, 7A + 8B. Here the pupils had not realised that the minus sign belonged to the 6B. So then I used

3A + 2B + 4A – 6B

Another harder question was 5A – 7C – 4A – 5C. Here the Cs start with a negative. One pupil who had the correct answer explained to the class that he had used his number line which all of the pupils have drawn in the back of their exercise books. He explained that they had to start at negative 7 and take off another 5, getting down to negative 12.

In this vignette we can see examples of practical intervention strategies such as peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), successful outcomes (Shayer et al, 2007), wait and think time (Pimm, 1987; Cohen et al, 1996; Wellington, 2001), different ways to solve a problem (Watson et al, 1998) and the use of message oriented speech (Brown, 1982). The active method worked for the pupils and again there was a poster produced which said that the sign went with the number after it to address the key theoretical principles of poor memory (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000).

5.3 Summary for the Ethnographic Study

In the vignettes above we have seen many examples of key theoretical principles and practical intervention strategies that address the causes of low attainment being facilitated in the classroom.

Of the two types of environment discussed, internal environment is seen as the most important as a teacher can change the concepts and prejudices of the external environment within the internal one. Teachers are encouraged to create a safe environment (Papert, 1980; Mounoud, 1981; Johnson et al, 1996; Boaler et al, 2010) in which pupils are able to 'go out on a limb' and explore safe in the knowledge that even if they fail they will have learnt something. The environment also gives an ideal arena for putting the mathematical topics into context (Dowker, 2004; Watson et al, 2003) using real life examples (Haylock, 1991).

Extensive use was made of both open and closed questioning techniques and as a result the socio-historical belief (Luria, 1976) that the teacher talks and pupils listen was negated to some degree. We must however bear in mind that closed questioning is normally more likely to be used due to time constraints of the curriculum. However in the case studies we can see that the use of both open ended and closed questioning techniques have been deployed and the use of open questioning allowed the pupils to improve their higher order thinking skills (Watson et al, 2003).

The order in which pupils are exposed to topics begs the question ‘Should we do topics in order according to the numeracy framework or as required’. Certainly from the evidence above we can conclude that there is a strong case for answering that we should teach topics as the need arises and not wait for the time that the numeracy framework suggests.

Recording of pupils’ understanding plays a large part of any teachers’ lives, sometimes to the detriment of their teaching, as it can be very time consuming. With the recording, or in fact lack of recording described above, the teacher can have a far better view of what each individual pupil has achieved and can tailor the pupils needs in a much more efficient manner. The vignettes provided many example of how formative assessment (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al, 2010) was used in an effective manner.

Parents who have had a negative experience during their schooling can pass this on to their children (Haylock, 1991) however we have seen in the vignettes that this negative influence can be overcome with pupils eventually becoming much more independent of their parents fears and insecurities.

Linking the abstract and the concrete (Dowker, 2000) can help some pupils visualise the problem and link the information that they need in order to solve the problem.

Within the communication section we can see examples in the vignettes of peer to peer explanation (Pimm, 1987; Baker et al, 2002; Dowker, 2004;

Boaler et al, 2010) and listener and message oriented speech (Brown, 1982) used in the classroom. The pupils no longer felt the need to say what they think I want them to say, rather they process information and find links between this information in order to reach their own answer or conclusion which leads to increased understanding (Weinert et al, 1990).

Pupil – teacher discussion (Chin, 2006) also took place, helping pupils scaffold (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010) to make sense of new topics and improve their problem solving skills. Pupils were at first reliant on the teacher to provide this scaffolding but through peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), started to provide this scaffolding themselves (Peer provided scaffolding; Cohen et al, 2004).

In the vignettes detailed above we can see that this had a direct effect on the pupils' understanding of the mathematics topic, not only for the pupil who was explaining, but also the pupil who was listening.

Communication is also very valuable when considering the interpretation of examination questions, especially the SATs. They do not, in general, ask straight forward things such as 'Use Pythagoras to solve the following'. Rather they would say ' a boat sailed 5 miles in a northerly direction the turned 90 degrees ……..'. This is reflected in some of the communication and logic problems such as the brothers and the sheep where the pupil has had to think outside the box and analyse the problem for the relevant facts. They then have to process these facts in order to solve the problem. Here we saw that communication in the lateral thinking puzzles facilitated the use of message oriented speech (Brown, 1982), assimilation and accommodation (Wadsworth, 1971) and helped pupils scaffold (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010) from one skill to another in order to solve subject specific problems.

In the memory section we have seen that both surface and deep learning styles' as described in the literature review chapter, have been used. Memory games were played in order to improve the pupils' memory skills, a cause of low attainment (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000). Memory was also seen to be important when pupils need to answer closed questions in their examinations. SATs type questions were used in the internal examinations at both Christmas and the end of the summer term and many of these questions are traditional summative closed assessments that promote memorisation by the students.

In the vignettes we have seen examples of many key theoretical principles and practical intervention strategies being facilitated in order to address the causes of low attainment in mathematics. In the following section the statistical analysis, based on the methodology previously described, is presented in order to determine any statistically significant improvement in the academic attainment of the low attainers.

5.4 Case studies Statistical Analysis

5.4.1 Introduction

The following will describe the statistical analysis performed on case study 1 and case study 2 and then move onto the detailed results of that analysis. In case study 1 there was one experimental group whose results were compared against the control group and in case study 2, two experimental groups were compared against a control group. In case study 1 the final attainment data of the Christmas 2005 and summer examination 2006 results were compared to KS2 SATs and entrance tests which were used as the starting attainment data. In case study 2 the Christmas 2006 results were compared to KS2 SATs and entrance tests as follows:

Case study 1 and 2 analysis.

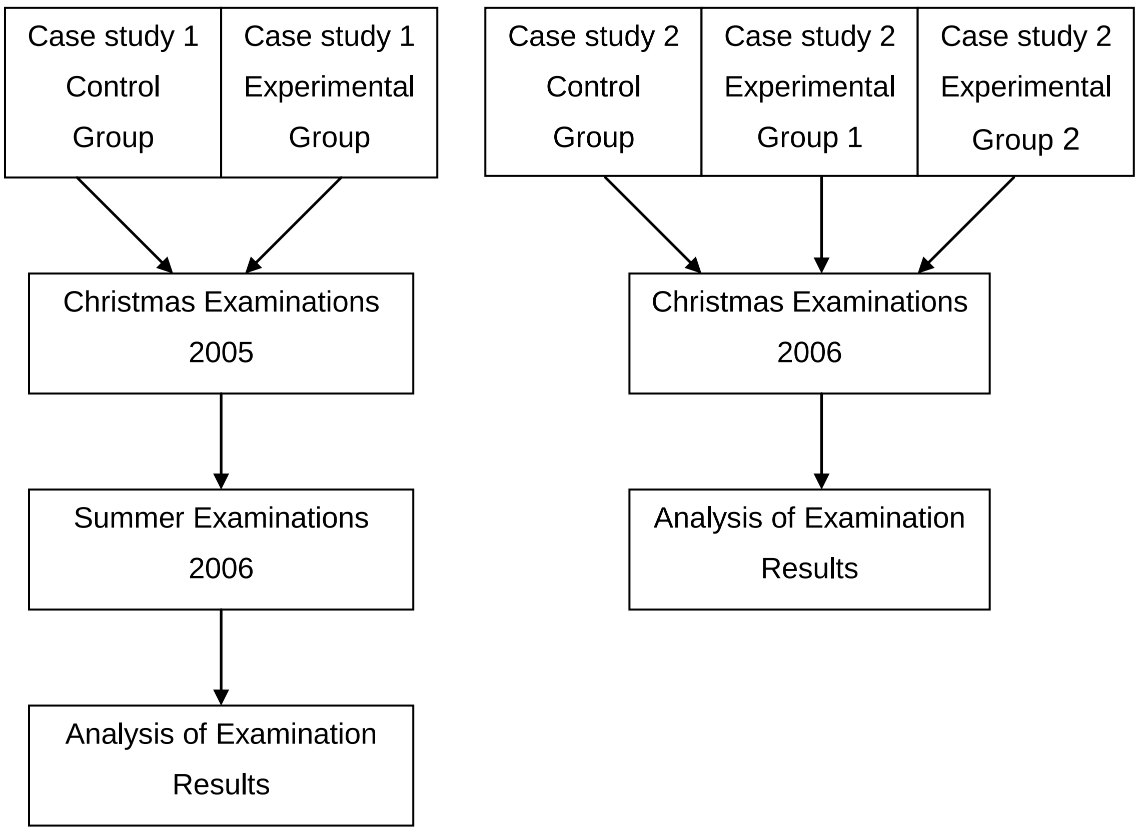


Figure 20 Case Studies 1 and 2 Statistical Analysis Diagram.

Before this analysis could be carried out the data had to be processed. This was done by using the statistical analysis package SPSS and Microsoft Excel.

The following show what groups was used in the case studies.

Case Study 1

Groups involved

- Experimental group
- Control group

Case study 2

Groups involved.

- Experimental group 1
- Experimental group 2
- Control group

In order to measure the spread of the data set the mean and standard deviation were calculated. If the standard deviation is low, the examination marks would mostly be close to the mean and if it was high then they would be over a large range. Scatter graphs will then be used to give the reader a pictorial view of the analysis followed by ANOVA and finally in both case studies a linear regression is shown. However as we have seen in the methodology chapter, there are 3 assumptions that are to be considered in order to support the validity of the linear regression results. These are:

- normality of residual errors

- linearity
- homoscedasticity

which are addressed in each case study.

The general formula used in the linear regression is shown below. How this was arrived at and this analysis technique in general is explained in detail in the methodology section.

$Y' = M_1$ x Starting attainment benchmark+ M_2 x group number + C

In the analysis for the case studies the:

Y' is the Christmas or summer examinations.

C value is shown as the constant (Regression constant)

M_1 is the multiplier for the Starting attainment benchmark examinations. (Regression co-efficient)

M_2 is the multiplier for the group number (2^{nd} regression co-efficient)

Hence the Predicted Christmas examination result (Y') = M_1 x (KS2 SATs or entrance test) + M_2 x group number constant (C)

Data used

In order to perform the data analysis the following data was collected.

Case study 1:

- School Entrance Test results
- KS2 SATs Results
- Christmas 2005 Internal Examination Results
- Summer 2006 Internal Examination Results

Case study 2:

- School Entrance Test results
- KS2 SATs Results
- Christmas 2006 Internal Examination Results

The KS2 SATs results and the school's entrance test results were then used as starting attainment baselines and compared against the Christmas 2005, Summer 2006 and Christmas 2006 internal examination results (final attainment).

Details of the makeup of all the groups in the case studies can be found in the methodology chapter, but essentially in case study 1 the experimental group consisted of 14 pupils and the control group had 16 pupils and in case study 2 one experimental group had 16, the other had 9 pupils and the control group had 14 pupils.

5.4.2 Case study 1 including outliers

5.4.3 Mean and standard deviation

The following analysis is for case study 1 and includes all pupils. Below is a table containing the mean and standard deviation for both the experimental and control groups for the entrance test, the KS2 SATs, the Christmas 2005 and Summer 2006 examinations.

	Entrance Test	KS2 SATs	Christmas 2005 Examination	Summer 2006 Examination
Mean				
Experimental Group	30	42	58	35
Control Group	52	72	72	60
Standard Deviation				
Experimental Group	11	10	14	12
Control Group	8	5	9	9

Table 23 Case Study 1. Mean and Standard Deviation. Christmas 2005 and Summer 2006 Examinations.

We can see from this table that the difference between the mean scores of the experimental and control groups was 22 in the entrance test and 30 in the KS2 SATs. As the groups were not parallel sets this is not surprising. By the Christmas 2005 examination this difference has become 14 and in the summer of 2006 examinations 25.

Thus we can see that the mean did vary between the experimental group and the control group in all baselines. However we can see that the experimental group had a wider dispersion of marks in the entrance test and this remained the case in the Christmas 2005 and summer 2006 1 standard deviation range.

The standard deviation is much larger for the experimental group than the control group in all test and examinations, the Christmas 2005 examination showing the largest standard deviation. This is due to the outliers, as we will see later. The standard deviations are shown in the chart below.

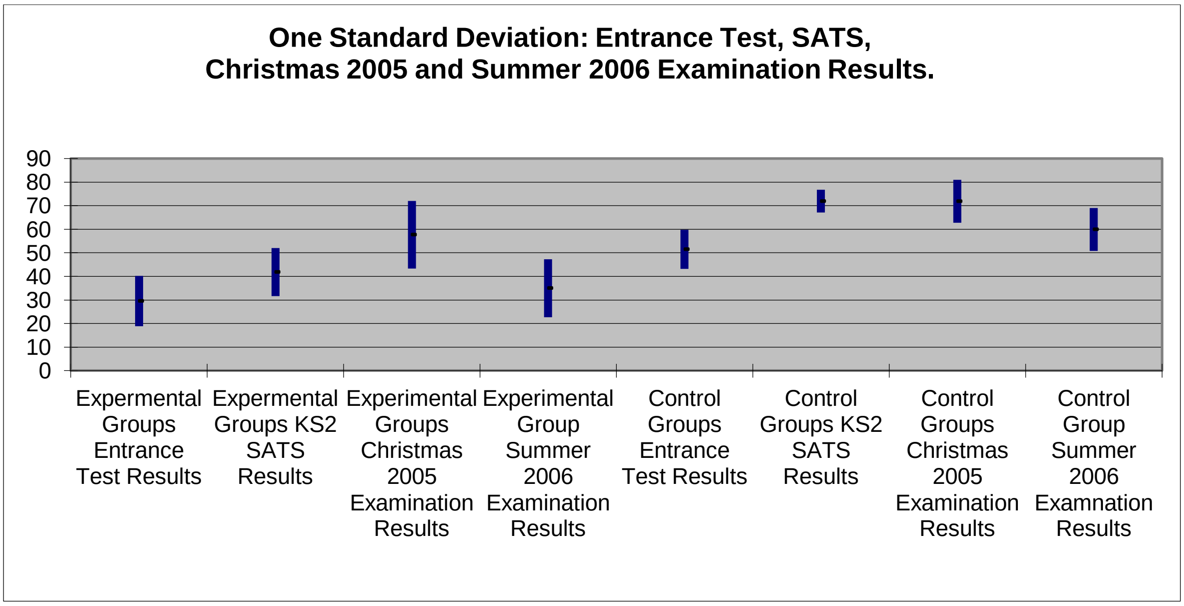


Figure 21 Case Study 1. One Standard Deviation. Christmas 2005 and Summer 2006 Examinations.

5.4.4 Scatter graph

When we look at the KS2 SATs v the Christmas examinations on the scatter graph below it is clear that there was an improvement in the experimental groups' attainment when compared with the control groups. It should be noted here that the experimental groups' data does not contain the outliers, as there was no data for their KS2 SATs results.

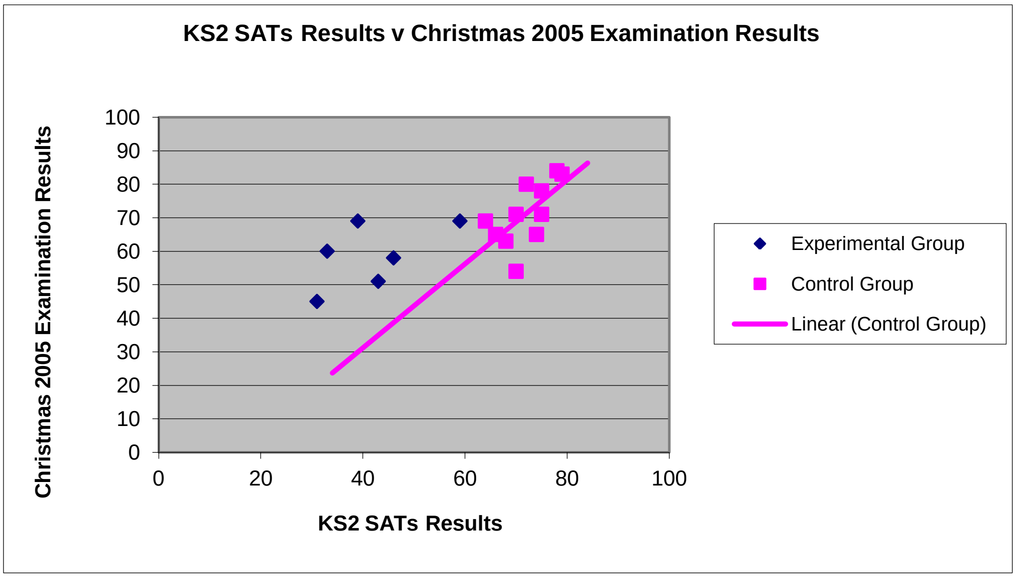


Figure 22 Case Study 1. Scatter Graph. KS2 SATs v Christmas 2005 Examination Excluding Outliers.

The same is true for the KS2 SATs v the summer 2006 examinations shown below where again there were no KS2 SATs results for the outliers. A clear improvement can be seen when the control groups' linear regression line is used.

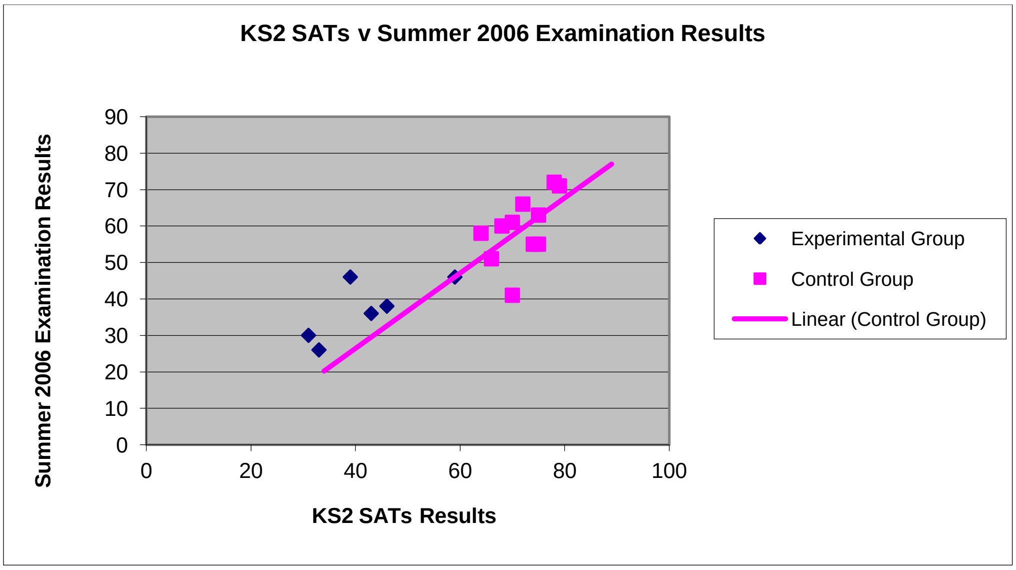


Figure 23 Case Study 1. Scatter Graph. KS2 SATs v Summer 2006 Examination excluding Outliers.

We have seen above the mean and standard deviation results for case study 1, however in the experimental group two pupils were identified as outliers and can be seen clearly on the first scatter graph below which shows the Christmas 2005 examinations against the entrance test. It is difficult to tell if there has been an improvement in the experimental groups' attainment here and we must look at the linear regression section in order to clarify this.

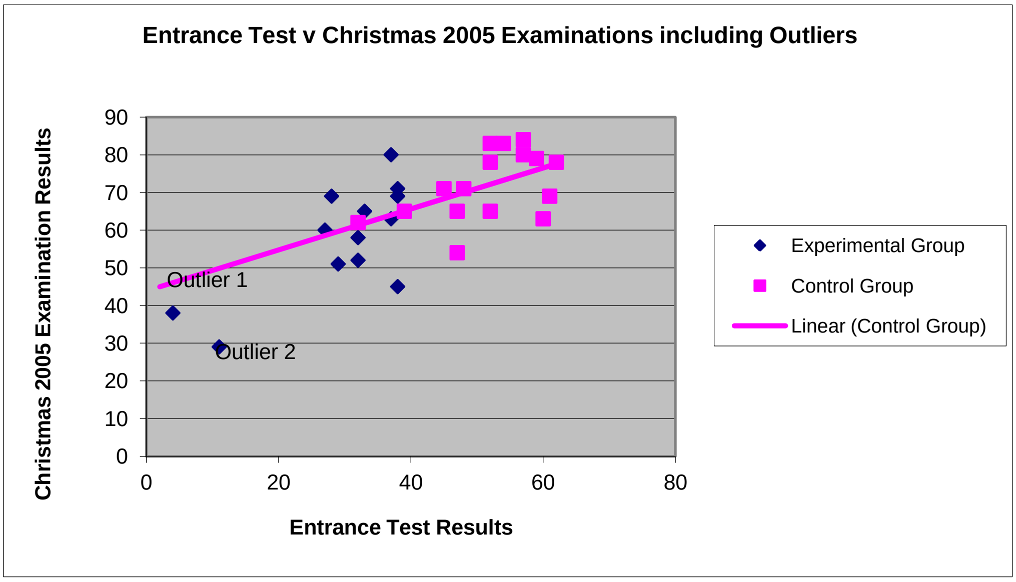


Figure 24 Case Study 1. Scatter Graph. Entrance Test v Christmas 2005 Examination including Outliers.

The same is true of the entrance test v the summer 2006 examinations shown in the scatter graph below, again the outliers can clearly be seen. It would appear here that the experimental group did not improve in their academic attainment when compared with the control group as can be seen in the gradient of the linear regression lines shown below. In order to get the magnitude of this we must look at the linear regression co-efficients detailed later in this section.

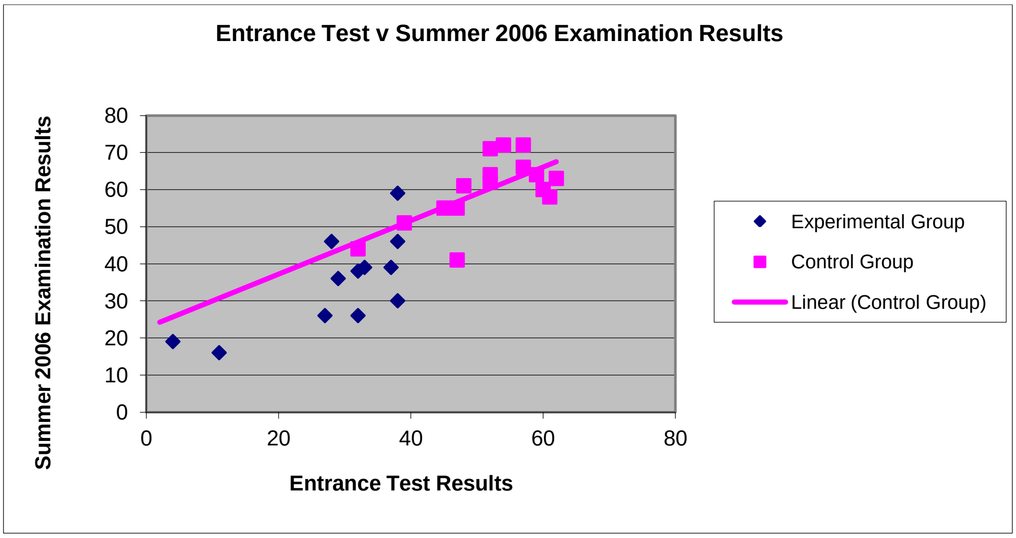


Figure 25 Case Study 1. Scatter Graph. Entrance Test v Summer 2006 Examination including Outliers.

However first we will consider the equality of the improvement of the examination results of the groups by performing ANOVA as described in the previous methodology chapter.

5.4.5 ANOVA including outliers

These groups have a normal distribution as described above, and hence a null hypothesis test can be performed. The following tables show the ANOVA of the Christmas 2005 and summer 2006 exams with different baselines:

- the KS2 SATS,
- the entrance test
- the KS2 SATS and the entrance test combined.

	Christmas 2005 Significance	Christmas 2005 F Value	Summer 2006 Significance	Summer 2006 F Value
KS2 SATS	.005	7.918	.000	22.052
Entrance Test	.000	18.891	.000	47.490
KS2 SATS & Entrance Test	.000	33.171	.000	69.680

Fig…ANOVA and F value analysis.

If the significance, or p-value, is less than 0.05 there is strong evidence that the null hypothesis can be rejected. (Tabachnick, 2001).

From the above table we can see that:

There was a significant difference in the improvement of the examination results from KS2 SATS to Christmas 2005 at the $p<.05$ level for the three conditions [$F(2, 14) = 7.92$, $p = 0.005$].

There was a significant difference in the improvement of the examination results from KS2 SATS to Summer 2006 at the $p<.05$ level for the three conditions [$F(2, 14) = 22.05$, $p = 0.000$].

There was a significant difference in the improvement of the examination results from entrance test to Christmas 2005 at the $p<.05$ level for the three conditions [$F(2, 26) = 18.89$, $p = 0.000$].

There was a significant difference in the improvement of the examination results from entrance test to Summer 2006 at the $p<.05$ level for the three conditions [$F(2, 25) = 47.49$, $p = 0.000$].
There was a significant difference in the improvement of the examination results from combined KS2 SATS and entrance test to Christmas 2005 at the $p<.05$ level for the three conditions [$F(2, 26) = 33.17$, $p = 0.000$].
There was a significant difference in the improvement of the examination results from combined KS2 SATS and entrance test to Summer 2006 at the $p<.05$ level for the three conditions [$F(2, 25) = 69.86$, $p = 0.000$].

There were no instances where the null hypothesis should be accepted and hence that there was a difference in case study 1 for all six possible scenarios performed.

The F value for the Christmas 2005 exams v the KS2 SATS of 7.918 is the weakest however it is still above the critical F value. This shows that the null hypothesis is not acceptable. The other Christmas 2005 results all returned a large F value leading again to a rejection of the null hypothesis. The F values for the summer 2006 exams are all large, the smallest being the Christmas exams 2006 v KS2 SATS which is over 22 leading to the rejection of the null hypothesis.

Given the ANOVA results indicating that the null hypotheses should be rejected, i.e. there is a statistically significant difference in the improvement in the academic attainment of the groups, a linear regression was performed. We have seen in the methodology chapter that ANOVA may overestimate the effects with small class sizes (Thompson, 1986), and that linear regression will quantify the difference (effect size), giving optimal predictions (Cohen, 1968). Here the dependent variable was the Christmas or summer exam marks. The independent variables were the KS2 SATS, the entrance test and the combination of the KS2 SATS and entrance tests. Next we will see how the linear regression estimates the size of the difference between the experimental and control groups for the Christmas and summer exams given the starting attainment baselines.

5.4.6 Linear Regression

Assumptions

Below are the results of the analysis of the 3 assumptions described earlier in this section and in detail in the methodology chapter.

Christmas 2005 examinations

KS2 SATs baseline Assumption Graphs

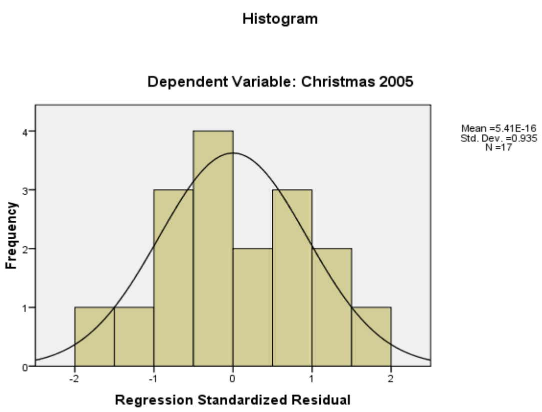


Figure 26 Case Study 1. Christmas 2005 examinations. KS2 SATs Normal Distribution Residual Errors.

We can see from the above that there is a normal distribution to the residual errors.

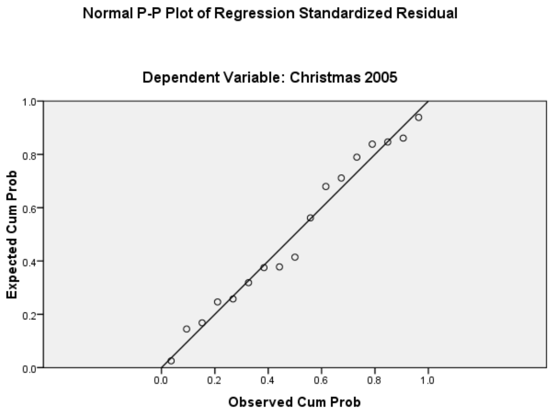


Figure 27 Case Study 1. Christmas 2005 examinations KS2 SATs P Plot of Regression Standardised Residual.

Here we can see that the results fall roughly along a diagonal line indicating normal distribution.

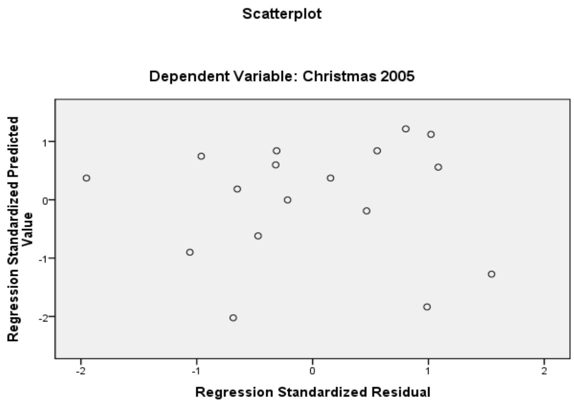


Figure 28 Case Study 1. Christmas 2005 examinations KS2 SATs Homoscedasticity Graph.

Whilst the above does not clearly show an even distribution and therefore homoscedasticity, it clearly shows lack of heteroscedasticity and hence given the two graphs above it is reasonable to conclude that the use of linear regression is realistic when KS2 SATs are used as a baseline.

Entrance Test Assumption Graphs

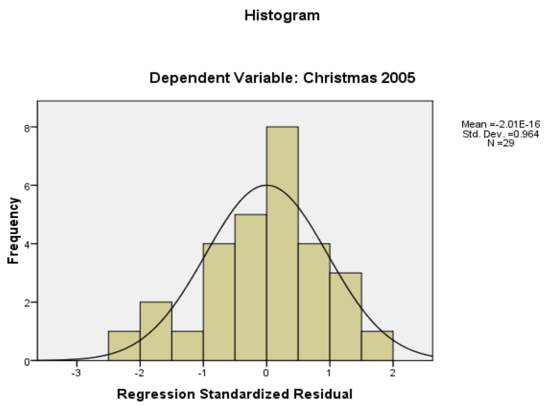


Figure 29 Case Study 1. Christmas 2005 examinations. Entrance Test Normal Distribution Residual Errors.

Again there is a normal distribution to the residual errors.

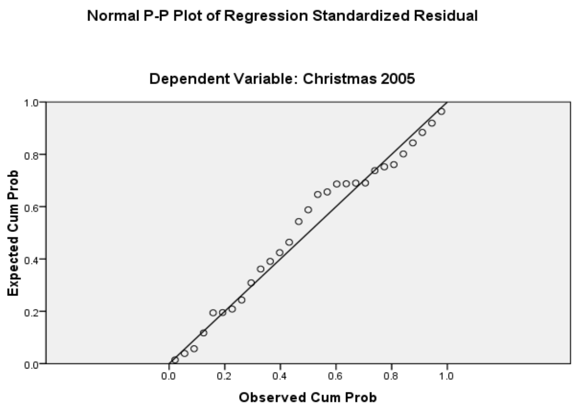


Figure 30 Case Study 1. Christmas 2005 examinations Entrance Test P Plot of Regression Standardised Residual.

We can see the data points are collected around the central line indicating normal distribution.

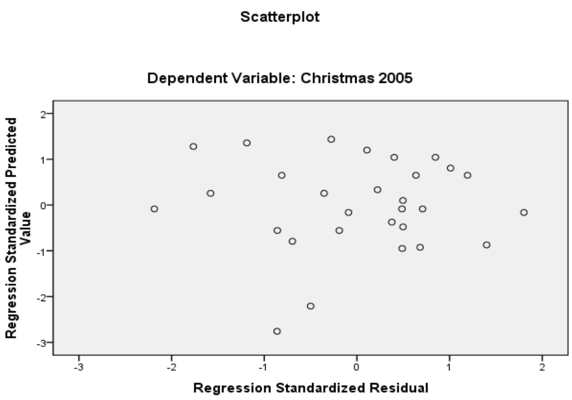


Figure 31 Case Study 1. Christmas 2005 examinations Entrance Test Homoscedasticity Graph.

The above does show an even distribution apart from the two outliers and therefore homoscedasticity if we do not take these into account.

Summer 2006 Results

KS2 SATs Baseline assumptions graphs

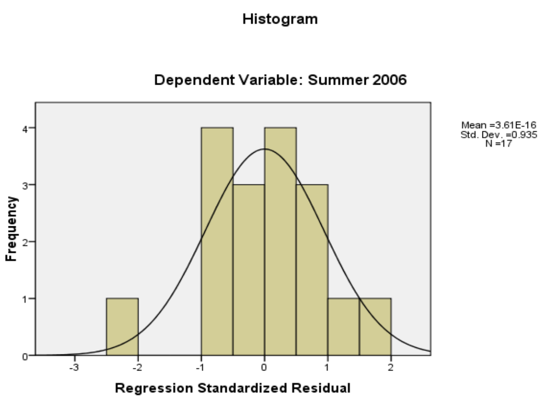


Figure 32 Case Study 1. Summer 2006 Examinations. KS2 SATs Normal Distribution Residual Errors.

Here the residual errors do not show a normal distribution making the linear regression less reliable.

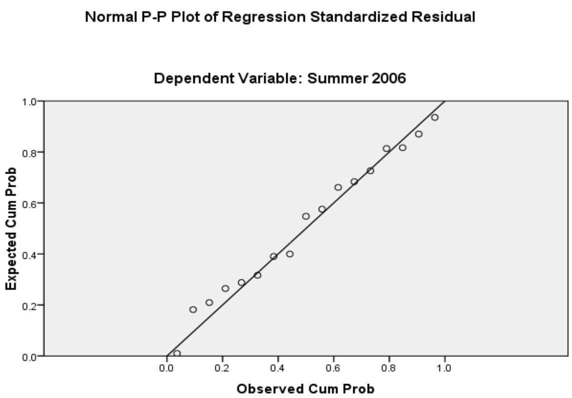


Figure 33 Case Study 1. Summer 2006 Examinations KS2 SATs P Plot of Regression Standardised Residual.

However, although there are fewer data points we can see again the data points are collected around the central line indicating normal distribution.

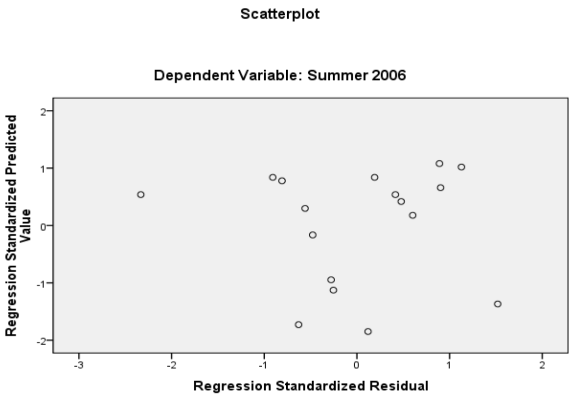


Figure 34 Case Study 1. Summer 2006 KS2 SATs P Plot of Regression Standardised Residual.

The above does not clearly show an even distribution and therefore homoscedasticity cannot be assumed. However there are very few data points and this could be seen as affecting the resulting scatter plot shape.

Entrance test baseline assumptions graphs

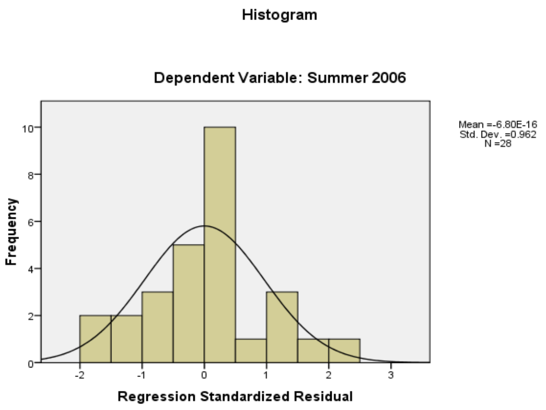


Figure 35 Case Study 1. Summer 2006 Examinations Entrance Test Normal Distribution Residual Errors.

Apart from the 0 – 1 sections there is a normal distribution to the residual errors. This would be reasonable to still use linear regression as the graphs below support it.

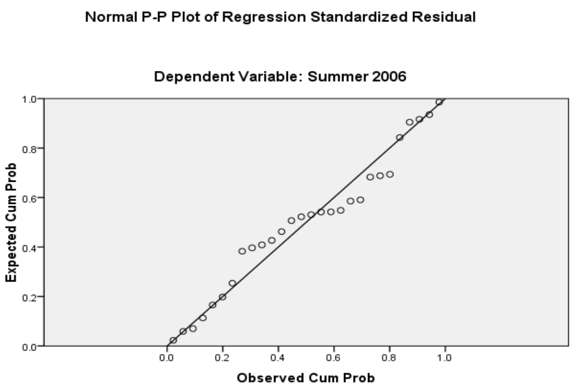


Figure 36 Case Study 1. Summer 2006 Examinations Entrance Test P Plot of Regression Standardised Residual.

We can see the data points are collected around the central line indicating normal distribution.

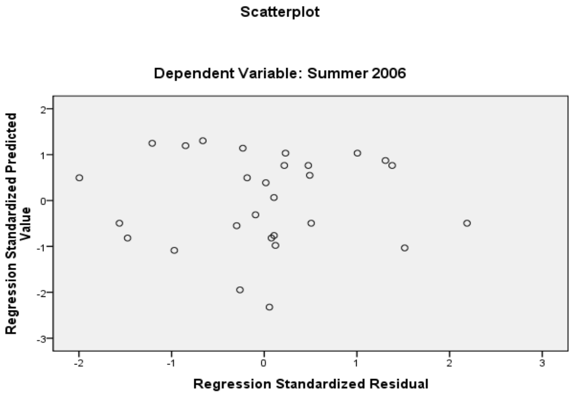


Figure 37 Case Study 1. Summer 2006 Entrance Test P Plot of Regression Standardised Residual.

The above shows a reasonably even distribution and therefore homoscedasticity.

All of the above would indicate that linear regressions could be carried out but bearing in mind Tabachnick et al (2001), who said the results of the linear regression will not be invalidated, only weakened if the graphical analysis did not show strong results of normality of residual errors, linearity and homoscedasticity. Hence the data was deemed to be acceptable to perform linear regression on however it should be noted that the predicted results should be viewed with Tabachnick et al's comments in mind.

Linear Regression Results

Linear regression can be used to predict an estimate for the Christmas 2005 and summer examination 2006 results given the KS2 SATs and entrance tests for case study 1 using the following formula.

$$Y' = M_1 \times \text{Starting attainment benchmark} + M_2 \times \text{group number} + C$$

Summary of Results Table for the group number co-efficients

	Christmas 2005 examination	Statistical Significance	Summer 2006 examination	Statistical Significance
Baselines	**M2 Co-efficient**		**M2 Co-efficient**	
KS2 SATs	**-10.084**	**0.320**	**0.508**	**0.955**
Entrance Test	**-3.8347**	**0.472**	**7.326**	**0.130**

Table 24 Case Study 1. Christmas 2005 and Summer 2006 Examination Linear Regression Co-efficients.

We can see from the above that there was a negative co-efficient for all of the Christmas 2005 examination results particularly marked for the KS2 SATs baseline.

For the experimental group:

Christmas examination prediction = M_1 x KS2 SATs + (-10.084 x 0)+ C

Christmas examination prediction = M_1 x KS2 SATs **+ 0** + C

For the control group:

Christmas examination prediction = M_1 x KS2 SATs + (-10.084 x 1) + C

Christmas examination prediction = M_1 x KS2 SATs **-10.084** + C

Based on the KS2 SATs baseline the control group were predicted –10.084 less than the experimental group for the Christmas 2005 examinations.

This shows that the experimental group did improve their academic attainment up Christmas 2005. However there was no negative co-efficient in the summer

2006 examinations analysis. The KS2 SATs co-efficient was very close to zero but the entrance test showed a positive co-efficient and hence it can be concluded that the experimental group did not improve their attainment in the summer term. However we have to take into account the outliers as when we look at the scatter graphs they can clearly be seen. When we look at the results where they are not included, i.e. the KS2 SATs v Christmas and the KS2 SATs v summer, the experimental group did make an improvement and hence the analysis excludes these 2 outliers was performed. This can be found in appendix 3.

Whilst the co-efficients suggest improved academic attainment in the Christmas 2005 examinations for the experimental group as compared to the control group, they are not statistically significant. For example although the M2 co-efficient for the KS2 SATS baseline is –10.084, the statistical significance is 0.320, well above the level suggested (Kinnear et al, 1999; Tabachnick et al, 2001). However we should also consider that small experimental group sizes can skew the statistical significance tests and so they should not be used mechanistically (Fitz-Gibbon, 1984). This would apply to the above where the experimental groups consisted of very small numbers of pupils.

5.4.7 Case study 2

This section deals with the second case study in which there were 2 experimental groups (sets 3 and 4 of 4) and one control group (set 2 of 4).

In this case study 3 sets of analysis were performed:

- experimental group 1 (set 4 of 4) v control group (set 2 of 4)
- experimental group 2 (set 3 of 4) v control group
- combined experimental groups 1 & 2 (sets 4 & 3 of 4) v control group (set 2 of 4)

These groups' data was analysed as follows:

- Christmas 2006 examination v KS2 SATs
- Christmas 2006 examination v entrance test

Again all data was processed using SPSS and Excel. I used KS2 SATs results and the school's entrance test results as starting attainment baselines.

5.4.8 Mean and standard deviation

The following chart shows the mean, median and standard deviation analysis of the individual experimental groups, the 2 experimental groups combined and the control group as percentages.

Mean	**Entrance Test**	**KS2 SATs Result**	**Christmas 2006 Examination**
Experimental Group 1	32	35	39
Experimental Group 2	59	60	53
Experimental Group 1and 2	49	53	46
Control	73	75	58
Standard Deviation			
Experimental Group 1	12	4	9
Experimental Group 2	7	5	9
Experimental Group 1and 2	14	13	11
Control	6	6	8

Table 25 Case Study 2. Mean and Standard Deviation. Christmas 2006 Examinations.

We can see in the first analysis of the individual groups that there is a greater difference in the means in the entrance tests between the experimental group 1 and experimental group 2 (27) than there is between experimental group 2 and the control group (14). This was reasonable due to setting.

The Christmas examination shows a smaller difference of 14 for the mean difference between experimental group 1 and 2, and 5 between experimental group 2 and the control group. This shows that although there was a large difference between the starting points of the groups the experimental groups' results became much closer to the control group by the Christmas examinations. This indicates that there was an improvement however more analysis is required. These marks were much lower than the previous examination marks at Christmas and could indicate that the examination was much harder.

When the 2 experimental groups' results were combined to compare against the control group the mean of the entrance tests had a difference of 24 and the KS2 SATs a difference of 22. By the Christmas 2006 examinations the difference between the means was only 12.Thus we can see that the experimental groups' results were getting much closer to the control group by the Christmas 2006 examinations.

The standard deviation for the control group was 6 in both the entrance tests and the KS2 SATs whereas the experimental groups had a combined standard deviation of 14 in the entrance tests and 13 in the KS2 SATs. From this we can see that the combined experimental groups had a wider dispersion of marks in both the entrance test and the KS2 SATs. By the Christmas examinations these had become much closer; 11 for the experimental groups and 8 for the control group. In fact the standard deviation is very close in all groups by the Christmas 2006 examinations.

This can be seen on the chart below.

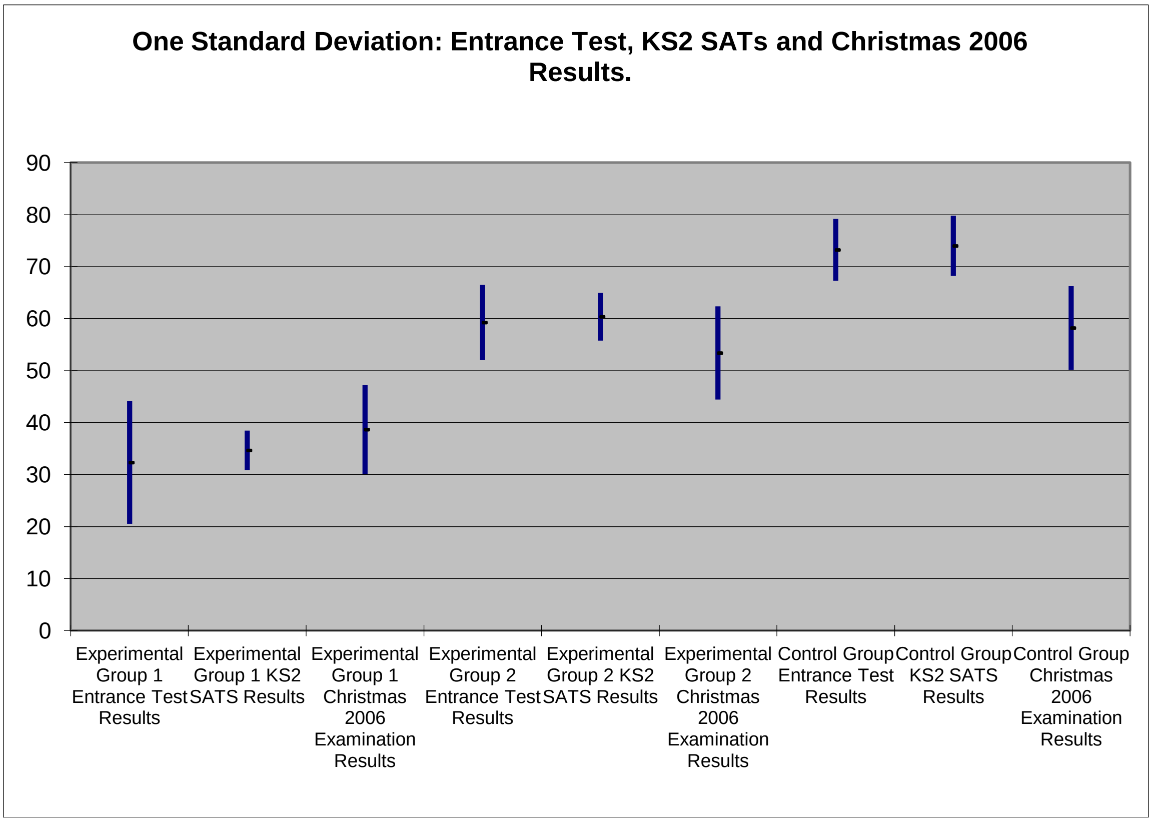


Figure 38 Case Study 2. One Standard Deviation. Christmas 2006 Examinations.

5.4.9 Scatter graphs

Next we shall see the KS2 SATs used as a baseline and plotted on scatter graphs for:

- experimental group 1 v the control group
- experimental group 2 v the control group
- combined experimental groups 1 and 2 v the control group.

The first scatter graph below shows experimental group 1 against the control group, using the KS2 SATs against the Christmas examinations. Although there were very small numbers in experimental group 1, the improvement can clearly be seen.

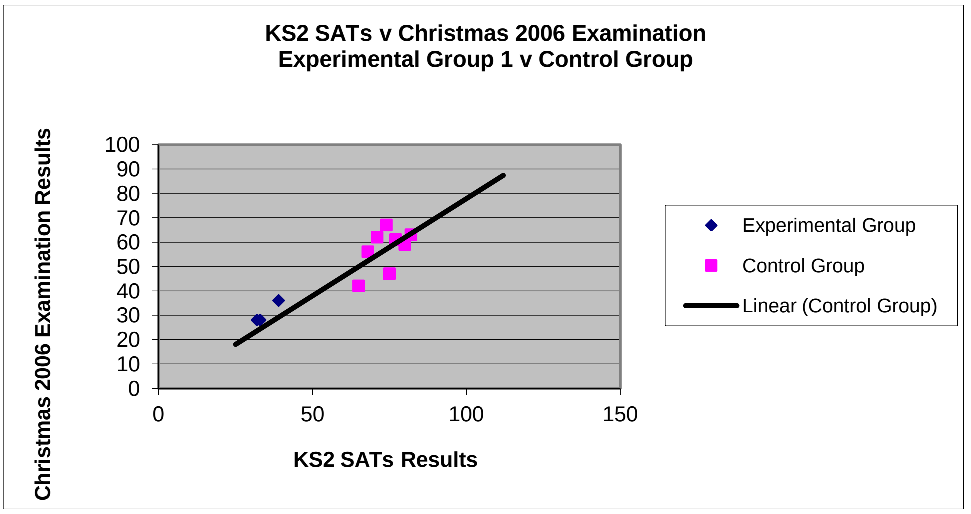


Figure 39 Case Study 2 Experimental Group 1 v Control Group Scatter Graph. KS2 SATs v Christmas 2006 Examination.

Next we can see experimental group 2's KS2 SATs results against the Christmas 2006 examinations and again it is clear that there was an improvement in the academic attainment of the experimental group when compared against the control groups' attainment.

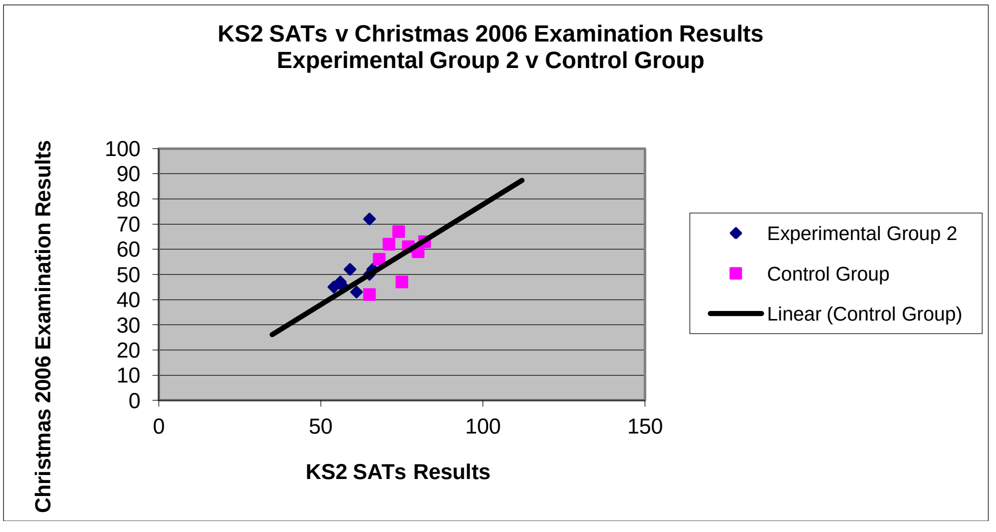


Figure 40 Case Study 2 Experimental Group 2 v Control Group Scatter Graph. KS2 SATs v Christmas 2006 Examination.

Finally, as the numbers for KS2 SATs results in both experimental groups were small, the two experimental groups were combined and compared against the control group. The following scatter graph does not clearly show an improvement and again we must look at the ANOVA and linear regression results.

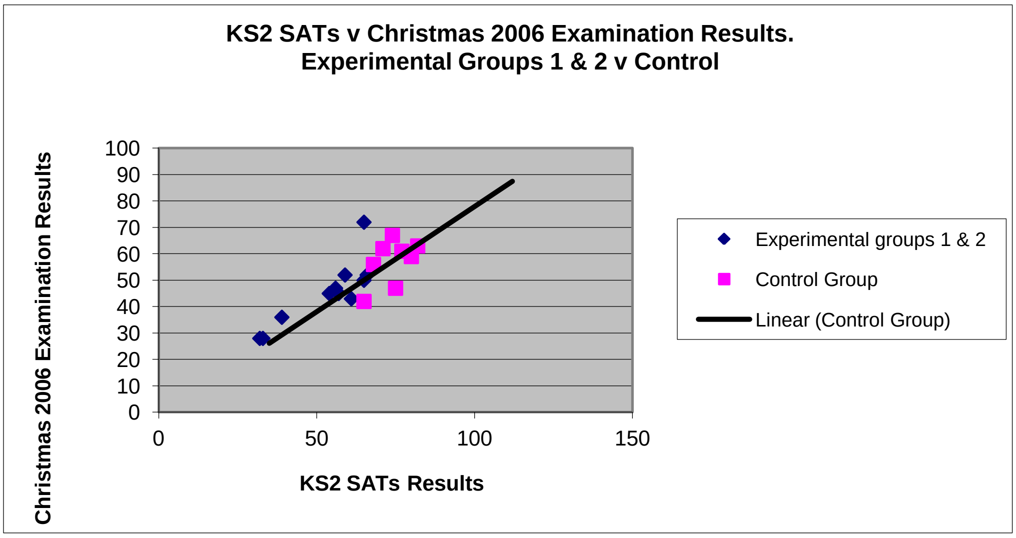


Figure 41 Case Study 2 Experimental Group 1 and 2 v Control Group Scatter Graph. KS2 SATs v Christmas 2006 Examination.

The following scatter graphs plot the entrance test against the Christmas 2006 examination results for:

- experimental group 1 v the control group
- experimental group 2 v the control group
- combined experimental groups 1 and 2 v the control group.

In the scatter graph below it is difficult to see visually if experimental group 1 improved their academic attainment by Christmas 2006 more than the control group and hence a linear regression was performed. The results of this regression can be seen in the following section.

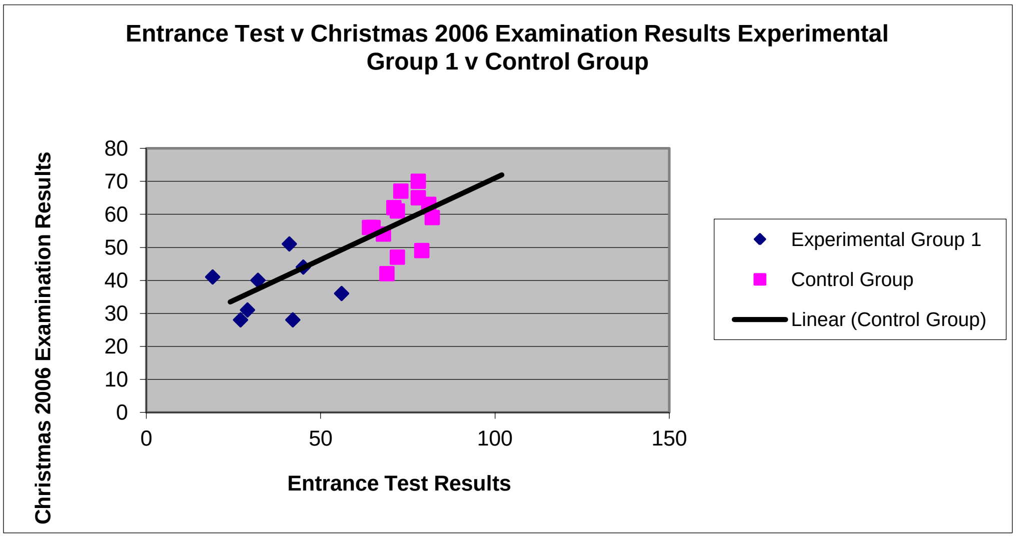


Figure 42 Case Study 2 Experimental Group 1 v Control Group Scatter Graph. Entrance Test v Christmas 2006 Examination.

Here again, when experimental group 2 are compared with the control group, it cannot be clearly seen from the scatter graph whether the experimental groups' attainment was greater than the control groups' and again in order to get a clearer picture ANOVA and linear regression was performed.

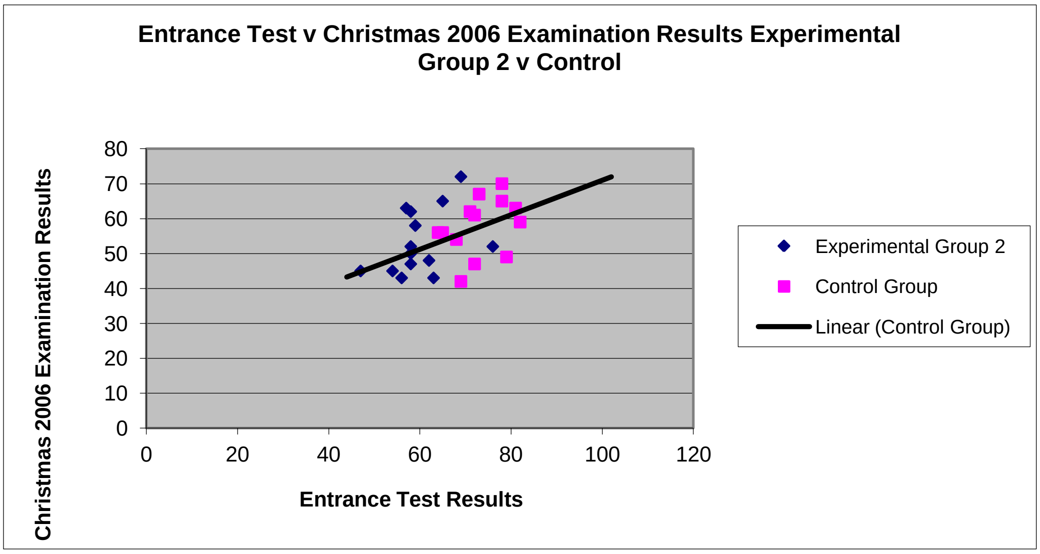


Figure 43 Case Study 2 Experimental Group 2 v Control Group Scatter Graph. Entrance Test v Christmas 2006 Examination.

In the following scatter graph the two experimental groups are shown against the control group with a baseline of the entrance test. It is again difficult to see graphically if there was any improvement made by the experimental groups.

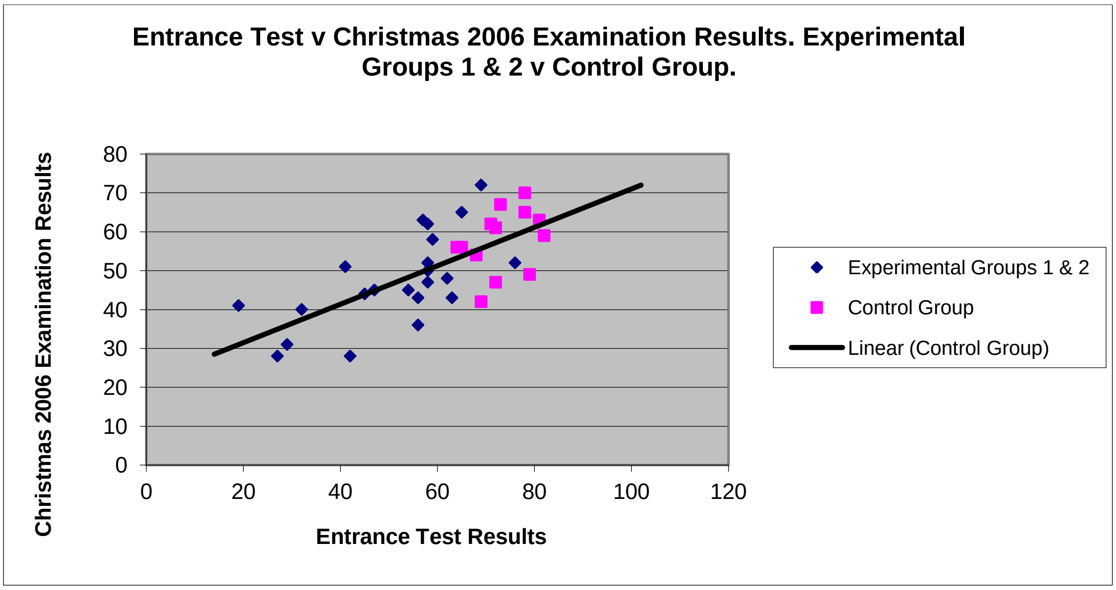


Figure 44 Case Study 2 Experimental Groups 1 and 2 v Control Group Scatter Graph. Entrance Test v Christmas 2006 Examinations.

5.4.10 ANOVA Case Study 2

These groups have a normal distribution as described above, and hence ANOVA can be performed to test the equality of the improvement of the examination results in the groups.

	Experimental group 1 v control		Experimental group 2 v control		Experimental group 1 & 2 v control	
	Christmas 2006 Significance	Christmas 2006 F Value	Christmas 2006 Significance	Christmas 2006 F Value	Christmas 2006 Significance	Christmas 2006 F Value
KS2 SATS	.001	18.936	0.041	4.141	.000	19.292
Entrance Test	.000	15.888	0.053	3.303	.000	15.172
KS2 SATS & Entrance Test	.000	18.668	0.036	3.825	.000	20.621

Figure 45 ANOVA Case Study 2.

We have previously seen that if the significance, or p-value, is less than 0.05 there is strong evidence that the null hypothesis can be rejected (Tabachnick 2001).

From the above table we can see:

There was a significant difference in the improvement of the examination results of experimental group 1 from the KS2 SATS to Christmas 2006 at the $p<.05$ level. [$F(2, 8) = 18.94$, $p = 0.001$].

There was a significant difference in the improvement of the examination results of experimental group 2 from KS2 SATS to Christmas 2006 at the $p<.05$ level. [$F(2, 13) = 4.14$, $p = 0.041$].

There was a significant difference in the improvement of the examination results of experimental groups 1 and 2 from KS2 SATS to Christmas 2006 at the $p<.05$ level. [$F(2, 16) = 19.30$, $p = 0.000$].

There was a significant difference in the improvement of the examination results of experimental group 1 from the entrance test to Christmas 2006 at the $p<.05$ level. [$F(2, 18) = 15.89$, $p = 0.000$].

There was not a significant difference in the improvement of the examination results of experimental group 2 from entrance test to Christmas 2006 at the $p<.05$ level. [$F(2, 25) = 3.30$, $p = 0.053$].

There was a significant difference in the improvement of the examination results of experimental groups 1 and 2 from entrance test to Christmas 2006 at the $p<.05$ level. [$F(2, 32) = 15.17$, $p = 0.000$].

There was a significant difference in the improvement of the examination results of experimental group 1 from the combined KS2 SATS and entrance test to Christmas 2006 at the $p<.05$ level. [$F(2, 18) = 18.67$, $p = 0.000$].

There was a significant difference in the improvement of the examination results of experimental group 2 from the combined KS2 SATS and entrance test to Christmas 2006 at the $p<.05$ level. [$F(2, 24) = 3.83$, $p = 0.036$].

There was a significant difference in the improvement of the examination results of experimental groups 1 and 2 from the combined KS2 SATS and entrance test to Christmas 2006 at the $p<.05$ level. [$F(2, 32) = 20.62$, $p = 0.000$].

The significance, or p value, in all but one case (entrance test for group 2 v control group, Christmas 2006 examinations) shows that the null hypothesis can be rejected. This is not the case however for experimental group 2 v control group in the Christmas 2006 exams when the entrance test was used, as the significance value is 0.053.

Next the F value is considered. The above results were reflected in the F values in that the experimental group 1 and the combined experimental groups both showed an F value between 15.172 and 20.621. This again shows that the null hypothesis should be rejected. However the experimental group 2's F values were between 3.303 and 4.141, lower than the critical F values of 4.225 – 4.6 and hence indicate that the null hypothesis should not be rejected. Hence we can conclude that there is no statistical support for a difference in the improvement of the examination results for group 2 and the control group in the Christmas 2006 examinations. However there is for experimental group 1 and the combined experimental group 1 and 2 as compared to the control group.

The following linear regression analysis was performed on all combinations of baselines as above but the results must now be tempered with the information that the null hypothesis for experimental group 2 v control group has not been rejected.

5.4.11 Linear Regression

Assumptions

Again before we consider the linear regression the results of the analysis of the 3 assumptions described earlier in this section must be calculated.

Christmas 2006

KS2 SATs baseline Assumption Results

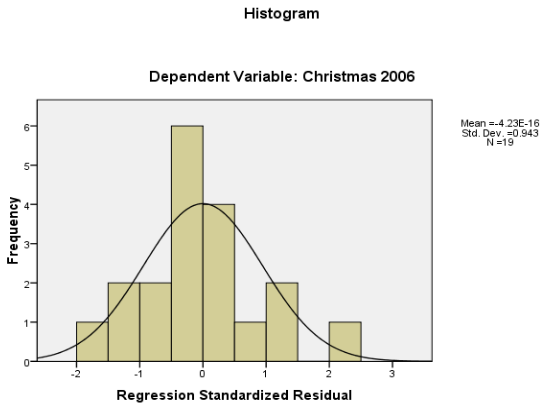


Figure 46 Case Study 2. Christmas 2006 Examinations. KS2 SATs Normal Distribution Residual Errors.

We can see from the above that there is not a normal distribution to the residual errors however there are very few data points and hence it was decided that this was within the tolerance for the linear regression to be carried out.

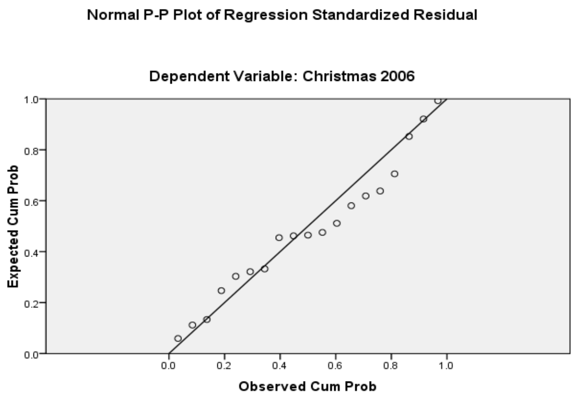


Figure 47 Case Study 2. Christmas 2006 Examinations KS2 SATs P Plot of Regression Standardised Residual.

Here the data points are collected around the central line indicating normal distribution.

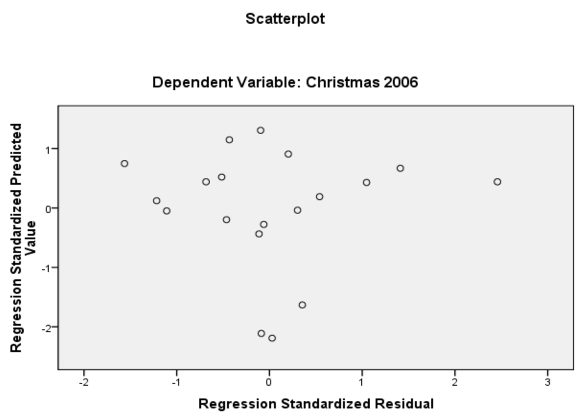


Figure 48 Case Study 2. Christmas 2006 KS2 SATs P Plot of Regression Standardised Residual.

The above does not show an even distribution with 3 data points clearly seen at the bottom of the graph and therefore homoscedasticity cannot be assumed. However as we have previously seen the graphs above do support the use of linear regression but the results are weakened.

Entrance Test baseline Assumption Results.

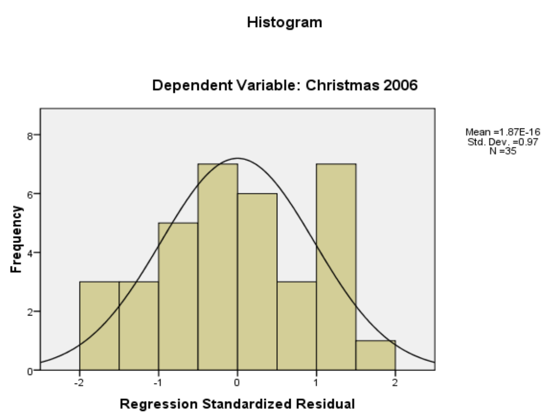


Figure 49 Case Study 2. Christmas 2006 Examinations. Entrance Test Normal Distribution Residual Errors.

We can see from the above that with the exception of 1 - 1.5 section, there is a normal distribution to the residual errors. This again was deemed to be acceptable given the two other supporting graphs below.

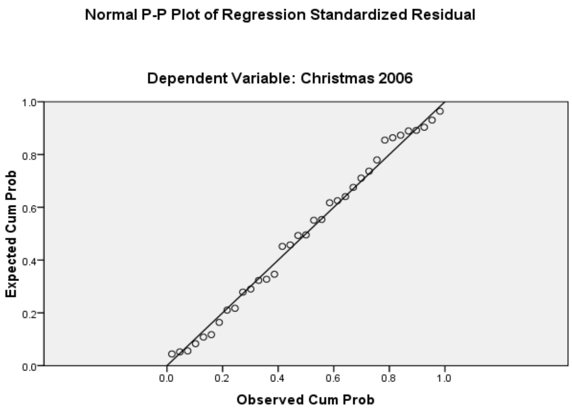


Figure 50 Case Study 2. Christmas 2006 Examinations Entrance Test P Plot of Regression Standardised Residual.

Here the data points are very close to the central line indicating normal distribution.

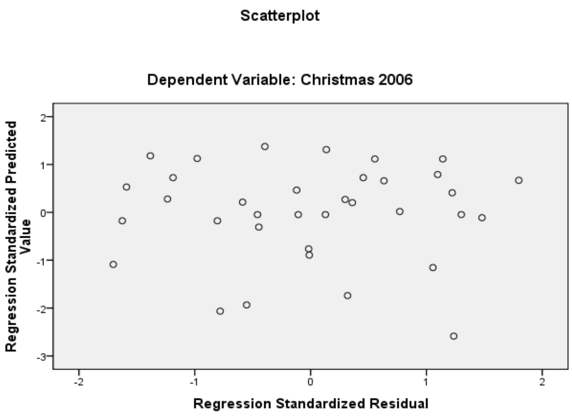


Figure 51 Case Study 2. Christmas 2006 Entrance Test P Plot of Regression Standardised Residual.

In the above graph there is an even distribution of the errors and therefore homoscedasticity.

Given the above results it was concluded that again it would be valid to use linear regression for case study 2. There were several instances where we should bear in mind that the results of the linear regression will be weaker such as the KS2 baseline v Christmas 2006 examination results however here we had very few data points.

Linear Regression Results

In the case study 2 there were two experimental groups being considered, namely the experimental group 1 and experimental group 2, and one control group.

Again using the linear regression formula:

$Y' = M_1$ x SAT or entrance test + M_2 X group number + C

And substituting the KS2 SATs and entrance test combined baseline gives an estimate for the Christmas 2006 examination as follows:

For the experimental group 1: (Group 0)

Christmas 2006 examination prediction = M_1 x KS2 SATs + (-6.633 x 0)+ C

Christmas 2006 examination prediction = M_1 x KS2 SATs + **0** + C

For the control group: (Group 1)

Christmas 2006 examination prediction = M_1 x KS2 SATs +(-6.633 x 1) + C

Christmas 2006 examination prediction = M_1 x KS2 SATs **-6.633** + C

For the experimental group 2: (Group 0)

Christmas 2006 examination prediction = M_1 x KS2 SATs + (-6.252 x 0)+ C

Christmas 2006 examination prediction = M_1 x KS2 SATs + 0+ C

For the control group: (Group 1)

Christmas 2006 examination prediction = M_1 x KS2 SATs +(-6.252 x 1) + C

Christmas 2006 examination prediction = M_1 x KS2 SATs **-6.252** + C

For the experimental groups 1 and 2: (Group 0)

Christmas 2006 examination prediction = M_1 x KS2 SATs (-5.027x 0)+ C

Christmas 2006 examination prediction = M_1 x KS2 SATs + **0** + C

For the control group: (Group 2)

Christmas 2006 examination prediction = M_1 x KS2 SATs +(-5.027x 2) + C

Christmas 2006 examination prediction = M_1 x KS2 SATs **–10.054** + C

The chart below shows the M2 co-efficients produced by the linear regression.

Summary Table of Results

Christmas 2006 Examination						
	Experimental group 1 v control	**Statistical Significance**	**Experimental group 2 v control**	**Statistical Significance**	**Experimental groups 1 and 2 v control**	**Statistical Significance**
	M_2 Co-eff		**M_2 Co-eff**		**M_2 Co-eff**	
KS2 SATs	**-6.633**	0.705	**-6.252**	0.361	**-5.027**	0.298
Entrance Test	**12.234**	0.184	**-2.840**	0.017	**-1.125**	0.780

Table 26 Case Study 2. Christmas 2006 Examination Linear Regression Co-efficients.

Experimental group 1 had a co-efficient of –6.633 when comparing the KS2 SATS results against the Christmas 2006 examinations indicating an improvement when the KS2 SATs were used as the baseline. However when the entrance test was used, the experimental group had not improved their academic attainment when compared with the control group.

We can also see from the above, that the experimental group 2 v control group shows that the experimental group did improve their academic attainment when measured against the control group in all of the baselines in this linear regression. The greatest improvement can be seen in the KS2 SATs results v the Christmas 2006 examination.

The same results can be seen in the combination of experimental groups 1 and 2 against the control group where all of the co-efficients are negative. Hence it can be concluded that the combination group also improved their academic attainment more than the control group.

We have seen in the methodology chapter that Fitz-Gibbon (1984) states that with small experimental groups statistical significance is unlikely to be seen. This is the case in all of the above with the exception of the experimental group 2 where the statistical significance was 0.017 when the entrance test was used as a baseline against the Christmas 2006 examinations for the linear regression. Hence we can conclude that the linear regression co-efficient of –2.840 is statistically significant; experimental group 2 performed better than the control group.

5.4.12 Analysis Summary

5.4.12.1 Mean and standard deviation

Case study 1

The difference in the means of the KS2 SATs in case study 1 started at 30 and the entrance test was 22. In the Christmas 2003 examinations this difference was only 14 indicating that the pupil's marks in the experimental group were becoming closer to the pupil's marks in the control group until Christmas 2005. The difference in the mean of the experimental group and the control group became greater in the summer 2006 examinations and this would suggest that there was no improvement in attainment. The one standard deviation range was much larger for the experimental group than the control group as there were 2 outliers in the experimental group. Hence analysis excluding these outliers was performed details of which can be found in appendix 3.

When the outliers were excluded, the mean difference for the entrance test between the experimental group and the control group was 18. As the sets were not parallel, this was expected. In the Christmas examinations this had changed to a difference of 10, indicating that the experimental group had improved their attainment. However this changed again to a difference of 21 in the summer 2006 examinations and this shows that the improvement was not carried through into the summer term. The standard deviation range did change and in the Christmas and summer examinations there was only 1 difference in the standard deviations for the 2 groups. This indicated that the groups were much less dispersed and the marks in the Christmas and summer examinations were much closer together within each group.

Case study 2

In case study 2, experimental group 1's entrance test mean was 41 marks different to the control groups and experimental group 2's was 14. This large difference was again expected due to the setting of the groups, experimental group 1 being group 4 of 4, experimental group 2 being group 3 of 4 and the control group being group 2 of 4. This mean difference was also reflected in the KS2 SATs. In the Christmas 2006 examinations the difference in the means had changed to be 19 between the experimental group 1 and the control group, and 5 between experimental group 2 and the control group. This suggests that there had been an improvement in both experimental groups' attainment in the Christmas 2006 examinations. The standard deviation reflected this and in the Christmas examinations there was only 1 difference when looking at the one standard deviation analysis.

In order to give the reader a pictorial view of the analysis, scatter graphs were performed and the following gives a brief outline of the results. The actual scatter graphs can be found in the detailed descriptions above.

5.4.12.2 Scatter graph

Case study 1

In the scatter graphs produced for case study 1 it was clear in the KS2 SATs v both the Christmas 2005 and the summer 2006 examinations that the experimental group had improved their academic attainment. However it was not clear for the entrance test v the Christmas 2005 and summer 2006 examinations and hence the reader should look at the linear regression for these instances.

In case study 1 excluding the outliers, the scatter graphs for the entrance test v the Christmas 2005 did not clearly indicate if any improvement had taken place in the attainment of the experimental group however in the entrance test v and 2006 examinations it appeared that no improvement had taken place.

Case study 2

When the entrance test results were used as a baseline it could not be seen clearly on any of the scatter graphs if there had been any improvement in the attainment of the experimental groups. When the KS2 SATs were used as the baseline, it could be seen that both experimental group 1 and experimental group 2 had improved attainment. However as the two experimental groups had few KS2 SATs results they were combined and compared against the control group. In this case it was not clear if there had been any improvement and hence the linear regression should be looked at.

5.4.12.3 ANOVA

Case study 1

It was concluded from the ANOVA results that the difference in the examination results for the experimental group and the control group for all of the 3 baselines; KS2 SATS, entrance test and the combined KS2 SATS and entrance tests was statistically significant.

Case study 2

In case study 2 the ANOVA results returned evidence that the difference between the improvement in the examination results of experimental group 1 and the control group in all cases was statistically significant.

Similarly there is evidence that the difference between the improvement in the examination results of the combined experimental group 1 and 2 v the control group in all cases was statistically significant.

However this is not the case for experimental group 2 where there was no statistical case for the null hypothesis being rejected.

Linear regression

The table below details the experiment effect and the linear regression co-efficients for all of the case studies and should be referred to with the narrative for the individual case studies.

Linear Regression co-efficients all case studies

	Christmas 2005 Examination	**Statistical Significance**	**Summer 2006 Examination**	**Statistical Significance**		**Statistical Significance**
Baselines Including outliers	**Co-efficients**		**Co-efficients**			
KS2 SATs	**-10.084**	**0.320**	**0.508**	**0.955**		
Entrance Test	**-3.8347**	**0.472**	**7.326**	**0.130**		

Baselines Excluding outliers	**Christmas 2005 Examination**	**Statistical Significance**	**Summer 2006 Examination**	**Statistical Significance**		**Statistical Significance**
Entrance Test	**-0.055**	**0.993**	**7.662**	**0.166**		
			Christmas 2006 Examination			
	Experimental group 1 v control		**Experimental group 2 v control**		**Experimental groups 1 and 2 v control**	
KS2 SATs	**-6.633**	**0.705**	**-6.252**	**0.361**	**-5.027**	**0.298**
Entrance Test	**12.234**	**0.184**	**-2.840**	**0.017**	**-1.125**	**0.780**

Table 27 All Case Studies. Christmas 2005, Summer 2006 and Christmas 2006 Examinations Linear Regression Co-efficients.

Case study 1

The linear regression returned negative co-efficients for all of the Christmas 2005 examination results against the KS2 SATs and entrance test. This indicated that the experimental group improved their academic attainment up to the Christmas 2005 examinations. There was no negative co-efficient in the summer 2006 examinations analysis. The KS2 SATs co-efficient was very close to a null effect. A positive co-efficient was returned when the entrance test and hence it can be concluded that the experimental group did not improve their attainment in the summer term 2006 for case study 1 including the outliers.

However we must remember that there were 2 outliers and hence the entrance test co-efficients were not as reliable as the KS2 SATs co-efficients.

It was also noted there was no statistical significance for any of the results however this is to be tempered with the fact that the groups were all small and hence this should not be the only result used to judge the success or otherwise of the experiment.

Case study 1 excluding outliers

The same assumptions were made as in case study 1 including the outliers. The table below details the experiment effect and the linear regression co-efficients, remembering that the outliers do not have KS2 SATs results and hence only the entrance test is needs to be considered (as the KS2 results would be the same).

In case study 1 excluding the outliers, negative co-efficient were returned for all of the baselines v Christmas 2005 examination results hence the experimental group did improve their attainment in the Christmas 2005 term. The entrance test showed a positive co-efficient of 7.662 that was a bigger positive co-efficient than in the case study 1 including the outliers.

Hence we can see that the experiment worked until the Christmas 2005 examinations on both the experimental group including and excluding the outliers. This positive effect was not carried through into the summer 2006 examinations. A fuller picture of the results can be found in appendix 3.

Case study 2

Again the same assumptions re linear regression were made as in case study 1. The linear regression for experimental group 2 v control group shows that the experiment had a positive effect for all of the baselines v the Christmas 2006 examination. The greatest improvement can be seen in the KS2 SATs results v the Christmas 2006 examination. This positive effect of the experiment can also be seen in the combination of experimental groups 1 and 2 v the control group for all baselines. The only group that the experiment did not have positive effects for was experimental group 1 when comparing the entrance test against the Christmas 2006 examination. From the linear regression co-efficients above we can conclude that in general, the low attainers did improve.

Again here we have to temper these results with the statistical significance. There was only one instance where statistical significance was shown, experimental group 2 v control when the entrance test was used as a baseline.

5.5 Chapter Summary

We have seen in the case studies that the supportive environment facilitated communication and memory. Both internal and external environments were considered and discussed. In essence ethnographical vignettes were used to describe classroom scenarios under headings of the 3 elements; environment, communication and memory.

From the statistical analysis we can see that in 8 cases out of 12 produced negative linear regression co-efficients, i.e. the experimental group had improved their academic attainment. When KS2 SATs were used as the baseline all except one instance produced negative co-efficients. The range of ‘improvement’ values (negative linear regression co-efficient) above is –10.084 to –0.055. In the one ‘no improvement’ case the magnitude was only 0.508. Although statistical significance was only shown in one case it was argued that the groups were small and a holistic approach to viewing the results should be taken. Hence whilst the results from the mean and standard deviation, scatter graphs, ANOVA and linear regression are not unequivocal, the evidence produced by the statistical analysis is compelling that the academic attainment of the low attainers in the experimental groups was improved. In the following chapter we will see recommendations for teaching and learning based on the findings from the case studies.

Chapter 6 Summary and Recommendations

6.1 Chapter Introduction

In the introduction chapter we looked at Mayers et al (2007), who describes two types of professionals, those who ‘do’ teaching and those who research into teaching. Research practitioners are those who aim to bridge the gap between these two professional worlds. They aim to take the research produced by one type of professional and implement it in the classroom as the other type of professional would.

In the following sections a brief description of the chapter conclusions will be described in terms of the cycle from pilot study (practitioner) to literature review (researcher) through methodology to case studies (research practitioner).

Following this, recommendations for teaching and learning will be made based on the findings from the case studies and the key theoretical principles and practical intervention strategies shown to address the causes of low attainment in mathematics in the literature review chapter.

Finally limitations of the study are then discussed followed by suggestions for further research that would allow for further iterations of the research – practice – research cycle.

6.2 Summary of chapters

We saw in the pilot study chapter how Y7 low attainer pupils, as defined by the school, were taught using accelerated learning via a detailed ethnographical narrative. The supportive environment and the 7 stages of the accelerated learning pedagogy used in the classroom were detailed and the teachers' and pupils' responses were captured.

The statistical analysis suggested that there was an improvement in the academic attainment of the experimental group when compared to the control group. However this pilot study had been carried out as a practitioner and was not based on academic research. In order to 'bridge the gap between the two professional worlds' and place the experiment into a more academic framework, further rigorous, in-depth case studies were carried out.

In the literature review chapter descriptions of low attainers were discussed as definitions that could be used in the experiment and the definition of:

Pupils who have not achieved a level 4 in their KS2 SATS.

was adopted.

It was shown in the literature review chapter that accelerated learning is based on a supportive environment and has a 7 stage cycle, and that CAME is based on 5 pillars of wisdom. Both of these pedagogies were shown to be underpinned by key theoretical principles and practical intervention strategies that address the causes of low attainment in mathematics. Hence in the methodology chapter it was argued that accelerated learning and CAME are suitable teaching pedagogies for use in the experiment.

We also saw in the literature review that the key theoretical principles and practical intervention strategies could be categorised under 3 key elements: environment, communication and memory.

The most appropriate method for other practitioners to replicate the experiment was shown in the methodology chapter to be a mixed methods approach using multiple case studies, including ethnographical narrative and archival analysis. This is adopted in the case studies chapter where ethnographical vignettes are used to describe how accelerated learning was used in the classroom capturing both the teachers' and pupils' responses. These are linked to the research in the literature review chapter under the headings of the 3 key elements shown to be integral to accelerated learning, thus connecting the practical with the research.

Then in the statistical analysis section of the case studies chapter in every instance but one, when the KS2 SATs results were used as a starting baseline, the experimental group demonstrated improved academic attainment when compared with the control groups' results. When the entrance test was used as a baseline there were three exceptions out of seven cases and reasons for this are suggested in the case studies chapter. Overall it was concluded that;

'In the experiment, the academic attainment of low attainers in year 7 (11 – 12 year olds) improved when accelerated learning was used as a teaching pedagogy in the classroom'.

Here we must take into account (Dowker, 2004, page 42), who states that:

'Numerical difficulties are highly susceptible to intervention'

and hence next we will see recommendations for teaching and learning based on the findings from the narrative in the case studies. These findings will be linked to the key theoretical principles and practical intervention strategies shown to address the causes of low attainment in mathematics as seen in the literature review chapter.

6.3 Implications for Teaching and Learning

We have seen that Accelerated Learning can be used as a framework in which to facilitate the key theoretical principles and practical intervention strategies shown to address the causes of low attainment in mathematics. Furthermore these principles and strategies have been categorised under 3 key elements of environment, communication and memory and it has been shown that there is an intertwining of the principles and strategies within these elements.

In the following sections I will recommend tools, such as using small white boards (Watson et al, 2003), from the case study vignettes demonstrating how the key intervention theories and practical intervention strategies suggested in the literature review were facilitated in the classroom. These will be described under the headings of the 3 elements found to be the most important of environment, communication and memory and will be given a label, such as E1, in order that they can be referenced in the toolbox matrix at the end of this section. We will start by looking at the tools facilitated under the key element of environment.

6.3.1 Environment

We have seen a wealth of evidence on the importance of providing a supportive learning environment in the literature review (Papert, 1980; Mounoud, 1981; Boaler et al, 2010). Without this supportive environment key theoretical principles and practical intervention strategies that address the causes of low attainment could not effectively be employed. The following section describe the tools that this supportive environment facilitates:

Two types of environment are described in the literature review and the case studies chapters, internal and external. The internal environment was shown to be the most important as the external environment can be changed from within the internal one as described in the ethnographic narrative in both the pilot and case studies.

E1. Create a safe supportive environment.

In the case studies I repeatedly informed the pupils that it was the method in which the answer was arrived at and not the actual answer given I was interested in leading to true understanding and retention of a topic (Hiebert et al, 1996). This can only effectively be achieved when a safe supportive environment is in place.

E2. Set ground rules

In order for such things as communication to take place ground rules must be put in place. We have seen instances in the case studies where deflecting questions (Pimm, 1987), are used by the pupils in order to sidetrack the teacher from the objective of the lesson. This could be seen as the main reason why discussion, as advocated by Pimm, 1987; Dowker, 2000; Shayer et al, 2007; and Boaler et al, 2010, is not favoured by some teachers.

However many examples of effective communication such as peer to peer communication as described in the case studies, e.g. in the lesson using closed questions about probability. Here the pupils explained how they got their answers to the rest of the class using both peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010) and message oriented speech (Brown, 1982). These practical strategies are most effective when the ground rules are in place.

E3. Promote active listening skills.

When pupils are using message oriented speech (Brown, 1982) the rest of the class needs to listen carefully to understand the message being conveyed. This often happened in the case studies when the small white boards (Watson et al 2003), were used and pupils with the correct answer explained their methods to the rest of the class.

This was also the case when pupils would be asked to come to the front of the classroom and explain to the rest of the group how they had arrived at their conclusions. An example for the case studies is the vignette describing long multiplication.

E4. Use praise and reward system.

The use of reward systems, within a supportive environment (Papert, 1980; Mounoud, 1981; Boaler et al, 2010) can create healthy competition between the pupils. In the case studies we have seen examples where As are given for effort, correct work, scoring highest on a test, greatest improvement etc. When the pupil gained 3 As they gained a merit with pupils often working harder to obtain this third A.

E5. Facilitate group work

A supportive environment can facilitating group work in which teachers should choose pupils who can work together and have a mix of pupils who have an understanding of the topics with pupils who do not. This can be seen in the puppy's playpen vignette where a spokesperson is nominated but the rest of the group must have an understanding of the solution that allowed for successful outcomes as advocated by Shayer et al (2007). This also facilitates talking for others (Pimm, 1987).

E6. Use summative assessment recording systems.

At the end of a topic a short summative test (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al, 2010), can be given and the results recorded. These results can then be used to choose the 5 – 10 starter questions used at the beginning of the lessons in the case studies using the small white boards (Watson et al, 2003). In the case studies pupils who had struggled with some aspect of the test were chosen to explain their answers, providing formative assessment of their understanding to feed back into the teaching and learning.

E7. Address negative influences from parents.

In the algebra lessons vignette we have seen that no reference was made to the topic until the pupils were confident with it. This meant that the negative influences from parents (Haylock, 1991) was not bought to bear.

We have also seen other examples in the case studies of parental influence such as when pupils were learning long multiplication. Here parents had been taught themselves a certain way of doing this and insisted that the pupils did it using the same method. However in the case studies many ways to solve this problem (Watson et al, 1998) are shown, each pupil choosing the method they found easiest.

E8. Contextualisation.

We have also seen in the case study vignette of the puppy's playpen how the practical intervention strategy of putting mathematics in context (Dowker, 2000; Watson et al, 2003), can help pupils understand a problem. Here the problem of a finding the largest area for a Dalmatian puppy's playpen was used in order to allow the pupils to make sense of the new topic of area. This vignette also include using real life examples (Haylock, 1991), as the puppy in question was infact my son's.

We have also seen contextualisation in the CAME lesson on desk size where pupils suggested metal desks should be used that, they informed me, cost about £100 each, (Putting maths in context). This lead onto a discussion on approximation which, although not due to be taught then, fitted naturally into the lesson.

E9. Teach topics as they 'naturally' arise.

In the case studies we have seen many examples where topics that have not yet been taught were needed in order to solve a problem. The vignette on estimating demonstrates that topics should be taught when the information is needed in the classroom rather than when the curriculum dictates they should be. In this example the problem was put into context (Dowker, 2000, Watson et al, 2003), by using a real life example (Haylock, 1991), of the distance to the chapel. Scaffolding was used to help approximate the distance and eventually standard form was introduced at this point.

Another example was the use of square numbers in puppy's playpen or the use of standard form in the estimating lesson. Here again we saw how scaffolding (Cockcroft, 1982; Cohen et al, 2004; Boaler et al, 2010) was used to allow pupils to access these new topics.

E10. Use formative assessment to inform teaching.

We have seen examples in the vignettes where small white boards have been used to facilitate formative assessment. (Ginsberg, 1977; Baker et al, 2002; Watson et al, 2003; Dowker, 2004; Boaler et al, 2010). This not only allows for the assessment to quickly feed back into the teaching and learning but can be used to enhance communication skills when the pupils explain their answers to the rest of the group, an example of message oriented speech (Brown, 1982).

In the case studies a method of using coloured dots in my mark book to indicate where a pupil is struggling with a particular topic. Here, although there is no formal recording of understanding, a teacher could use this assessment to inform their teaching. They could use the 5 – 10 question starter questions, as described in the case studies, to focus on these topics.

6.3.2 Communication

It was felt that one of the issues that had a negative effect on the academic attainment of low attainers was under-developed communication skills such as discussion (Pimm, 1987; Dowker, 2000; Chin, 2006; Shayer et al, 2007; Boaler et al, 2010) or listener and message oriented speech (Brown, 1982). This is discussed in depth in the literature review and methodology chapters under the element of communication. In the pilot and case studies we have seen tools being used to overcome this and these chapters should be referred to for a fuller picture of the application of the tools listed below.

C1 Teacher - pupil communication

It is important to break down the socio-historical beliefs (Luria, 1976), that a teacher talks and pupils listen in order for effective communication to take place in the classroom.

In the black magic vignette we can see that the teacher has to enter the pupils world of communication. This helps them to understand how a pupil thinks and consequently the methodology a pupil might employ to get to an answer. This is also the case for the dairy lee cheese problem where the shape of a piece of dairy lee cheese was used in the taboo game to describe the number of degrees in a triangle.

This allows the teacher to use scaffolding more effectively as they have an idea of why a pupil has given a certain response to a problem. There are many examples of scaffolding (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010), being used in the case studies such as the vignette two step relations where the pupils were scaffolded to work out the number of leaves on 100 twigs.

The case studies also contain examples where red pen was used only to mark correct answers. This not only re-enforced these correct answers but also allows the teacher to use scaffolding when the pupils had got the wrong answer. We have seen in the case studies that by using the prompts in scaffolding the pupils often corrected the answer themselves.

C2 Questioning techniques

At first closed questions were used in the case studies and the small white boards (Watson et al, 2003) were used to allow for formative assessment. However in order to encourage cognitive thinking skills (Cohen et al, 2001) a cognitive constructivism approach was taken and more open questions were used. This can be seen in the vignette on pictograms and bar charts where pupils had to decide which form of graph would be most appropriate in which situation. This vignette also describes the opportunities for peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), teacher to pupil communication, message oriented speech (Brown, 1982) that comes about as a result of using open questions. .

C3 Group work.

We have seen in the environment section above that group work is dependent on a supportive learning environment. In this section we will consider how group work impacts on communication.

In the puppy's playpen vignette pupils were placed in groups of 4. We have seen in the environment section how this facilitated the practical intervention strategies of talking for others (Pimm, 1987) and successful outcomes (Shayer et al, 2007) but the most important strategies are associated with communication skills. We can see in this vignette examples of scaffolding

(Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010), peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), Mediation (Vygotsky, 1978), message and listener oriented speech (Brown, 1982) and peer provided scaffolding (Cohen et al, 2004).

Other vignettes containing examples of group work are the CAME lessons; Two step relations and desk size.

C4 Pupil to pupil communication

If we look at the substitution lesson vignette we will see that when pupils first start to come to the front of the class to explain their findings, they direct their explanation at the teacher. It takes time for them to realise that they are communicating their methods and reasons to the rest of the class, using listener and message oriented speech (Brown, 1982).

Pupil to pupil communication is also used when using the small white boards. It is easy to see which pupils have correct and incorrect answers. One of the vignettes describes a pupil with the correct answer explaining how they came to there answer to a pupil with the incorrect answer and this, according to Hiebert et al (1996) makes the pupil doing the explaining retain the knowledge and be more competent in the topic.

In the vignette where pupils sit back to back, describing a shape to each other, they are using many practical intervention strategies such as working in pairs (Bonwell, 1991), peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), listener and message oriented speech (Brown, 1982) and are actively engaged (Bruner, 1961).

We have seen examples of peer scaffolding (Cohen, 2004), in the case studies where pupils help each other to make sense of new topics by asking a series of structured questions (Weinert et al, 1990). There are several vignettes where pupils have asked ‘how did you do that?’ or have looked at the different answers they have and worked out why they were different. However, we have seen that teachers must keep a close eye on this as pupils can scaffold each other to the incorrect answer.

C5 Communication and Lateral thinking puzzles.

We have seen in the black magic puzzle that the pupils need to manipulate the information that they have and find links between these facts. This can help working memory (Weinert et al, 1990), the under-utilisation of which is shown to be a cause of low attainment.

We have also seen examples of the two brothers and the sick sheep in the field both of which promoted listening skills.

C6 Communication games

Many communication games were played in both the pilot and case studies. The main game played is detailed in the communication section of the case studies but in essence it is where a pupil comes to the front of the classroom, turns their back to the white board, and a name of an person or object is written above their heads. They are given 20 questions to ask the rest of the class in order to find out what or who they are. The class can only answer yes or no. Here pupils need to use not only communication skills such as message oriented speech (Brown, 1982), peer to peer communication but also cognitive skills and thinking patterns (Vygotsky, 1978) in order to process the information given and formulate the next question.

Taboo was also one of the communication games played in the case studies again encouraging communication and listening skills.

C7 Peer help.

We have seen examples in the case studies where one pupil has helped another by explaining the steps that should be taken to solve a problem. One pupil helped a peer to work out the internal angle in a triangle given an external angle, another example can be seen in the long multiplication vignette. Here the pupil demonstrated their method explaining using message oriented speech (Brown, 1982) whilst the other pupil was using listener oriented speech.

6.3.3 Memory

We saw at the very beginning of this thesis that the author felt that pupils had poor memory skills and this was shown to be a cause of low attainment in the literature review chapter. The memory strategies used in the pilot and case studies were depicted in the vignettes of the ethnographical narrative and should be referred to in order to obtain fuller details of the memory tools listed below.

M1 Play memory games.

Memory games such as ‘on the way to market’ and ‘the tray game’ were used in the case studies. Another memory game was to write up to 20 linking facts / objects on the white board at the beginning of the lesson. The pupils had to see how many they could remember at the end of the lesson. Over time pupils can remember not only all 20 facts / objects but could put them in the correct order. This helped pupils who had poor memory skills (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000).

M2 Memory Aides.

Memory aids such as posters and number lines can be places around the classroom helping pupils who have immature strategies for memorisation (Wood, 1991). Examples from the case studies are the BODMAS and Touching means Times posters. These aids can also be used to scaffold (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010) in order that the pupils can access higher order thinking skills.

Another way of promoting memory is to use actions such as the darts player for 180 degrees in a triangle. This can be seen as action learning, a key theoretical principle advocated by Bonwell (1991). Another example of active learning is using your fingers to remember the 9 times table as described in the case studies.

We have also seen that low attainers have immature strategies for memorisation (Wood, 1991) and hence colours were used in the collecting like terms vignette. This helped pupils remember that the sign went with the following term.

M3 Use of summative and formative assessment techniques.

Examples have been given of 5 – 10 starter questions being used not only to inform teaching and learning but also to bring topics into short term memory.

This technique was used extensively in the classroom in the pilot and two following case studies.

M4 Use starters to revisit topics.

5 – 10 questions on topics previously studies were used in the case studies as starters to the lessons. These were often answered on the small white boards and this revisiting of topics was shown to help with the poor memory skills identified as a cause of low attainment (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000).

The following matrix shows which of the stages of accelerated learning each tool, as described above, can be used / facilitated in. It should be noted that, as described many times previously, the 3 elements of environment, communication and memory are intertwined and hence some tools relate to two or more of the elements.

Stage	Environment / Communication / Memory
Connect to the learning.	**E1, E2, E3, E4, E6, E7, E8, C1, C2, C4, C6, C7, M2, M3, M4.**

The Big Picture	**E1, E2, E3, E4, E5, E6, E7, E8, C1, C2, C4, C5, C6, C7, M1, M2, M3, M4.**
Describe the Output	**E2, E3, E5, C1, C2, M2.**
Input	**E2, E3, E5, E6, E7, E8, E9, C1, C2, C6, M2, M3.**
Activity	**E1, E3, E4, E5, E6, E7, E8, E9, E10, C1, C2, C3, C4, C7, M2, M3.**
Demonstrate	**E1, E2, E3, E4, E5, E6, E7, E10, C1, C2, C3, C4, C6, C7, M2, M3.**
Evaluate	**E1, E3, E4, E5, E6, E10, C1, C2, C5, C6, M1, M2, M3.**

Table 28 Toolbox Matrix.

Here I must re-iterate what Cohen et al (2004, page 167) say:

'There is no single blueprint for effectiveness, though there are very many characteristics of effective teaching and effective learning'.

Accelerated learning is one blueprint that has been shown to improve the academic attainment of low attainers in Y7. It is underpinned by key theoretical principles and practical intervention strategies that address the causes of low attainment. These are categorised under 3 key elements: a supportive environment, communication and memory. The interventions and tools discussed above are intertwined within these 3 key elements providing some of the characteristics for effective teaching and learning. However although these interventions and tools are intertwined, when we consider the use of the tools there are several that could be considered more important for teaching and learning as they allow more opportunities for facilitating / implementing the theories and strategies that address the causes of low attainment.

These are:

- Small White Boards
- Scaffolding
- Group Work

If we begin by looking at the key theoretical principles and practical intervention strategies we can see that many of these could be facilitated / implemented through the use of the small white boards.

6.3.4 Small White Boards

Small white boards can help in the creation of a safe supportive environment. Pupils can hold up their answers and if they are incorrect they can see correct answers around them. They can then rub out their answer and replace it with the correct answer. Here the fear of failure (Haylock, 1991), is being addressed. Obviously here teachers then have to ask the question of ‘How did you get that answer’ or ‘Why did you change your answer’. Thus opportunities for active listening skills and discussion via message oriented speech (Brown, 1982) are created.

They can be used for formative assessment at the beginning of the lesson for the 5 – 10 starter questions. Here the pupils’ answers feed back directly and quickly into the teaching and learning.

The answers to both open and closed questions can be asked using the small white boards and this is useful when immediate feedback about the understanding of a topic is needed. The benefits of open and closed questions but in essence the use of the small white boards would provide opportunities for discussion (Pimm, 1987; Dowker, 2000; Chin, 2006; Shayer et al, 2007; Boaler et al, 2010), peer provided scaffolding (Cohen et al, 2004), successful outcomes (Shayer et al, 2007), message and listener oriented speech (Brown, 1982).

Pupils who have incorrect answers can easily see correct answers. The pupils who have the correct answers can then explain to the rest of the group how they arrived at their answer. The pupil explaining then retains the knowledge and is more competent in the topic (Hiebert et al, 1996).

Frequently revisiting topics using the small white boards can help with poor memory skills, a cause of low attainment (Bruner, 1961; Ginsberg, 1977; Biggs, 1985; Dowker, 2000). The use of small white boards allows pupils to use their working memory (Staver et al, 1988) as they often only write the answer down, processing and linking the information required to solve the problem, in their heads.

So we can see that small white boards are used in all of the three key elements of environment, communication and memory and hence is considered as one of the most important tools to be used to address the causes of low attainment.

Next we will consider scaffolding as a tool to facilitate / implement the key theoretical principles and practical intervention strategies that address the causes of low attainment.

6.3.5 Scaffolding

Firstly we must consider that it is important to break down the socio-historical beliefs (Luria, 1976), that a teacher talks and pupils listen in order for effective communication to take place n the classroom. Scaffolding offers an opportunity for this to happen.

Scaffolding (Cockcroft, 1982; Dowker, 2000; Cohen et al, 2004; Boaler et al, 2010), can be used to teach topics as they naturally occur. We have seen the example in the puppy's playpen vignette where the pupils were scaffolded to the correct answer even though square numbers were not due to be taught according to the curriculum.

When scaffolding was used in the approximation lesson it lead to standard form being introduced. It could be said this provides an opportunity for teachers to stretch pupils within a safe supportive environment provided by scaffolding.

When a teacher uses scaffolding they need to interpret the response of the pupil in order to know what question to ask next. This is a form of formative assessment where the answer to the question provided by the pupil informs the teaching and learning.

We have also seen that red pen was used to mark only correct answers. This provided the opportunity for the teacher to ask questions such as 'How did you get your answer' or 'Why did you do that'. The pupils can then be scaffolded to the correct answer, often seeing for themselves where they have made a mistake in the calculation before then end of the problem. This gives the pupil an understanding of how they got to their answer as opposed to just having the correct answer.

Scaffolding also allows the teacher to understand why or how the pupil has arrived at their answer often addressing misconceptions that the pupil may have with the methodology.

Peer provided scaffolding can be very beneficial for the scaffolder where they help another pupil to make sense of a topic. According to Hiebert et al (1996), the explaining or scaffolding of a solution to a peer can result in more retention and comprehension of the topic. In peer to peer scaffolding many communication theories and strategies can be used such as peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), listener and message oriented speech (Brown, 1982), working in pairs (Bonwell, 1991) and active reasoning (Wertsch, 1979).

However as previously stated, the teacher must be aware that peer to peer scaffolding can result in scaffolding to the wrong answer. Often in these cases there is a common misconception and the teacher should intervene and take over the scaffolding.

Scaffolding can also improve memory skills. Memory aides such as posters can be used to scaffold pupils to the correct answer. Here the teacher can point to the poster at the relevant point in the scaffolding. Here scaffolding could be seen as a strategy for memorisation, a cause of low attainment (Wood, 1991).

And finally scaffolding can be seen as a way to improve working memory (Staver et al, 1988), as pupils need to process and link information in their heads during the scaffolding process in order to answer the question.

Again we can see that scaffolding can be facilitated / implemented in all 3 key elements. In the next section we will consider the tool of group work which, although is a practical intervention strategy suggested by Haylock, 1991; Watson et al, 2003 and Boaler et al, 2010, was also deemed to be an important tool to address the causes of low attainment.

6.3.6 Group Work

When group work is facilitated the groups benefit from a mix of pupils who understand the topic and those who do not thus allowing for successful outcomes (Shayer et al, 2007).

In the vignette of puppy's playpen group work facilitated the intervention strategy of talking for others (Pimm, 1987). Here pupils are using listener and message oriented speech (Brown, 1982) to help each other to a solution.

Again here when group work is facilitated we can see that when pupils have to explain why they want to use a particular method or approach to the rest of the group, they are reinforcing their own knowledge. This will lead to more retention and comprehension of the topic (Hiebert et al, 1996).

In the CAME vignettes we have seen a suggestion that the groups elect a spokesperson however, the rest of the group needs to have an understanding of the solution to be presented to the class. Hence here the group work is facilitating active listening skills in order that the pupils who are having the methods or solutions explained to them would be able to explain this solution if required to do so.

As well as the above forms of communication, group work also facilitates peer to peer communication (Pimm, 1987; Baker et al, 2002; Dowker, 2004; Boaler et al, 2010), working in pairs (Bonwell, 1991), mediation (Vygotsky, 1978), peer provided scaffolding (Cohen et al, 2004) and active reasoning (Wertsch, 1979) all of which have been shown to address the causes of low attainment in mathematics.

Finally as we have seen many times that the above tools could not be facilitated or implemented without a supportive environment being present.

However we have seen in the methodology chapter Brown (2003) says that small-scale quantative studies only give insights and that these can be tested on larger scale quantative data studies. Also Fitz-Gibbon (1984) states that the ‘one off’ experiment is far less important due to the smallness of the sample.

These results may not be replicable and suggests that replication will provide more reliable results.

Hence we will now compare the findings of this thesis with previous research in the field. We have seen details of larger scale case studies in section 4.8 of methodology chapter and further details of the following experiments can be found there. In that section Kutnick et al's experiment (2008) is discussed where pupils were subjected to teaching strategies that could improve the effectiveness of group work. At the end of the study pupils in the experimental group were shown to have high levels of communicative interaction with their partners. According to Kutnick et al the pupils in the experimental group improved their academic attainment more than those pupils in the control groups. Here we can see that group work, as recommended by this thesis, can have a positive impact on pupils' attainment. It could also be argued that as scaffolding and the use of small white boards have been shown to be communication tools, they would also contribute to increased academic attainment.

We also saw details of a large scale project by Blatchford et al (2005) namely SPRinG. Here the main aim was to consider how group work impacted on communication and joint problem solving. Blatchford et al reported that the experimental group performed significantly better than the control group in the post experiment test. They suggest that this is the case where topics required high order thinking skills. Blatchford et al also instigated the Scottish version of the experiment ScotSPRinG. Here they saw better results for the experimental group in science. So if we compare this to this thesis we can see that as mathematics can be considered as requiring higher order thinking skills the same results would be applicable if group work, communication and joint problem solving were used as part of the teaching pedagogy. Infact we have seen that group work is one of the recommended tools and communication is one of the key elements of this thesis which frequently utilises the scaffolding and small white board tools.

In Gathercole et al's experiments (2004a, 2004b) they conducted test on working memory. They state that memory aides such as number lines were used to enhance memory. In the thesis' experiment poster were placed around the classroom and memory games played. These memory aides were often used in the scaffolding process as visual prompts and examples of this can be found in the case studies chapter. The memory aides have been described under the key element of memory but, as we have also seen, can be classified under the element of environment.

We have also seen in Pickering et al's experiment (2001) discussed in the methodology chapter, that pupils who had problems with communication also had low scores on working memory tests. In this thesis the connection between communication and memory has been made and, specifically that scaffolding, as recommended above, could be used. In scaffolding pupils are prompted to the correct answer using a series of structured questions making connections to the required information in their memories thus linking the key elements of communication and memory.

And finally if we consider Towse et al's experiment (2003) we can see again that the findings of this thesis are supported by previous research. Towse et al concluded that in order to improve working memory pupils should be encouraged to remember a number of items. We have seen in both the pilot and case studies of the thesis how memory games such as on the way to market, memorising a number of connected items from the start of the lesson to the end and the tray game were played in order to facilitate this. Often the small white boards were used to write down the connected items and pupils held up their answers. Here assessment of who had recalled the most items can easily be made and pupils are encouraged to explain their methods of recalling.

We have seen above suggestions for interventions and tools that can address the problems low attainers have in mathematics and these were supported by the findings of previous research in the field that used larger scale studies. We have also seen specific recommendations made of small white boards, scaffolding and group work again supported by previous research. However as with any study or research there are limitations and in the following section we will discuss these limitations in two sections, firstly limitations due to the experiment itself and secondly limitations due to the statistical analysis. Further evidence of how these limitations were addressed can be found in the relevant chapters. However, where appropriate, a brief reason why it was felt that the experiment and analysis could still be considered valid is given for each limitation.

6.4 Limitations of the study

We will start by considering the limitations of the study due to the experiment itself.

6.4.1 The Experiment

The pilot study was conducted in a state school and all of the case studies were conducted in independent schools. This could, and indeed if we consider the results from the pilot study v the results from the case studies, did have an impact on the results. It could be argued that in state schools there is more room for improvement as the pupils are starting with lower academic achievements.

However the case studies were conducted in an independent school and if we accept the argument above, then the pupils were starting with higher academic attainment. This could be counterbalanced by the fact that in the experiment's independent school discipline was not a problem. Hence it was easy to facilitate communication, group work and hand control of the classroom over to the pupils. This would allow the recommended strategies and tools to be used more easily and hence it could be argued that this would allow for greater improvement in independent schools. However greater improvement was not shown when compared to the state school and further research would have to be conducted in order to clarify this point.

If we now consider the size of both the experimental and control groups we can see that these were small and this experiment was only conducted in two schools. Hence it is difficult to attribute the improvement in academic attainment solely to the accelerated learning. By considering other larger scale case studies in the elements of environment, communication and memory the source of the improved academic attainment has partly been addressed but further work would be needed and some ideas are suggested in the further research section below.

When setting up the experiment it was difficult to ascertain if the control group would be exposed to accelerated learning as some of the techniques used in this teaching pedagogy are used in effective teaching and learning as we have seen in the literature review chapter. It is difficult therefore, to state categorically that the control groups were not exposed to any techniques used in the accelerated teaching pedagogy. It is possible however, to say that the control groups were not exposed to the whole accelerated learning cycle just by asking the teachers as described in the methodology chapter.

It is also difficult to attribute the increased academic attainment to any specific key theoretical principle or practical intervention strategy. It has been stated many times that these are intertwined just as the 3 key elements of environment, communication and memory are. It could be argued that one strategy has a large positive affect whereas another has a negative effect. However if these are being used at the same time, it could manifest as a small positive effect for both strategies.

When the difference in attainment was measured the starting benchmark was the KS2 SATs results and it has been discussed in the methodology chapter that may be unreliable with teachers teaching to the test in some schools and not in others. Hence the starting baseline for the pupils in both the pilot and case studies could be considered as open to interpretation.

We also need to consider that the internal school examination papers were used as the final attainment data and these were based on KS3 SATs papers as shown in the methodology chapter. It has been discussed how these examinations were chosen for the experiment as the answer booklets for these questions give detailed explanations of how marks should be awarded. The teachers of both the experimental and control groups marked their own groups' papers and even though the answer booklets were used, marking was still open to subjective interpretation by those individual teachers.

And finally the improved attainment could be attributed to the teacher (personality, relationship with pupils, teaching style etc) and in order to negate this, case study 2 had two experimental groups and one control group. Different teachers taught the experimental groups and in the case of the group not taught by the teacher in the pilot study or case study 1, the improved attainment was evident when both the KS2 SATs and school's entrance test was used as a starting baseline.

6.4.2 Statistical analysis

Next we will consider the limitations of the study due to the statistical analysis. Firstly we can see that the potential improvement is different for the highest scoring pupils than the low attainers, i.e. if a pupil had scored 90% in their KS2 SATs then they are starting at a higher level than the low attainer who only scored 20%. The low attainer has more improvement potential due to this. It could also be argued that the questions become harder on the SATs papers and hence it is more difficult to obtain a higher result. Here we could consider the results from the pilot study where the potential improvement in attainment is similar for both groups. The improved attainment of the experimental group here is substantial when compared with the experimental group.

We must also consider that parallel sets were available in the pilot study but not in the case studies. There was not a good crossover in groups' results (as they were not parallel sets) in the case studies. Hence it is problematic to correlate like with like in terms of the pupils' starting attainment. It should be noted that the pilot study statistical analysis returned the greatest improvement in academic attainment. As the pilot study was conducted on parallel sets, it might have been possible to replicate this greater positive effect in the case studies if parallel sets had been available for the experimental and control groups in the case studies.

The two lowest attainers in case study 1 did not have a KS2 SATs result. This would ask questions of the validity of the potential improvement results as the two weakest pupils' data could not be considered. These two lowest attainment pupils skewed the data as can be seen in the case studies statistical analysis section and were classed as outliers. In order to account for this a separate statistical analysis was performed without their data. This resulted in a smaller improved academic attainment when the entrance test was used as a baseline. As stated above the pupils did not have a known KS2 SATs result and hence the analysis performed with KS2 SATs as a baseline did not change. This asks the question of the suitability of the KS2 SATs as a baseline however the discussion in the methodology chapter indicates that it is suitable.

In case study 2 some pupils in the second experimental group would not be classed as low attainers according to the definition adopted however there was no choice except to accept this, as no parallel group of low attainers was available at the school.

When we consider the ANOVA results for experimental group 2 v control group in the Christmas 2006 exams when the entrance test was used, the significance value is 0.053. This indicated that the null hypothesis should be accepted. Furthermore the F value for experimental group 2's results ranged from 3.303 – 4.141, below the critical values of 4.225 – 4.6. Hence the null hypothesis should be rejected in all of these cases and it can be concluded that there is no statistical support for difference in improvement of the examination results for group 2 and the control group in the Christmas 2006 examinations.

In case study 1 the linear regression co-efficients suggest improved academic attainment in the Christmas 2005 examinations for the experimental group as compared to the control group, however these were not shown to be statistically significant. Even though the M2 co-efficient for the KS2 SATS baseline was –10.084, the statistical significance well above the level suggested (Kinnear et al, 1999; Tabachnick et al, 2001) at 0.320. However small experimental group sizes can skew the statistical significance tests and so they should not be used mechanistically (Fitz-Gibbon, 1984). Given the experimental group consisted of very small numbers of pupils this could be thought to apply here.

In the analysis itself for the case studies several assumption violations were considered and these are detailed in the methodology and, using specific data, in the case studies chapters. These were:

Absence of outliers was a potential problem in case study 1 as there were 2 pupils who were identified as outliers. Consequently the analysis was performed with and without (see appendix 3) outliers.

Variables are measured without error. Here, as stated in the methodology chapter, steps were taken to limit the possibility of marking errors but as shown above with subjective interpretation of the internal examination answers, this cannot be ruled out.

Normal distribution of errors. It was shown in the statistical analysis section of the case studies that some of the groups did not have a normal distribution. This could, and in fact did in some cases, skew the data and a test for skewness was performed however the data was still found to be suitable for use in SPSS. Again evidence of this is discussed in the case studies analysis section.

Linearity, as described in the methodology chapter, was tested for and graphs of this can be found in the analysis sections of the case studies. There are some instances such as the summer 2006 examinations, where the regressed standardised residuals did not show normal distribution and hence the linear regression is less reliable but still of value.

Homoscedasticity is also demonstrated via graphs in the appropriate chapter sections and in some cases it was found that the variance of the errors was not equally distributed, however this would not invalidate the result, only weaken it. (Tabachnick et al, 2001).

Some of these limitations could be addressed by further research and the following section makes suggestions from the whole schools', the teachers' and the pupils' perspectives.

6.5 Future research possibilities

The toolbox could be implemented in different ways depending on the school's and teachers' circumstances and perspectives. Pupils selected for the experiment could also have a bearing on the use of the toolbox and below are some considerations for further research based on these ideas.

6.5.1 The Whole School

The case study research was conducted in independent schools however the larger gain in academic attainment was seen in the pilot study. This was conducted in a state school and hence and it would be interesting to see if these results could be replicated in state schools.

We have seen a discussion on other large scale case studies in both in the methodology chapter and in this chapter. Here key theoretical principles and practical intervention strategies were identified for addressing the causes of low attainment however it has been suggested that it is difficult to separate the impact of each of the individual practical intervention strategies. A meta data analysis of these individual strategies could be conducted to see if any of these had a greater impact, positive or negative, than any other.

Schools have different cultures when considering the state / private school or foreign schools such as the Chinese or Hungarian school. Some cultures advocate investigational work whilst others favour didactic teaching. We have seen different results from the state and the private schools in the experiments conducted in this thesis and a question would be if this toolbox were implemented in schools from different cultures, would the tools be used in the same way or produce similar results?

The schools perception of expected behaviour of both pupils and teachers could have an influence on how the toolbox is implemented for instance; if group discussion is entered into, this will cause noise in the classroom. Often this can be seen as a sign of weakness in a teacher as the classes being ‘out of control’. If the group discussion tool were used would it change the schools’, teachers’ or pupils’ perceptions of what is acceptable in the classroom? This would be a change from the socio-historical beliefs described in the literature review chapter, and could change teaching and learning perceptions.

6.5.2 The Teacher

The final examination papers were based on KS3 SATs papers. As the starting attainment was also based on SATs would there be any difference if another examination based on different type questions were to be used.

As with the schools view on classroom management, teachers vary widely in their enforcement of classroom management rules. The toolbox asks them to relinquish their classroom and allow pupils to take charge. How would teachers who find this difficult use the toolbox? Would they change it somehow and would they still achieve the similar results?

Teachers have to be willing to take any path down which the investigation takes them. This is discussed in length in the literature review chapter, and obviously this has an impact on how the tools can be used. Can teachers change or do they always need to be on firm well-trodden ground? Is a change in personality required in order to use the tools effectively or can teachers just use the tools that they are comfortable with the greater, the same or less improvement in the academic attainment of the low attainers.

If this toolbox was delivered as an INSET over 1 day or as a programme with support over one term / one academic year, would it have any effect on the teaching style of the teachers taking part. Would we see teachers changing their relationship with the pupils in the classroom?

How do different teachers use, say, the posters? Do some use them for communication such as described in the case studies whilst others may just use them just as memory aides?

6.5.3 The Pupils

It may also be interesting to consider if this toolbox would be as effective with older pupils such as those in Key Stage 4, taking their GCSEs. These pupils may well have a very different approach to learning to those in Y7. This idea could also be applied to KS2 pupils.

It would be useful to conduct the experiment on parallel sets as with the pilot study. The pilot study analysis returned the greatest improvement results and hence this would suggest that more research into parallel low attainer groups should be undertaken.

In case study 2 some pupils in the second experimental group would not be classed as low attainers according to the definition adopted. Did these pupils have an influence on the low attainers? The peer support tool is one example in which it may have. Further analysis could be conducted on their starting and final attainments of the pupils in this experiment such as:

- Experimental non low attainers v control group
- Experimental group 2 low attainers only v control group
- Experimental group 2 low attainers v experimental group 1 (all were low attainers).

The socio-economic and cultural differences of the pupils in the experiment were discussed but this information was deemed as not relevant for this experiment. Further research on this aspect could be undertaken as in the pilot study greater academic attainment was seen. This was conducted in a state school and a comparison of the socio-economic and cultural differences between schools could be conducted to confirm or refute the idea that more improvement could be made in state schools.

There were day and boarding pupils and it would be interesting to look at if there was any difference in the improved attainment for either of these groups. Pupils who boarded might not have such a great parental influence with things such as help with homework but as we have seen in the thesis, this is not always a positive thing. The negative beliefs held by the parents could cross over to the pupils. On the other hand these pupils do not have as much parental support or, as we have seen, hindrance as ones who go home every night.

At the school in the case studies the SEN department commented that pupils in the low attainers groups in the experiment had improved their academic attainment in other subjects as well as mathematics. It would be interesting to see if this teaching pedagogy could also be successfully applied to low attainers in other subject areas.

And finally, the toolbox could be used to develop a course for INSET in schools. In fact, the author has been invited to deliver INSET using the toolbox on several occasions. On one such occasion this was delivered to 23 science teachers from a consortium of 10 schools who attended the INSET day. This would suggest that similar research in different subjects might warrant further investigation.

So we can see from the above that there are many exciting research possibilities emanating from the study, some of which would build on the findings of this research and some building on other existing research.

In summary, the pilot study results demonstrated unequivocally that the pupils in the experimental group had improved more than their counterparts in the parallel control group. In the more academically rigorous case studies parallel groups were not available. However when the standardised KS2 SATs were used as the baseline then in four out of five instances the experimental groups outperformed the control groups in terms of increased academic attainment. This provides a powerful argument that:

'The academic attainment of low attainers in year 7 (11 – 12 year olds) improves when accelerated learning is used as a teaching pedagogy in the classroom'

It is the hope of the author that this will inspire other teachers (practitioners) to bring research into their classrooms and take the bold step of becoming research practitioners.

Chapter 7 References

Adey P.S, Shayer M. (1994). Really Raising Standards: London: Routledge.

Adhami M, Johnson D, Shayer M. (1998). Thinking Maths, Cognitive acceleration in maths project, (CAME) Heinemen publication, Oxford.

AtKisson A. (1991). The value of playing games, singing songs, listening to stories and how learning is improved by the power of suggestion. An Interview with Libyan Labiosa Cassone by Alan AtKisson The Learning Revolution, Context Institute.

Backhouse J.K. (1989). Better mathematics for low attainers. Educational studies in mathematics Vol 20 (1). Kluwer academic publishers.

Baker S, Gersten R, Dae-Sik L. (2003) A Synthesis of Empirical Research on Teaching Mathematics to Low achieving Students. The Elementary School Journal, Vol 103 (1). Chicargo Journals.

Bancroft J.W. (1978). The Lozanov Method and Its American Adaptations. The Modern Language Journal, Vol. 62. Blackwell Publishing on behalf of the National Federation of Modern Language Teachers Associations

Barnard N. (2005). Special needs: Stretching exercises. T.E.S.Teacher. T.E.S. Publications.

Barnes H. (2005). The theory of realistic mathematics education as a theoretical framework for teaching low attainers in mathematics. Pythagoras, Vol. 61. Association of maths education S.A.

Biggs, E. (1985). Teaching mathematics 7-13: Slow learning and able pupils, NFER-Nelson, Windsor.

Black P. Wiliam D. (1998). Inside the Black Box: Raising Standards through Classroom Assessment. Department of Education and Professional Studies. Kings College. London.

Blatchford P, Galton M, Kutnick P, Baines E. (2005). Improving the effectiveness of pupils' groups in classrooms. ESRC/TLRP final report.

Bloom B S (ed.) (1956) Taxonomy of Educational Objectives, the classification of educational goals Handbook I: McKay. Cognitive Domain. New York:

Boaler J. (1997). Experiencing School Mathematics. Teaching styles, Sex and Setting. Open University Press.

Boaler J. (2009). The Elephant in the Classroom. Teaching Students to love and learn Maths. Souvenir Press. London:

Boaler J, Altendorff L, Kent G. (2010). Complex Instruction in England – the Journey, the new schools, and the initial results. NRICH.org, nrich.maths.org/content/id/7011/CI_Schools_in_UK2.pdf

Bonwell, C, Eison, J. (1991). Active Learning: Creating Excitement in the Classroom AEHE-ERIC Higher Education Report No.1. Jossey-Bass. Washington, D.C.:

Brace N. Kemp R, Snelgar R. (2000). SPSS for psychologists. Palgrave, Macmillan.

Brewer J. (2003).Ethnography in Miller R. and Brewer J. (Eds) The A - Z of social research. SAGE publications. London.

Brewer J, Hunter A. (1989). Multimethods Research: A Synthersis of Styles. Newbury Park, Calif; SAGE publications. London.

Brown G. (1982). The Spoken Language. Linguistics and the Teacher. Routledge and Kegan Paul. London.

Brown M. (2003). What research evidence tells us about effective mathematics teaching for children aged 6 – 13. The proceedings of the quadrennial international congress on mathematics education (ICME9), Makuhari, Tokyo, Japan.

Bruner, J. S. (1961). The Act of Discovery. Harvard Educational Review Vol 31 (1).

Bryman A. (1984). The debate about quantative and qualitative research: A question of method or epistemology? British Journal of sociology, Vol 35 (1).

Bryman A. (2001). Social Research Methods. Oxford University Press.

Bryman A, Bell E. (2003). Business Research Methods. Oxford University Press.

Campbell D.T. (1969). Reforms as Experiments. American Psychologist Vol 24.

Campbell D.T, Stanley J.C. (1963). Experimental: quasi-experimental designs for research on teaching. Handbook on research on teaching, Chicago Rand McNally.

Chin. N. (2006). A longitudinal investigation into the relationships between Malaysian students' preferred learning styles, their perceptions of their classroom environment and their academic achievement. PhD thesis. University of Exeter.

Cockcroft Report. (1982). Mathematics counts Report of the Committee of Inquiry into the teaching of mathematics in schools under the chairmanship of Dr WH Cockcroft: Her Majesty's Stationery Office. London.

Coe, R. (2002). It's the effect size, stupid: what effect size is and why it is important. Paper presented at the Annual Conference of the British Educational Research Association, University of Exeter, England.

Cohen J. (1968). Multiple regression as a general data-analytic system. Psychological Bulletin, Vol 70 (6).

Cohen L, Manion L, Morrison K. (1996). A guide to Teaching Practise. Routledge.

Cohen L, Manion L, Morrison K. (1997). A guide to teaching practice. Routledge Falmer. Taylor and Francis group.

Cohen L, Manion L, Morrison K. (2004). A guide to teaching practice. Routledge Falmer. Taylor and Francis group.

Cohen L, Manion L, Morrisson K. (2007). Research methods in Education. Routledge Falmer. Taylor and Francis group.

Collis K.F. (1978). Chapters 3 and 4 in J.A.Keats, K.F.Collis and G.S.Halford (Eds), Cognitive Development: Research based on Neo-Piagetian approach. John Wiley and Sons. NY.

Cooter K , Robert B. Cooter Jr. (2004). One Size Doesn't Fit All: Slow Learners in the Reading Classroom. The Reading Teacher, Vol. 57.

Cowie, B, Bell, B. (1999). A model of Formative Assessment in Science Education. Assessment in Education, Vol 6 (1).

Crooks T. (2001). The Validity of Formative Assessments. Draft paper presented at British Educational Research Association 27th annual conference. University of Leeds, England.

Crowther D.T. (1995). The Constructivism Zone. Electronic Journal of Science Education, Vol 2 (2).

Denvir B, Stolz C, Brown M. (1982). Low attainers in mathematics 5 – 16. Policies and practices in schools. Schools Council G.B. Working Paper.

DfEE. (1999). Weighing the Baby: Report of the independent Scrutiny Panel on the 1999 Key Stage 2 National Curriculum Tests in English and Mathematics. DfEE Publications.

DfEE. (2001). Key stage 3. National Strategy. Framework for Teaching Mathematics: Years 7,8 and 9. DfEE Publications.

DfEE. (2001). Key stage 3 National Strategy Springboard 7. DfEE Publications.

DfES. (2003). 'Summary of misconceptions' (Statutory Assessment Tests) DfES Publications.

Dowker, A. (2000). 'Numeracy recovery: a pilot scheme for early intervention with young children with numeracy difficulties.' Support for Learning, Vol 16 (1).

Dowker, A. (2004). What works for children with mathematical difficulties? Nottingham: Research report RR554. DfES publications.

Driver R, Oldman V. (1986). A constructivist approach to curriculum development in science. Studies in Science Education Vol 13 (1).

Dunn, S., Matthews, L., & Dowrick, N. (2010). Numbers Count: developing a national approach to early intervention. In I. Thompson (Ed.), Issues in teaching numeracy in primary schools (2nd Edition) Open University Press.

Entwistle N. (2001). In Sterberg R.J. and Zhang L.F. Perspectives on Thinking, Learning and Cognitive Styles. Lawrence Frebaun. London.

Eteach. (2009). http://www.eteach.com/

Fein G. (1979). Echoes from the nursery: Piaget, Vygotsky, and the relationship between language and play. New Directions for Child and Adolescent Development, Vol 1979 (6). Wiley.

Fitz-Gibbon C. (1984). Meta-Analysis: An Explication. British Educational Research Journal. Vol 10 (2).

Fitz-Gibbon C, Tymms P. (2002). Technical and Ethical Issues in Indicator systems. Educational Policy Analysis Archives. Vol 10 (6).

Flick U. (2009). An introduction to qualititive research. Sage Publications, London.

Friend M, Bursuck W. (1996). Including Students with Special Needs: A Practical Guide for Classroom Teachers. Prentice Hall / Allyn & Bacon.

Gathercole S.E, Alloway T.P. (2004a) Working memory and classroom learning. Professional association for teacher of students with specific learning difficulties. Vol 17. University of Durham.

Gathercole S.E, Pickering S.J, Knight C, Stegmann Z. (2004b). Working memory skills and educational attainment: Evidence from National Curriculum assessments at 7 and 14 years of age. Applied cognitive psychology Vol 18 (1).

GATSBY http://www.gtf.org.uk/projects0304ma.htm

Giles D. (1993). Logo with low achievers. Journal of research on computing in education. Vol 26.

Ginsberg, H. (1977). Learning difficulties. In A. Floyd (Ed.) Developing mathematical thinking. Open University Press. London.

Glickman C.D, Gordon S.P, Ross-Gordon J.M. (2003). Supervision and instructional leadership: a developmental approach. Allyn and Bacon. Boston, MA.

Goetz J.P , LeCompte M.D. (1984). Ethnography and Qualitative Design in Education Research. Academic Press. Florida.

Greenfield P. (1997). You can't take it with you: Why Ability Assessments don't Cross Cultures. American Psychologist. Vol 52 (10).

Gross R, McIlveen R, Coolican H. (2000). Psycology, A New Introduction. Hodder & Stoughton.

Gulliford R. (1971). Special Education Needs. Routledge & Kegan Paul Ltd.

Haring N.G, Eaton M.D. (1978). The fourth R: Research in the classroom. Merrill. Ohio.

Haylock D. (1991). Teaching Mathematics to Low attainers, 8-12. Chapman. London.

Hay McBer. (2000). Research into teacher effectiveness: A model for teacher effectiveness. Report to the department for education and skills. London: Hay McBer.

Heller L.R, Fantuzzo J.W. (1993). Reciprocal peer tutoring and parent partnership; Does Parent involvement make a difference? School Psychology Review Vol 22 (3).

Hiebert J, Wearne D. (1996). Instruction, Understanding and Skill in multidigit addition and subtraction. Cognition and Instruction. Vol 14 (3).

Herscovics H, Lincherski L. (1994). A cognitive gap between arithmetic and algebra. ESM 27. Kluwer.

Hokanson B and Hooper S. (2000). Computers are cognitive media: defining the potential of computers in education. Computers in human behaviour. Vol 16 (5).

Jervis A. (2006). Accelerated learning for maths teachers. Dragonfly training. Abbey.

Johnson P, Gott R. (1996). Constructivism and evidence from children's ideas. Science Education Vol 80 (5).

Johnson R.A, Wichern D.W. (2007). Applied Multivariate Statistical Analysis. 6th edition. Pearson Education International. Pearson Prentice Hall. N.J.

Kirschner P.A, Sweller J., Clark R.E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. Educational Psychologist Vol 41 (2).

Kinnear P.R, Gray C D. (1999). SPSS for windows made simple. Psychology press. Taylor and Francis group.

Kutnick P, Ota C, Berdondini L. (2008). Improving the effects of group working in classrooms with young school-aged children: Facilitating attainment, interaction and classroom activity. Learning and Instruction. Vol 18 (1).

Leonard M. (2003). Interviews in Miller R. and Brewer J. (Eds) The A - Z of social research. Sage publications.

Lozanov G. (1978). Suggestology and outlines of suggestopedy. (Trans M. Hall-Pozharlieva & K. Pashmakova). Gordon & Breach, Oxford.

Luria A.R. (1976). Cognitive development: Its cultural and social foundations. Harvard University Press. Cambridge MA.

Mayer, R. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. American Psychologist Vol 59 (1).

Mayers T, DeFreitas S. (2007). in Betham H, Sharpe R, Rethinking pedagogy for a digital age. Routledge. Oxon.

Merriam S.B. (1988). Case Study Research in Education. A Qualitative Approarch. Jossey-Bass Inc. San Fransisco, CA.

Messick S. (1995). Validity of Psychological Assessment. American Psychologist. Vol 50 (9).

Mounoud P. (1981) Cognitive development: Construction of new structures of internal organisation. New directions in Piagetian theory and practice. Hillsdale: Earlbaum.

National Curriculum Council. (1989). Mathematics Non Statutory Guidance. NCC.

Newstead S.E. (1996). The Psychology of student assessment. The Psychologist. Vol 9 (12).

NIST/SEMATECH e-Handbook of Statistical Methods/ http://www.itl.nist.gov/div898/handbook/

Oakes.J. (1989). What education indicators. The case for assessing school context. Education Evaluation and Policy Analysis. Vol 18 (2).

O'Leary R. (2003). Social Surveys in Miller R. and Brewer J. (Eds) The A - Z of social research. Sage publications.

Osborne J.W. Waters E. (2002). Four assumptions of Multiple Regression that Researchers should always test. Practical Assessment, Research and Evaluation. Vol 8(2).

Papert S. (1980). Mindstorms, children, computers and powerful ideas. Harvester. Sussex.

Palmer D. (2005). A motivational view of Constructivist-Informed Teaching. International journal of science education. Vol 27 (15).

Pellegrini A.D, Bartini M. (2000). An empirical comparison of methods of sampling aggression and victimization in school settings. Educational Psycology Vol 92 (2).

Pellegrini A.D. (2001). Practitioners review. The role of direct observation in the assessment of young children. J.Child Psychol.Psychiat. Vol 42(7).

Piaget J. (1952). The child's conception of number. Routledge and Kegan Paul Ltd. London.

Piaget J. (1991). Advances in Child and Adolescent Psychology in Light P, Sheldon S, Woodhead M., (Eds) Learning to Think. Routledge and OUP. Oxford.

Pickering S.J, Gatercole S.E. (2001). Working memory test battery for children. Psychological Corporation. UK.

Pimm D. (1987). Speaking Mathematically. Communication in the classroom. Routledge. London.

Ragin C.C, Becker H.S. (1992). What is a case? Exploring the Foundations of social inquiry. Cambridge University press. Cambridge.

Russell R, Ginsburg H.P. (1984) Cognitive analysis of children's mathematical difficulties. Cognition and Instruction. Vol 1 (2).

Shayer M. (1987). Cognitive acceleration through science education II. Economic and Social Research Council (ESRC). London.

Shayer M. (2003). Not just Piaget, not just Vygotsky, and certainly not Vygotsky as an alternative to Piaget. Learning and Instruction. Vol 13. Elsevier Science Ltd.

Shayer M. and Adhami M. (2006). The long term effects from the use of CAME (Cognitive Accelerated Mathsematics Education), some effects from the use of the same principles in Y1 and 2, and the maths teaching of the future. Proceedings from the British Society for Research into Learning Mathematics. Vol 26 (2).

Shayer M. and Adhami M. (2007). The impact of a thinking skills approach (CAME) on students' mathematical ability. Education studies in Mathematics. Vol 64. Springer.

Shayer M, Adhami M. (2010). Realizing the cognitive potential of children with a mathematics focus. Post-test and long term effects of a 2 year intervention. British Journal of Educational Psychology. Vol 80 (3).

Shepard J. (2003). Sociology and You: Glencoe McGraw-Hill. Ohio.

Shepard L. (1990). Psychometricians' Beliefs about Learning. Paper presented at the annual meeting of the American Educational Research Association. Boston.

Shepard L. (1991). Psychometricians' Beliefs about Learning. Educational Researcher. Vol 20 (7).

Smith A. (1996). Accelerated Learning in Practice. Network Educational Press.

Smith D. (1987). The Limits of Positivism in Social Work Research. The British Journal of Social Work. Vol 17 (4).

Staver J.R, Jacks T. (1988). The influence of cognitive reasoning level, cognitive restructuring ability, embedding ability, working memory capacity and prior knowledge on students' performance on balancing equations by inspection. Journal of research in science teaching Vol 25 (9).

Sternburg R.J. (1997). Thinking styles. Cambridge University Press. Cambridge.

Tabachnick B.G, Fidell L S. (2001). Using Mulitvariate Statistics 4th edition. Pearson Education Company, M.A.

Tashakkori A. (2009). Are we there yet?; The state of the mixed methods community. Journal of mixed methods research. Vol 3 (4).

Thissen D, Wainer H. (2001). Test Scoring. Erlbaum. Mahwah, NJ.

Thom R. (1973). Modern Mathematics: Does it exist ? in A.G.Howson (ed), Developments in mathematics education. Cambridge University Press, Cambridge.

Thomas M. (1993). Comparing theories of child development. 3rd edition. Belmont, California. Wadsworth publishing company.

Thompson B. (1986). ANOVA versus regression analysis of ATI designs: An empirical investigation. Educational and Psychological Measurement, Vol 46 (4).

Topping K. (1998). Peer Assessment between Students in Colleges and Universities. Review of Educational Research. Vol 68 (2).

Topping, K. (2007). Group Work: Transition into Secondary: Full Research Report. ESRC End of award report. RES-000-22-1382. Swindon; ESRC.

Towse J, Cowan N, Horton N. (2003). Response timing in children’s working memory. Research grant report RES-00022-0452.

Vidal, S. (1997). Regression is a Univariate General Linear Model Subsuming Other Parametric Methods as Special Cases. Paper presented at the annual meeting of the Southwest Educational Research Association, Austin.

Vygotsky L. (1978). Mind in society. The development of higher psychological processes. Harvard University Press. Cambridge MA.

Wadsworth B.J. (1971). Piaget’s Theory of Cognitive Development. Longmann.

Warburton K. (2003). Deep Learning and Education for Sustainability. International journal of sustainability in higher education. Vol 4 (1).

Watson A, Mason J. (1998). Questions and Prompts for Mathematical Thinking. Association of Teachers of Mathematics. Derby.

Watson A, De Geest E, Prestage S. (2003). Deep improvement in Mathematics: The Improving Attainment in Mathematics Project. University of Oxford.

Weinert F.E, Helmke A, Schneider W. (1990). Individual differences in learning performance and in school achievement: Some plausible parallels and some unexpected discrepancies. In H. Mandl, E. DeCorte, N. Bennet, H.F. Friedrich (Eds.), Learning and instruction. European research in an instructional context. Pergamon. Oxford.

Wellington J, Osbourne J. (2001). Language and literacy in Science Education. Open University Press.

Wertsch J.V. (1978). 'Variations of adults' directives to children in a problem solving situation. Unpublished manuscript. North-western University. Evanston, IL.

Wertsch J.V. (Ed) (1979). The concept of activity in Soviet psychology. M.E.Sharpe. Armonk, NY.

Wise.D. (2002): Accelerated Learning. C.S.C.S. Broadsheet no 76. www.cchsonline.co.uk/school/teachinglearning/acclearningb.pdf. University of Leicester.

Witzel A. (2000). The problem centred interview. Forum qualitative social research (Online journal) Vol 1 (1). www.qualitative-research.net.

Wood D. (1991). Learning to think. Aspects of teaching and learning. Routledge. The Open University Press.

Woods P.A, Bagley C, Glatter R. (2001). Rejecting schools: Towards a fuller understanding of the process of parental choice, School leadership and management. Vol 21 (3).

Woodward J, Baxter J. (1997). Making the Task Meaningful; Technology, literacy and the instructional needs of students with learning disabilities. Paper presented at the annual meeting of the American Education Research Association, Chicargo.

www.gtce.org.uk/researchofthemonth. (June 2001). Improving learning through cognitive intervention.

www.edu.dudley.implc.co.uk

Yin R, Davis D. (2007). Adding new dimensions to case study evaluations: The case of evaluating comprehensive reforms. In G.Julnes & D.J.Rog (Eds).

Informing federal policies for evaluation methodology.(New directions program Evaluation, No 113,). Jossey-Bass. San Francisco.

Yin R. (2009). Case study Research, design and methods. Applied social research methods series. Sage publications.

Zhang L. (2002a). Thinking styles and the big five personality traits. Educational Psychology. Vol 22 (1).

Zhang L. (2002b). Thinking styles: Their relationship with modes of thinking and academic performance. Educational Psychology Vol 22 (3).

Appendix 1 Analysis of Examination Papers by Element and Tool

The following section details the examination papers used for the internal examinations at Christmas 2005, summer 2006 and Christmas 2006. Each table details the number of marks allocated for the question, the question number, the main element used in the teaching pedagogy for the particular topic and the tools that could be used.

The Christmas 2005 Examination

Calculator Paper	**Question Number**	**Environment**	**Communication**	**Memory**	**Other**	**Tools**
Marks						
2	1		X			Co-Ordinates logic puzzles - complete the square on a grid
3	2	X	X	X		Long Multiplication and division- learnt pedagogy - peer help
7	3		X	X		Addition - placement - HTU - peer help
2	4	X	X			Graph - poster - environment - verbal communication
4	5	X	X			Graph - poster - environment - verbal communication
6	6	X	X			Graph - poster - environment - verbal communication
5	7	X	X	X		Angles at a point, triangle - darts -
3	8	X	X			Angles - corresponding, straight line – darts score- white boards
5	9	X	X			Isosceles triangle, logic problem starters
8	10		X			co-ordinates - logic puzzles – complete the square on a grid
45	total	28	45	15	0	

Non Calculator Paper	Question Number	Environment	Communication	Memory	Other	Tools
Marks						
8	1		X		X	spatial awareness N,S,E,W = walking around the class
3	2		X			drawing angles
4	3		X		X	spatial awareness folding paper shapes / reflection
6	4	X	X			symmetry - white boards- back to back-communication
2	5	X	X	X		long division - learnt pedagogy from junior schools – peer help
6	6			X		centimetres, metres - ml, litres
6	7	X		X		add mult div sub : learnt from primary never changed pedagogy
4	8	X	X	X		units of 10s CAME unit
2	9	X	X			pictograms -posters environment verbal communication
4	10		X			interpreting graphs
45	total	20	33	18	12	

Table 29 The Christmas 2005 Examination Analysis by Element / Tool.

The Summer 2006 Examination

non calculator Paper	Question Number	Environment	Communication	Memory	Other	Tools
Marks						
3	1		X	X		number lines poster
4	2	X	X	X		graph= poster and verbal explanation= communication
4	3	X		X		add mult div sub : learnt from primary never changed pedagogy
3	4	X		X		grams in kilo, scales
2	5		X	X		Range memory, CAME lesson = communication
2	6	X		X		fractions on line - white boards
6	7		X	X		mean median CAME lesson = communication
4	8	X		X		% =memory plus posters =environment
2	9		X		X	rotation = spatial awareness
3	10	X	X	X		angles in triangle, posters, darts example
2	11	X		X		algebra learnt behaviour, posters
2	12		X	X		long multiplication - peer help
2	13	X		X		algebra learnt behaviour, posters
4	14	X	X	X		angles in triangle, posters, darts example
2	15				X	Ratio (topic not covered)
45	total	28	26	41	4	

Calculator Paper	Question Number	Environment	Communication	Memory	Other	Tools
Marks						
3	1		X		X	Spatial awareness -draw hexagon
4	2		X	X		Number placement - HTU - peer help
3	3	X			X	Money problem
5	4		X	X		Reading scales - algebra - learnt behaviour, posters
4	5	X				spatial awareness -faces shapes in classroom
5	6	X	X	X		triangle properties, angles in triangle, darts, posters
3	7	X	X	X		long div, % - junior school, white boards.
4	8	X		X		approximations - % - white boards, starters
7	9	X	X	X		interpreting graphs - peer communication – posters
3	10	X				algebra simplifying, substitute – white boards
4	11	X	X	X		order of operation - starters
45	total	33	31	32	6	

Table 30 The Summer 2006 Examination Analysis by Element / Tool.

The Christmas 2006 Examination

Calculator Paper	Question Number	Environment	Communication	Memory	Other	Tools
Marks						
1	1	X	X	X		Addition subtraction of decimals-learnt pedagogy – peer help
2	2	X	X	X		Subtraction monies - placement - HTU peer help
3	3	X	X	X		Percentages posters
1	4		X			Fraction of an amount peer help
7	5	X	X	X		Fractions to decimals posters
4	6		X	X		Fraction of an amount white boards
8	7	X	X	X		Mean median mode CAME lesson verbal communication
4	8	X	X			Substitution algebra white boards learnt behaviour
2	9	X	X	X		Change fraction to percentage posters white boards
2	10	X	X			Sequences posters
3	11	X	X	X		Comparing fractions and percentage reduction posters
3	12				X	Trial and error
40	total	32	37	30	3	

Non-Calculator Paper	Question Number	Environment	Communication	Memory	Other	Tools
Marks						
2	1	X	X			Sequences posters
4	2	X	X	X		Addition subtraction of decimals-learnt pedagogy – peer help
2	3	X	X	X		Subtraction monies - placement - HTU peer help
2	4	X	X			Area perimeter - poster - environment verbal communication
2	5	X	X			Cancelling fractions - environment verbal communication
3	6	X	X	X		Mode median - CAME lesson verbal communication
3	7	X				Probability Posters
4	8	X	X			Simplifying algebra white boards learnt behaviour
4	9	X	X			Substitution algebra white boards learnt behaviour
4	10	X	X			Sequences posters
2	11	X	X			Compound area
2	12	X	X			Substitution learnt behaviour white boards
6	13	X	X	X		Adding subtracting fractions
40	total	40	37	15	0	

Table 31 The Christmas 2006 Examination Analysis by Element / Tool.

Appendix 2: Examination Paper Analysis Graphs

Below graphical analysis of the questions on the examination papers are shown. The proportion of marks from questions associated with each of the 3 elements are shown as percentages of the overall total, e.g. in the Christmas 2005 calculator exam, although 100% of the 45 mark total were associated with communication, there were also 28 marks associated with environment and 15 associated with memory. Overall communication accounted for (45 / (45+28+15), i.e. 51% of the paper.

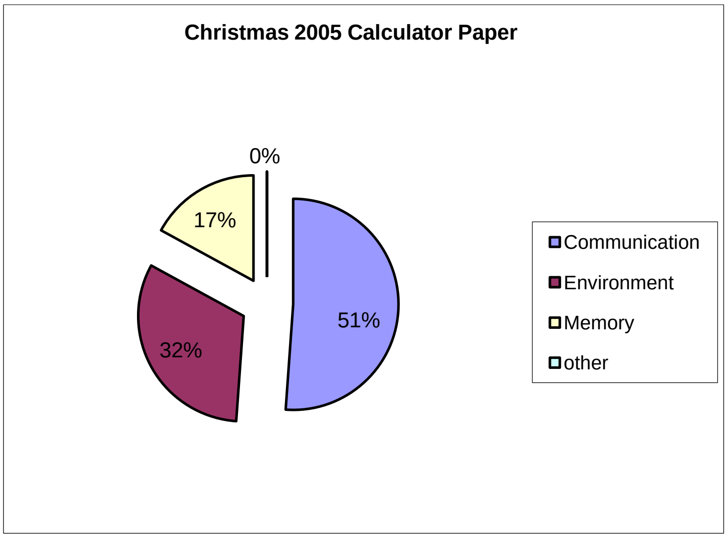


Figure 52 Christmas 2005 Calculator Examination Paper Analysis.

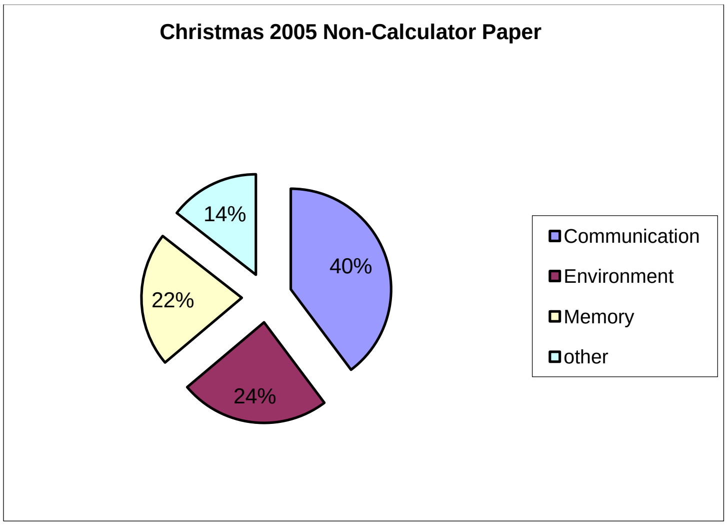


Figure 53 Christmas 2005 Non -Calculator Examination Paper Analysis.

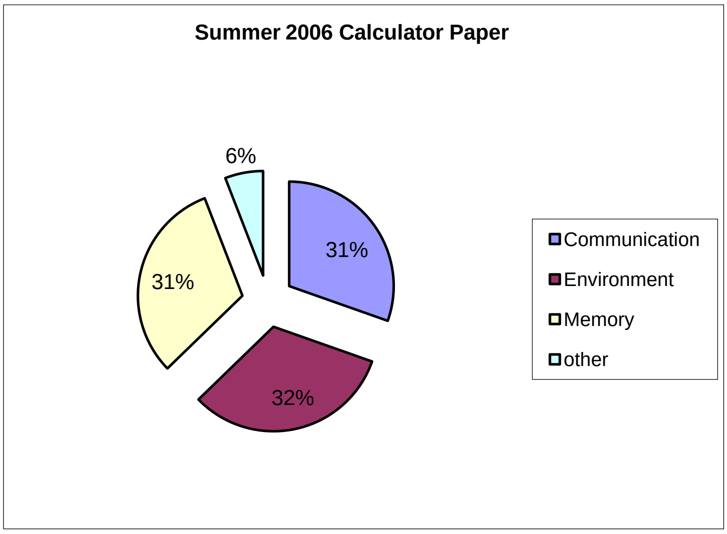


Figure 54 Summer 2006 Calculator Examination Paper Analysis.

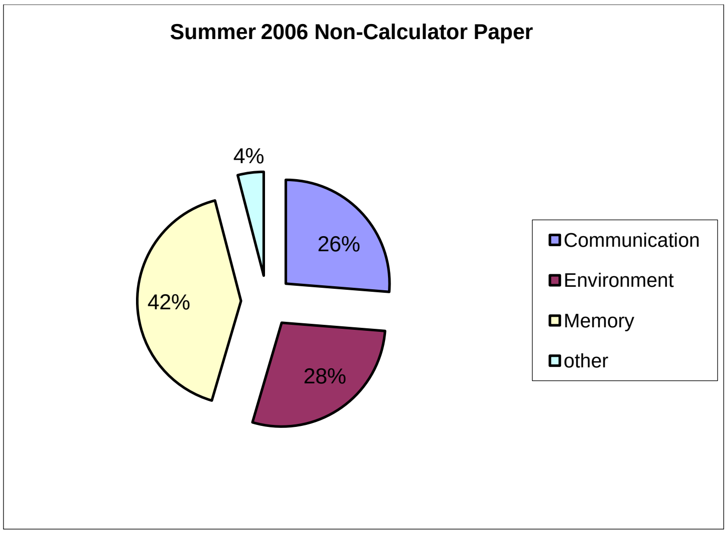


Figure 55 Summer 2006 Non-Calculator Examination Paper Analysis.

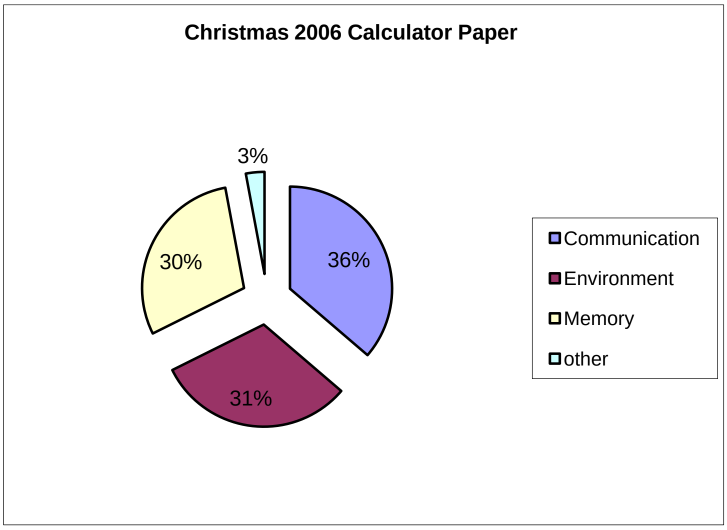


Figure 56 Christmas 2006 Calculator Examination Paper Analysis.

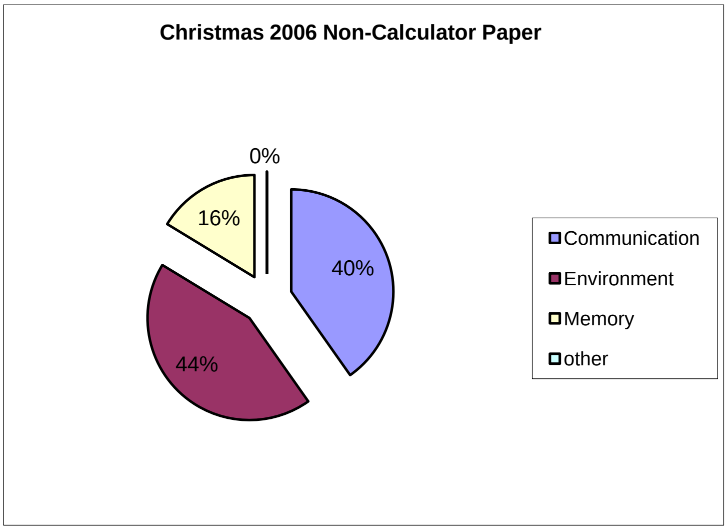


Figure 57 Christmas 2006 Non-Calculator Examination Paper Analysis.

	Christmas 2005		Summer 2006		Christmas 2006	
	Calc	**Non-Calc**	**Calc**	**Non-Calc**	**Calc**	**Non-Calc**
Communication	51%	40%	30%	26%	37%	40%
Environment	32%	24%	33%	28%	31%	44%
Memory	17%	22%	31%	42%	29%	16%
Other	0%	14%	6%	4%	3%	0%

Figure 58 Analysis of Examination Results all Papers as a Percentage.

Appendix 3 Case Study 1 Statistical Analysis

Excluding the Outliers

Case study 1 excluding outliers

Due to the concern that the outliers might be disproportionately affecting the analysis it was thought prudent to perform the analysis excluding these pupils. The following section contains this analysis.

We will see from the skewness statistics below that the data including the outliers returned a skewness value of –0.861. Whilst this would not be considered too extreme to use in the following SPSS analysis it is close to the –1 limit described by Brace et al (2000). Excluding the outliers the skewness value reduces to -0.258 and hence it was decided to perform the analysis excluding the two outliers identified above in order to confirm the robustness of the results of the analysis. It should be noted however, that as the KS2 SATs results for these pupils was not known any analysis based on this baseline would produce the same results as the analysis above.

Skewness

The normal distribution bell curve shows a negative skew and hence the data is skewed to the right for the KS2 SATs. The other values are close to zero showing that the data is only slightly skewed in any direction. The values are all between 1 and –1 and hence can be used in the analysis. This can be clearly seen in the table below.

Test	Case study 1 including outliers Skewness Statistic	Case study 1 excluding outliers Skewness Statistic
Christmas 2005	-0.861	-0.258
Summer 2006	-0.393	-0.246
Baseline (KS2 SATs + Entrance)	-0.768	-0.267
KS2 SATs	-0.829	-0.829
Entrance	-0.682	0.089

Table 32 Case Study 1. KS2 SATs and Entrance Test Skewness Statistic including and excluding Outliers.

7.1.1.1 **Mean and standard deviation**

The first set of analysis compares the experimental group's mean and standard deviation without the outliers against the control group. As the 2 outliers did not have a KS2 SATs result please refer to case study 1 for any analysis reliant on KS2 SATs results.

Without outliers.	Entrance Test	Christmas 2005 Examination	Summer 2006 Examination
Mean			
Experimental Group	34	62	39
Control Group	52	72	60
Standard Deviation			
Experimental Group	4	10	10
Control Group	8	9	9

Table 33 Case Study 1. KS2 SATs and Entrance Test Mean and Standard Deviation excluding Outliers.

Here we can see that there was a difference in the mean of the starting benchmark's attainment of the entrance test. The experimental group's mean was 34 as opposed to the control group's mean of 52. However, this is not surprising as the sets were not parallel. There was a standard deviation of 4 for the experimental group and 8 for the control group. This means that the experimental group's marks ranged from 30 to 38 within 1 standard deviation and the control group's marks ranged from 44 to 60 also within 1 standard deviation.

When we compare this with the Christmas 2005 examination results we can see that the experimental groups' mean was 62 and the range given within 1 standard deviation is 52 to 72. The control group's mean was 72 in the same examination with a range for 1 standard deviation of 63 to 81 showing a much larger dispersion for the control group. This can be seen pictorially on the following chart that shows the mean and 1 standard deviation for both the experimental and control groups.

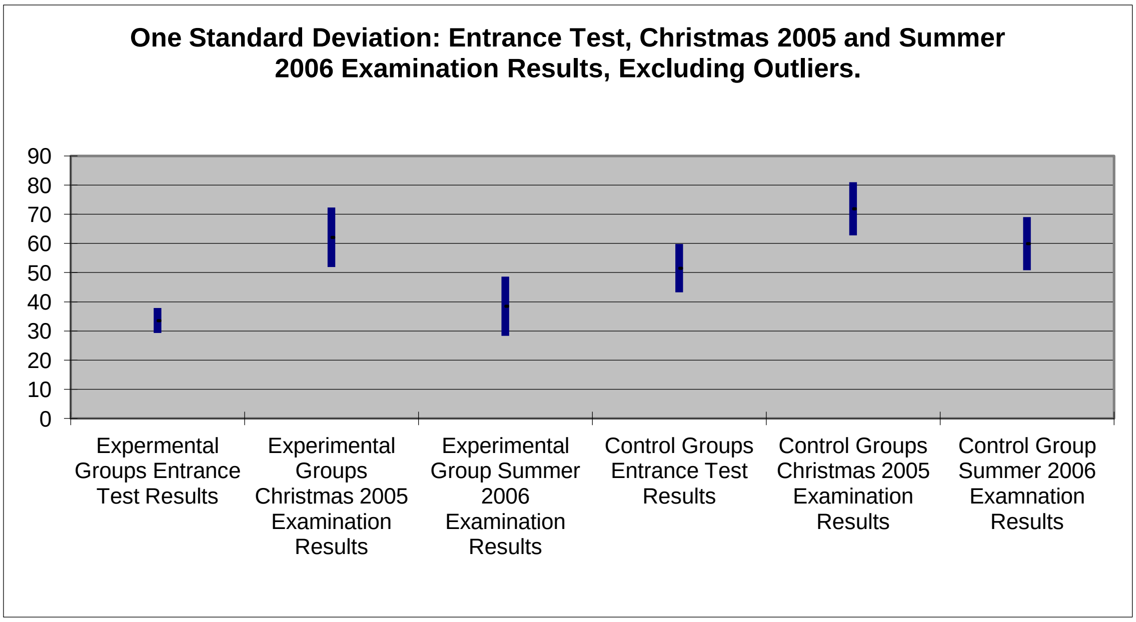


Figure 59 Case Study 1. Entrance Test One Standard Deviation Christmas 2005 and Summer 2006 Examinations excluding Outliers.

So we can conclude that the experimental group's 1 standard deviation range was much smaller than the control groups' and the mean was much lower showing that the experiment groups' starting attainment benchmarks were much closer than the control groups. This changed by the Christmas 2005 examinations where the increase in the mean for the experimental group shows a greater improvement than the mean for the control group. However there is also a greater range in the 1 standard deviation for the experimental group's Christmas examination than for its entrance test. The control group's range has also changed to be less in the Christmas examination than in the entrance test. Here we can see that the experimental group obtained a larger range of results at Christmas than they had started with in their entrance test results.

The standard deviation has changed in the experimental group now that this does not contain the outliers. It is now 4 as opposed to the control group's 8. The KS2 SATs results have not changed, as there was no data for the outliers available. The standard deviation in the Christmas 2005 examinations has gone down without the outliers and is now in-line with the control group, likewise the results for the summer examinations.

7.1.1.2 Scatter graphs

The following scatter graphs show pictorially the entrance test results v the Christmas 2003 and summer 2006 examinations, excluding the 2 outliers.

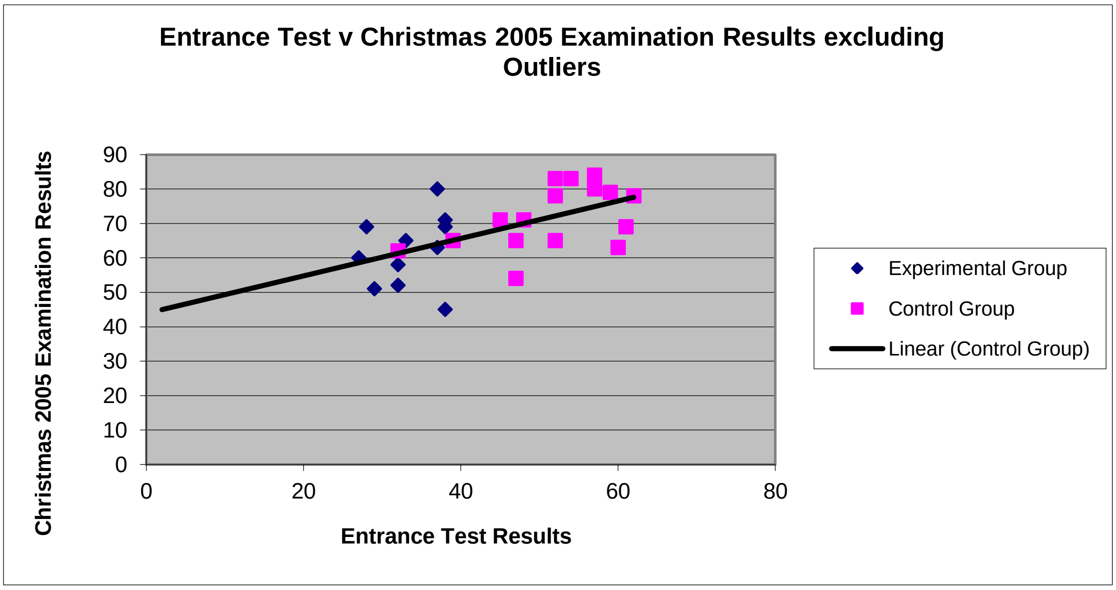


Figure 60 Case Study 2 Scatter Graph with Regression Line. Entrance Test v Christmas 2005 Examination excluding Outliers.

On this first scatter graph, it is not clear if the experimental group have made an improvement in their academic attainment when considering the linear control group line and hence the reader should consult the ANOVA and linear regression detailed below.

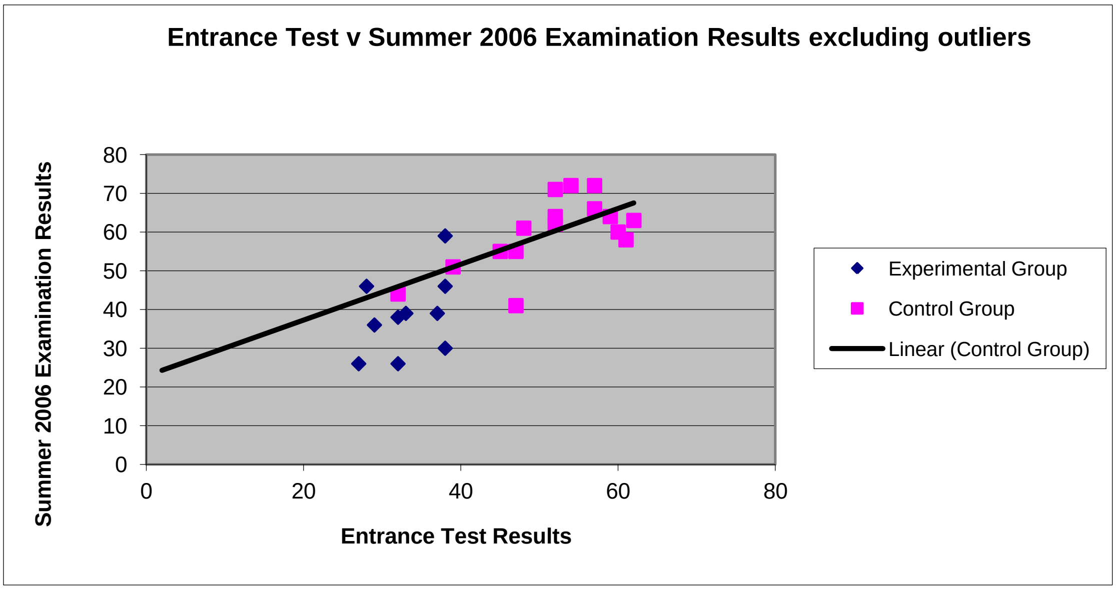


Figure 61 Case Study 1 Scatter Graph with Regression Line. Entrance Test v Summer 2006 Examination excluding Outliers.

However on the scatter graph above it is clear that there was no improvement in the experimental group's academic attainment when compared to the control groups.

7.1.1.3 ANOVA excluding the outliers

We have seen that there is a normal disruption to the data without the outliers and that there is a strong relationship particularly between the KS2 SATS and the Christmas 2005 and summer 2006 exams. Next I performed the ANOVA analysis with the null hypothesis that based on the starting attainments:

- there is no difference between the experimental and control groups exam results in the Christmas 2005 exams.

	Christmas 2005 Significance	Summer 2006 Significance	Christmas 2005	Summer 2006 F Value
Excluding outliers				
KS2 SATS	.005	.000	7.918	22.052
Entrance test	.007	.000	6.195	27.087
KS2 SATS & Entrance test	.000	.000	12.419	42.853

Figure 62 ANOVA Analysis Case Study 1

We can see from the table above that there were no instances where the null hypothesis was proven as all significances, or p-values, were below 0.05 and hence that there was a difference in case study 1 for all ANOVA performed. The entrance test v the Christmas 2005 exam showed the greatest significance at 0.007 and the KS2 SATS v the Christmas 2005 exams was calculated at 0.005, but both of these are again short of the 0.05 which would have made the null hypothesis acceptable. The KS2 SATS results again have not changed due to the 2 pupils not having a KS2 SATS result to add to the data analysis.

The high F values also demonstrate that the null hypothesis should be disregarded. as most values are large. The Christmas exams 2005 had 2 values that were less than 8 however these are within the critical F values for rejecting the null hypothesis.

We have seen that there is a strong correlation using the combined baseline of the KS2 SATS and entrance test, and has the highest F values. This indicates that the combined baseline would offer the most reliable analysis, with the KS2 SATS being the next most reliable.

Next the linear regression is performed on the data.

7.1.1.4 Linear regression

Assumptions

Below are the results of the analysis of the 3 assumptions described earlier in the methodology and case studies chapters.

Christmas 2005 Examination Results

Entrance Test Assumption Graphs

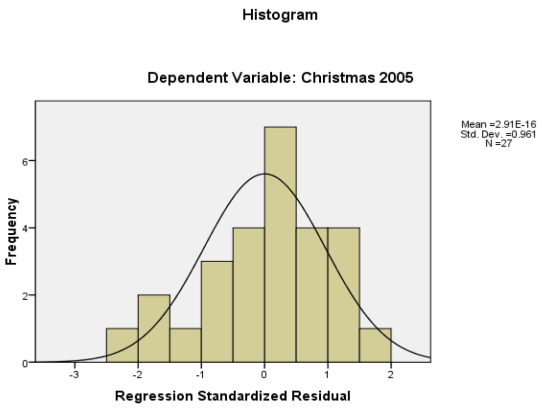


Figure 63 Case Study 1 excluding Outliers. Christmas 2005 Examinations. Entrance Test Normal Distribution Residual Errors.

There is a normal distribution to the residual errors as shown above.

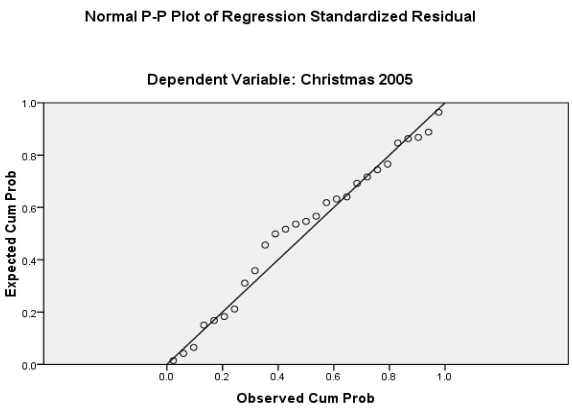


Figure 64 Case Study 1 excluding Outliers. Christmas 2005 Examinations. Entrance Test P Plot of Regression Standardised Residual.

Here again we can see the data points are collected around the central line indicating normal distribution.

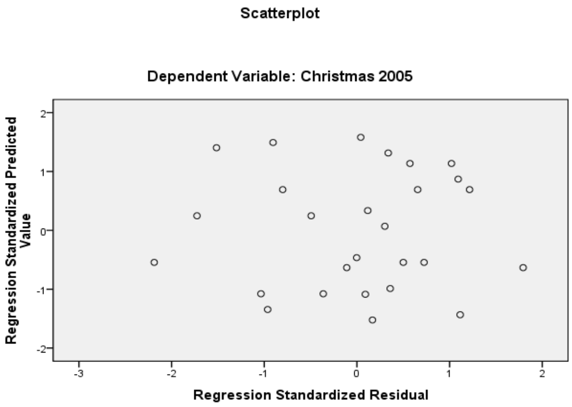


Figure 65 Case Study 1 excluding Outliers. Christmas 2005 Entrance Test P Plot of Regression Standardised Residual.

The above shows an even distribution of the errors and therefore homoscedasticity.

Summer 2006 Examination Results

Entrance Test Assumption Graphs

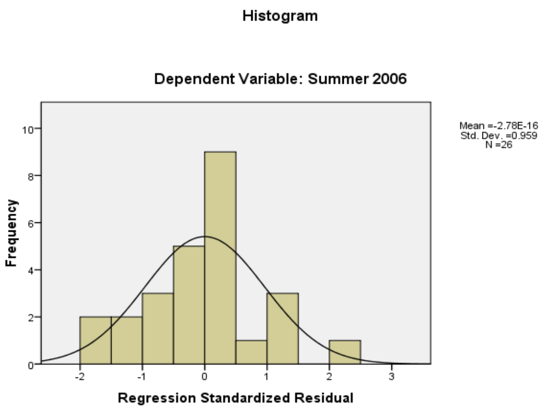


Figure 66 Case Study 1 excluding Outliers. Summer 2006 Examinations. Entrance Test Normal Distribution Residual Errors.

Again there are sections in the above graph that do not support normal distribution of the residual errors however the graphs below do support the use of linear regression.

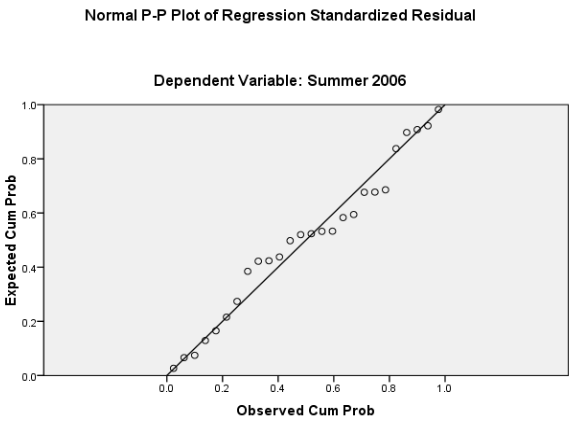


Figure 67 Case Study 1 excluding Outliers. Summer 2006 Examinations. Entrance Test P Plot of Regression Standardised Residual.

A similar pattern again can be seen here where the data points are collected around the central line indicating normal distribution.

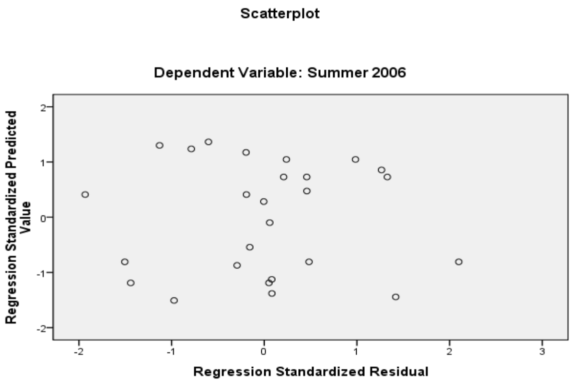


Figure 68 Case Study 1 excluding Outliers. Summer 2006 Entrance Test P Plot of Regression Standardised Residual.

Again here we can see a reasonably even distribution and therefore homoscedasticity and hence the results show that linear regression would be valid for case study 1 excluding the outliers.

Linear Regression Results

Linear regression co-efficients are shown in the table below for the entrance test as a baseline only.

Summary of Results Table for the group number co-efficients

Baselines Excluding outliers	**Christmas 2005 Co-efficients**	**Statistical Significance**	**Summer 2006 Co-efficients**	**Statistical Significance**
Entrance Test	**-0.055**	**0.993**	**7.662**	**0.166**

Table 34 Case Study 1. Linear Regression Co-efficients including Outliers.

We can see from the above table that there was a small negative co-efficient for the Christmas 2005 examination results demonstrating that the experimental group did improve up to the Christmas 2005 examinations. The entrance test showed a positive co-efficient, as it had with case study 1 including the outliers, and hence it can be concluded that the experiment did not have a positive effect in the summer 2006 term.

We must again here consider the statistical significance of these results. We have seen that according to Fitz-Gibbon (1984) a statistical significance of 0.05 is noteworthy and in the above where the entrance test is compared to the Christmas 2005 and summer 2006 examinations there is no statistical significance between the performances of the groups.