DEVELOPING AUTONOMY THROUGH EFFECTIVE TEACHING AND LEARNING IN SECONDARY SCIENCE FOR ABLE PUPILS

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Abstract

This research arose from a deep concern regarding the falling numbers of able pupils who choose to study the physical sciences beyond GCSE. The research investigates the impact of the teaching and learning methodologies used in secondary school science on the attitudes and aspirations of able pupils towards the study of science and whether enabling a more autonomous role in the classroom might be beneficial.

The mixed-methods research design had two phases. The first phase surveyed year 9 pupils and their science teachers across three comprehensive schools in Staffordshire. The second phase was an action research study involving the researcher working with the science department in a fourth Staffordshire comprehensive school over the following academic year.

The findings of the initial phase of the research indicated that able pupils were disaffected with the science education that they received in school. Evidence from this phase of the research suggested that the didactic nature of teaching and learning in the science classroom was partly responsible for failing to inspire the ablest pupils to further study of science. The action research classroom interventions offered more autonomous learning opportunities for able pupils within science lessons. The impact of the action research on the pupils was a reported preference for the 'ownership of task' afforded to them in the classroom and an increased uptake of the option to study science at advanced level. The impact on the science teachers was a greater awareness of the importance of *how* they teach as distinct from *what* they teach. It supports a constructivist approach to the learning and development of both pupils and teachers, showing that serious reform of teacher initial and continuing education is needed if progress is to be widespread

The implications of this research inform the ongoing debate regarding 'best provision' for able pupils in science; but a greater significance is that it also informs a model of 'best provision' for the urgent continuing professional development of science teachers. This research is particularly relevant to recent government policy on both science education and on the provision for gifted and talented pupils.

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Introduction

1.1 A Crisis in Science Education?

The introduction of the National Curriculum for Science in 1989 changed the way in which science subjects were taught up to the age of sixteen in U.K. schools. No longer were physics, chemistry and biology to be routinely taught and assessed as discrete subject disciplines. Instead they were to be amalgamated into an overarching science qualification along with elements of earth science and astronomy. At the time the move was greeted enthusiastically by those who saw it as a solution to teacher shortages in specific science areas.

One consequence of the change was to remove any element of choice from most pupils under 16, over which science disciplines they studied. It also enabled specialist teacher shortages to be masked since more science teachers were required to teach all sciences regardless of their individual specialism. Another unforeseen consequence of the introduction of the National Curriculum for Science (DfEE, 1999a) was that it disadvantaged able children. At a national conference on exceptionally able children, organised by the Department for Education, Pyke (1993) reported that teachers of very able children had told Sir Ron Dearing, who had been charged with proposing modifications to the National Curriculum, that the overload of material prevented able children from developing quality and depth in their thinking. Teachers felt that it should not be a race to get through the curriculum content, but that there should be time for pupils to investigate and build their capacity for creative thinking (Montgomery, 1996).

Recent policy changes in 2007 have reversed this trend; curriculum content has been slimmed down and pupils gaining a National Curriculum attainment level of 6 at the end of key stage 3 are to become entitled to study the separate sciences at key stage 4 (DfES, 2006b). However the specialist teachers to teach the physical science subjects are still in short supply (Smithers and Robinson, 2006) with 24% of 11 – 16 comprehensive schools not having a single teacher who has studied physics to any level at university. The importance of specialist teachers has been highlighted by

Ofsted (1998), who report a positive relationship between specialist knowledge and enthusiasm of teachers and higher pupil attainment. Worryingly the numbers of specialist physics teachers has declined by 46.4% between 1984 and 1996 and specialist chemistry teachers by 39.2% (The Royal Society, 2007). To reverse this decline more graduates and 'A' level students in both of these subjects will be needed.

The motivation for this research has arisen from a growing sense of unease regarding the success of science education in secondary schools. One of the reasons for this unease is founded in publications of figures regarding the numbers electing to take science subjects at Advanced level, at degree level and then to pursue training as science teachers for the next generation. Is this the legacy to the next generation for the introduction of the National Curriculum for Science? In an article published in the Times Educational Supplement (Slater and Lepkowska, 2005) Mike Tomlinson, a former Chief Inspector of Schools and the president of the Association for Science Education maintained that health and safety concerns, the National Curriculum and tests were turning pupils off science.

"We need to find ways to put back creativity and a bit of risk-taking into science teaching. It is ironic that since the point at which science was made a compulsory subject we have seen fewer students go on to study physical science at degree and 'A' level. We have a huge problem." (Slater and Lepkowska, 2005, p.11)

In 2005 physics and chemistry 'A' level entries were 35.2% and 12.6% lower than in 1991 despite an increase of 12.1% in overall 'A' level numbers and many university physics and chemistry departments closed (Jenkins, 2006). In March 2006, The Royal Society held a conference in London which reported on,

> "The Society's deep concerns over the dramatic decline, ongoing since 1991, in the numbers of young people opting to pursue A-levels in the physical sciences." (Hyam, 2006, p. 2)

The report concluded that the losses occur throughout the education system but most particularly at ages 16, 17 and 18 when young people are able to exert choices about the subjects that they study. DfES (2006a) figures reveal that, whilst the number of pupils achieving a science GCSE grade A* to C rose by 8.7% from 2002 to 2004 the number achieving a physics 'A' level over the same period fell by 3.7%. The implication is that although more young people are passing science GCSE at a good standard, fewer are inclined to take physical science subjects to 'A' level. The question arising is, why is the study of science in secondary school failing to inspire the ablest pupils to take further the study of physical science to 'A' level and degree level? Could this have something to do with the way that science is being taught in our secondary schools? The rise in the number of pupils achieving GCSE A* to C grades may be indicative of a rise in 'teaching to the test' methodologies in the classroom. The fall in the number of pupils aspiring to study physical sciences any further than GCSE may also indicate that this approach does not motivate large numbers of pupils to the further study of physical sciences.

Why is it important for pupils to continue to higher levels with the study of science? The benefits of a higher level science education can be considered in terms of both benefits to the individual and benefits to wider society. For the individual a scientific education can lead to a deeper understanding of scientific global issues, a facility with an increasingly technological society, a greater degree of career choices and improved financial prospects, an enjoyment of science and an intrinsic appreciation of scientific challenges. For wider society the benefits can be considered to be benefits to the economy, less reliance on a pool of overseas talent for innovation and development in industry and an improved pool of specialist teachers.

The Science and Innovation Investment Framework 2004 – 2014 (DfES, 2006b) emphasised the importance of a strong supply of scientists, engineers and technologists in order to support further U.K. research and development initiatives and set targets of year on year increases in the numbers of young people taking 'A' levels in physics, chemistry and mathematics. In order to do this it was recognised that there was a need to improve the achievement of pupils at both Key Stage 3 and GCSE and to increase the numbers of teachers with a specialism in the physical sciences. However whilst this framework spelt out what needed to be done it shied away from how such outcomes were to be achieved at classroom level, leaving that in the hands of educationalists and teachers rather than politicians.

It would seem that there is a particular need to focus on our best and brightest pupils in schools and to find out why they are not motivated to higher study by the science education that they are receiving. Work done by the National Association for Gifted and Talented Youth (NAGTY) (Eyre, 2007a) suggests that what works for these pupils is a very specific intervention in order to avoid underachievement. However, the degree of understanding of this need amongst teachers is not widespread and provision for the most able pupils within schools is patchy, with many schools concentrating GCSE resources on grade C/D borderline achievers in the interests of improving performance figures. One of the purposes of this research is to look at the current situation in schools with a view to evaluating current practice and suggesting an improvement paradigm.

1.2 The aims and objectives of the research

In this thesis the following research questions are addressed:

1. What is the impact of teaching and learning methodologies utilised in the science classroom on the attitudes and aspirations of able pupils in science?
2. How might teachers be supported in changing their practice in the science classroom towards the adoption of more autonomous teaching and learning methodologies for able pupils?

In pursuing the answers to these research questions the research design focussed upon three pertinent objectives. These were:

1. To assess the attitudes of able pupils and their teachers towards the teaching and learning methodologies currently used in science classrooms.
2. To evaluate whether the promotion of teaching and learning methodologies, which enable able pupils to have more autonomy in the science classrooms, may improve attitudes and aspirations towards the continued study of science.
3. To investigate whether school based action research may prove to be an effective means of achieving the continued professional development of teachers towards improved classroom practice.

At the outset of this research, in the summer of 2003, the National Strategy for Science (DfES, 2007a) had not yet been envisaged and over the following five years, as my research has progressed, many of its findings have been echoed within national policy ‘personalised learning’ innovations. This synergy with large scale, government funded research lends validity to the research findings discussed here. Whilst this research was only ever aimed towards informing local practice for initial teacher education and continuing professional development, the credibility of its findings has been greatly strengthened by the commonality of issues raised with those that feature on the national agenda for school improvement.

1.3 Learning lessons from the past

Since the introduction of the National Curriculum for Science in 1989 there has been a steady decline in the uptake of sciences, particularly physical sciences post 16 (Hyam, 2006). Our ablest pupils are not being inspired by the science education that they receive in school to continue into higher education courses or careers in science (Jenkins, 2006). One inevitable consequence of this downturn in interest in physical science education is a lack of specialist teachers for the current generation of pupils in schools. If able pupils do not have able teachers to inspire them then this downward spiral will be perpetuated.

The extensive body of literature on accurate identification and specialised provision for able pupils in science education (e.g. Guilford, 1950; Renzulli, 1977; Eyre, 1997; Freeman, 1998; Urban, 2003; Campbell et al, 2004a; Eyre, 2007a; Taber 2007d) is reviewed in chapter 2 of this thesis. Opinions are divided upon what constitutes 'best evidence' for identification and what form 'best provision' should take. Within the literature review the variance of this opinion and the evidence presented to support the arguments put forward are further analysed. For the purposes of the research carried out in this study two categories of 'ability' are defined. The interpretation of 'giftedness' is taken to apply to the small population of pupils who demonstrate exceptional *domain-specific ability* in science. However, since this constitutes a very small sample of pupils, and the use of such small samples may threaten the validity of the research, it was felt necessary to focus on a larger sample of 'top set' pupils, who were identified by their schools, on the basis of cognitive attainment tasks and teacher nomination, as having a '*general ability*', which may not necessarily be science specific. Since the identification of such pupils may be a contentious issue (Freeman, 1998) it was decided to adopt an 'identification by provision' model (Taber, 2007d), which was inclusive of pupils who were not on the school gifted and talented register.

Much of the previous literature on provision for able pupils has dealt with this issue by considering the needs of these pupils in isolation from the needs of their classroom teachers. The provision of out of school enhancement activities has often excluded the classroom teacher and has been found to have little impact upon classroom practice (Ofsted, 2001). Whilst research does exist which looks at the development of the teacher alongside the development of the pupil (Pedder, 2006), such studies are less common than those which look at provision for able pupils alone or professional development for teachers in isolation. In the light of this it was felt that it was important that the primary focus for this research should be upon what takes place within the classroom. This does not deny the worth of out of classroom enhancement activities but recognises that the major impact upon pupils is what happens within the classroom (Eyre, 2002) and it is there that attention needs to be focussed.

Much of the teaching taking place within secondary science classrooms is didactic in nature (Miller and Osborne, 1998; Pomerantz and Pomerantz, 2002; Black et al, 2006). There is evidence that this style of teaching is not the most effective for able pupils because it denies them ‘ownership’ of their learning (Gilbert, 2006). A wealth of research literature on teaching and learning methodologies for able pupils in science is reviewed within chapter 3 and the arguments for the relative effectiveness of these methodologies, in a variety of contexts, analysed. One important common finding emerging from previous research is the value that able pupils place upon autonomous learning (e.g. Adey, 1991; Montgomery, 1998; Fisher, 2004; Black et al, 2006; Watts and Pedrosa de Jesus, 2007). However this is not to be misinterpreted.

Autonomous learning does not mean that able pupils can be just left to ‘get on with it’, as many teachers may be tempted to think (Sisk, 1987). There is a need to scaffold the learning (Vygotsky, 1978) of able pupils using constructivist teaching and learning techniques just as much as is the case for other, less able pupils (Duit, 1994). Unfortunately many teachers are not cognisant of the special needs of able pupils and some consider that specialist provision is elitist (Eyre, 2007b). There is a need for teachers to have a better understanding of their role in providing a facilitative learning environment within which their able pupils may flourish. This will generally not be achieved by positivist approaches, which deny pupils access to the processes of genuine scientific enquiry (Eyre, 1997; Murphy et al, 2001; Warwick and Stephenson, 2002; Hodson, 2003; West, 2007). The conflict experienced by teachers between the temptation to use positivist methodologies to ‘get through the work scheme’

(Lorsbach and Tobin, 1997; Rutland, 2005; Taber, 2007d) and the beliefs that they may hold regarding the value of constructivist teaching and learning methodologies in promoting more meaningful learning for their pupils, is debated within chapter 3.

It is hardly surprising that able pupils are not aspiring to become scientists if they are not being introduced to the nature of genuine scientific enquiry in the classroom. However, effecting culture change within classrooms is not easy (Marshall et al, 2006a; Pedder, 2006; Scott, 2007) and although an increasing number of government strategies are aimed towards this end (DfES, 2006a; DfES, 2007a), it is unlikely to result in change unless teachers are first convinced of the need for change. Thus embedding autonomous learning into classroom practice is likely to depend on a good supply of quality teachers who are capable of reflecting on their practice and have high levels of subject expertise. Such science teachers are in short supply. What kind of professional development experience is likely to assist in developing such teachers? There is some evidence (Maker and Schiever, 1982; Shayer, 1996; Boaler, 1997; Bayliss et al, 2003; James et al, 2006; Taber and Riga, 2007; DFES, 2007b) that teacher engagement in action research within their own context may be effective in helping teachers to become reflective practitioners. Previous initiatives which have involved action research methodology, are described within chapter 3 and have been influential in deciding to adopt an action research strategy for the second phase of this research project.

In chapter 4 a full exploration of what is meant by ‘autonomous learning’ is carried out. The advantages of teaching and learning methodologies which promote autonomous learning, are outlined and the impediments to embedding such methodologies within the classroom are described. Autonomous learning involves the learner in taking responsibility for their own learning, exercising decision-making powers in the classroom regarding how to develop their learning and being able to evaluate their own progress. One advantage of autonomous learning is that able pupils find it more motivational than teacher-directed learning methodologies (Kanevsky, 1990; Rimm, 1995; Martin, 2002). When pupils can access their learning through contexts that are more relevant to their own experience, then their learning has greater personal meaningfulness and becomes more deeply embedded within their understanding (Brown, 1989). Another advantage is that it involves able pupils in the metacognitive process, which is reported by Shore et al (2003) to stimulate cognitive pathways. One might ask why, if there are such advantages to autonomous learning, it is not embedded into the teaching and learning methodologies utilised within most classrooms.

There are a number of impediments to the adoption of autonomous learning methodologies and these are considered at the conclusion of chapter 4. The major identified impediments are the perception amongst teachers that such methodologies are incompatible with the programme of study for National Curriculum science; the perceived dichotomy between enquiry based learning and pre-ordained science and the lack of experiential base for some pupils to access the more difficult abstract concepts. Indeed a number of teachers may argue that constructivist techniques are unsuitable because they rely on a sound basis of pre-existing knowledge, which can often be absent or flawed. There is also a danger that failure on the part of pupils to make progress towards the planned learning outcomes, risks damaging pupil self esteem and the temptation in such circumstances is for the teacher to take over and teach the 'right' concepts didactically. Motivation is closely allied to the expectancy of success (Good and Brophy, 1994) and those pupils who do not experience immediate success can lose motivation.

Many pupils may not be ready to take responsibility for their learning and may find the expectation that they should, intimidating (Renzulli and Gable, 1976; Zimmerman and Martinez-Pons, 1990). However, other research (Scruggs and Mastropieri, 1998) has shown that when teachers are able to apply autonomous learning strategies pupils can be assisted to acquire independent study skills. Thus despite the impediments, it is a desirable outcome that teachers should be helped to move towards the adoption of autonomous learning strategies for able pupils as an important *addition* to their repertoire of teaching skills. The consensus of opinion is that autonomous learning practices produce more mature work habits, self reliance and motivation for further study (Taylor and Fraser, 1991; Tretten and Zachariou, 1995; Poncini and Poncini, 2000; James et al, 2006, Pedder, 2006). If this is the case then perhaps teaching and learning methodologies, which promote pupil autonomy, may go some way towards remedying the disaffection for science education, which previous research has reported to be evident amongst able pupils in secondary schools.

1.4 Decisions regarding research design

Before decisions were taken regarding the most appropriate research design to employ in carrying out this research, it was felt necessary to inform such decisions by reviewing the methodologies used in previous, related research. In chapter 5 a review of such research methodologies is carried out and the selection of the research methodology chosen for this research defended. The methodology chosen for any research project must be 'fit for purpose' in so far as it must adequately address the objectives of the research. The mixed methods research design chosen for this research addresses the research questions more effectively than either methodology alone, provide stronger inferences and allow a greater diversity of different views to be presented.

In this two-phase study, both quantitative and qualitative methods were used within each phase of the research. The first, pilot study phase of the research is predominantly quantitative but reinforced by some qualitative interviews and the second phase of the research is predominantly qualitative 'action research' but reinforced by questionnaires. The triangulation achieved by such sequential designs does much to strengthen the convergent validity of the inferences gained and helps to provide a fuller, more in-depth picture of the situation being investigated.

1.5 The pilot study

The objective of the pilot study was to investigate perceptions of the teaching and learning methodologies commonly used in the science classroom and the attitudes of able pupils and their teachers towards science education. The research methodology and findings of this phase of the research are discussed in depth in chapter 6 of this thesis.

Three schools were surveyed in the summer of 2003 in the city of Stoke-on-Trent. Three years earlier the Local Education Authority (LEA) had introduced provision for gifted and talented pupils through the Excellence in Cities initiative (DfEE, 1999b). Most of this provision was through out of school enhancement activities and science clubs, although most teachers in schools had received professional development training regarding classroom provision for able pupils.

The selection of potential schools was decided on the basis of an interview with the LEA science adviser. The criteria for selection were that each geographical 'school cluster group' should be represented and that all schools should have a similar pupil intake and performance profile. Each cluster group had a cluster co-ordinator who supervised the work of the gifted and talented co-ordinator within each school. A number of Head teachers were contacted regarding the value of the research and from those who volunteered their schools for participation three were selected. Permission to access data within each school was sought from both the LEA and the school Head teacher.

The research methods used for the pilot study involved interviews with school senior managers and questionnaires to all year 9 pupils. Year 9 was chosen since all pupils were taught a common curriculum and most were at the point of making decisions regarding GCSE options, decisions that may affect their future careers. The choices made by the researcher over the use of the specific research instruments used are debated further within chapter 6. It was decided to adapt an American questionnaire previously used by Misiti et al (1991) in middle schools in Pennsylvania for use with the pilot schools. This was both in the interests of time management and strengthening validity since this questionnaire had been pre-validated for use with cross-cultural groups and tested for internal consistency. However the analysis of the questionnaire data required the researcher to become familiar with the use of SPSS (Statistical Package for the Social Sciences) and this proved to be time consuming. The ethics of questionnaire administration can also influence research strategy and this is given a fuller consideration within chapter 6, however the decision was taken for the questionnaire to be administered within class time in the interests of gaining a high response rate.

In chapter 6 a detailed report on the findings of the quantitative analysis is given. The decision to adopt the pre-validated questionnaire proved to be an effective strategy and the data set obtained was robust, conforming to a normal distribution and therefore subject to conventional statistical analysis. The reliability of the data was high with good internal consistency and its convergent validity was well established. As had been found in the review of literature on previous research the attitudes of the pupils surveyed towards school science education were decidedly negative. There was found to be a strong correlation between the positivity of pupils towards school science and the aspiration to continue with the study of science beyond GCSE. This may be an important finding because it indicates that if ways can be found to raise the attitudes of able pupils towards science education then this may result in more able pupils studying these subjects beyond age 16, with a resulting improvement in the supply of a scientifically well informed work force.

Confirming previous research described within the literature review, it was the perception of the difficulty of the physical sciences which resulted in pupils having especially negative attitudes towards these subjects. Pupils who were identified as gifted in science by their schools were likely to have less negative attitudes towards physical sciences but their attitudes were still not positive. The suspicion on the part of the researcher that it may be the subject specialism of the teacher that was influential on the attitudes of the pupils towards certain subject disciplines proved to be unfounded, at least at key stage 3. It was also found that pupils who had parents with scientific backgrounds were no less negative than the other pupils in the study.

Another indication from the pilot study was that there was a correlation between pupil positivity to science and the number of science books that pupils reported having in their home, although the direction of this correlation cannot be determined from this quantitative analysis. This may have some importance for determining whether positive attitudes help to promote independent study or vice versa. All pupils were found to have high self-esteem and there appeared to be no relation between this and their attitude to school science or their perception of its difficulty. Being identified by the school as being scientifically gifted did not appear to correlate with these pupils' attitudes to school science education but it did correlate with the pupils' aspirations to continue with the study of science beyond GCSE.

When questioned about preferred teaching and learning methodology all pupils favoured 'hands on' activities over passive learning. Gifted pupils showed a strong preference for activities which allowed them some decision making powers in the classroom such as scientific enquiries, research exercises and creative activities. However, a comparison of those teaching and learning activities cited by pupils as most preferred with those most commonly utilised by teachers showed a mismatch in frequency.

Overall the quantitative model was found by multiple regression analysis to account for 40% of the observed outcome. In other words 40% of the variance in pupil positivity to science could be accounted for by the factors investigated in this model. This is a high proportion for a quantitative model and reinforces its robustness. However, although the pilot study had allowed the researcher to gain some insight into the attitudes of pupils and their teachers towards school science it did not explain the reasons behind the widespread dissatisfaction or what might be done to help to turn the situation around. In a quest for greater understanding it was decided that a second phase of research was necessary which would investigate the situation more closely through a localised action research project.

1.6 The action research study

The action research study began in the autumn of 2004. Its objectives were threefold. Firstly to observe, within the school context, the constraints experienced by science teachers in delivering the science curriculum, secondly to observe the teaching and learning methodologies used with able pupils in science and thirdly to design and trial a collaborative, interventionist strategy, in the classroom using teaching and learning methodologies which promoted pupil autonomy and evaluate their impact.

The interpretation of 'action research' as referred to in this study is a research design which includes the analysis of a situation, a collaborative action designed to try to improve that situation involving the reflective practice of a group of teacher-researchers and an evaluation of the impact of the actions taken. Other definitions of 'action research' (e.g. Lewin, 1948; Stenhouse, 1979; Hopkins, 1985; Kemmis and McTaggart, 1992; Zuber-Skerritt, 1996; Cohen et al, 2003; Reason and Bradbury, 2001) are critiqued in chapter 7 and the evolution of the methodology of action research explored.

The criticism that action research has contextual limitations (Altrichter et al, 1993; Hammersley and Atkinson, 1995; Hammersley, 2002) may well be relevant to this study but the school chosen for the study was a typical 11 – 16 comprehensive school, drawing from both middle class and working class catchment areas and was judged by the researcher and LEA science adviser to be representative of the schools within the region. In order to establish a comparison between the action research school and the schools used within the pilot study, a pre-test questionnaire was given to both pupils and teachers in the action research school, as had been done in the pilot study. The indications from this questionnaire analysis were that there was indeed a high degree of commonality between the attitudes of the pupils in the action research school and those found in the pilot study schools.

From the outset of the period of the action research in the autumn of 2004 through to the summer of 2005, the science departmental staff meetings provided a ‘dialogue group’ for discussion of the progress of the action research. However, the exchange of dialogue within the group did, at times, become contentious and it became apparent that there were both departmental and school wide pressures at play that would need sensitive handling. A more detailed discussion of this ‘politics of fieldwork’ (Denzin and Lincoln, 1998) is contained within chapter 7. At the first of the science department meetings in the late September of 2004, it was decided, for comparison purposes, that the action research should be carried out with classes at the start of key stage 3 in Year 7 and at the start of key stage 4 in Year 10.

In Year 7 there were two parallel ‘top set’ groups 7A and 7B, taught by the same science teacher, a situation which lent itself to the establishment of an experimental research design, wherein 7A became the ‘experimental group’ and 7B the ‘control group’. In Year 10 there was a single ‘top set’ group. Some members of this set featured on the school’s gifted and talented register and were identified as having a wide range of ‘abilities’, some scientific and others not. However there were also a significant number of pupils in this set who were not on the school gifted and talented register and this made a useful comparison group.

At the outset the researcher spent three weeks observing the regular classroom teacher with each of these three classes. At the end of this period the observations of the teaching and learning methodologies used were discussed at a science departmental meeting. It was from these discussions that a design for the intervention study developed. The full details of this design are described within chapter 7.

Following this initial observational period, the researcher was then asked by the science teachers to exemplify, by teaching the next module of work for class 7A using methods which attempted to give more autonomy to the pupils and allow them more decision making powers in the classroom than had hitherto been observed. However the science department were anxious that their pupils should not be disadvantaged by this intervention and constraints were placed upon the researcher regarding the scheme of work to be adhered to and the assessment methods to be used. This did somewhat limit the degree of 'ownership' of task that the pupils could gain over their work and was perhaps reflective of the apprehension felt by the science department regarding changes to teaching and learning methodology. During the intervention lessons the classroom teacher made observational notes. 7B continued to be taught in the traditional way by the same classroom teacher.

At the next science department meeting the perceptions of the observer were reported. The report stated that the teaching and learning methodologies used during the intervention differed little from previous practice although the pupils' perceptions, as ascertained by group interview, were that they had indeed had much more control over their work during the intervention period. These conflicting views required some reflection and analysis of the attitudes underlying the responses. These are further discussed within chapter 7. The end of module tests for 7A and 7B were on a par and it was acknowledged that the intervention had not had any detrimental effect on the pupils. Thus it was decided that the experiment should be repeated with fewer constraints the next term.

At the start of December the intervention exercise began with the Year 10 group. This consisted of an experimentally based scientific enquiry, introduced by the researcher, which allowed the pupils to make most of the major decisions regarding the direction and design of their experiments. The pupils were unused to taking this much responsibility for their learning and some found the approach intimidating. However, other pupils found the experience liberating and ultimately produced work which demonstrated high standards of analysis and reflection. The classroom teacher again observed the lessons and a report of these observations is described within chapter 7. The report stated that the pupils showed improved knowledge transfer and evaluation skills when working autonomously and recommended changes to the work scheme to include more such activities.

Following these two intervention exercises it was decided that the researcher would again play the role of observer to the classroom teacher. During this time it was noted that the practice of the science teachers had changed and the teaching and learning methodologies observed during this second phase of observation were less didactic. Pupils were allowed a greater part in the classroom dialogue and their questions were not closed down so promptly as had been the case previously. They were also asked to hypothesise more and express their thinking through the use of analogies and models. Homework tasks required the pupils to undertake more independent study and some of the work given was outside that of the prescribed work scheme. The expectations that the teachers had of their pupils were observed to be much higher.

Encouraged by these observations it was decided in March to repeat the intervention with 7A as they began a new module of work on electricity. This time the researcher had licence to deviate from the set work scheme and assessment structure. A new science teacher acted as observer and reported back to the science departmental meeting. It was reported that the encouragement of pupil discussion in the classroom had led to many misconceptions about electricity being uncovered, which could then be challenged by experiment. Thus the consensus of opinion was being formed that pupil autonomy did add something to the teaching and learning dynamic without apparent loss in examination performance. Pupil group interviews also revealed that most pupils, especially the more able pupils in 7A, preferred autonomous learning. However in Year 10 some pupils expressed the view that it was easier when they had been told what to do. The evidence presented in chapter 7 leads to the conclusion that overall the intervention resulted in more reflective practice on the part of the teachers and greater involvement in the lesson on the part of the pupils.

As an adjunct to the action research within the classroom some of the Year 10 and 11 pupils were invited along with their classroom teacher to take part in a physics enhancement Saturday School at the University. This involved trainee teachers exemplifying autonomous teaching and learning methodologies and is described within chapter 7. This resulted in follow-up work being taken back into school and the autonomous learning activities experienced by the selected group of pupils being disseminated more widely back in school. Thus the enhancement experience was impacting upon the classroom experience of both the selected pupils and others taught by the same teacher.

At the end of the action research period pupils completed post-test questionnaires. Although pupil negativity had increased for all pupils, an effect previously noted by Osborne et al (2003), it was found that pupils within the experimental groups had an increased aspiration to study science and this correlated with an increased number of science books reportedly in their homes. Further evidence of this increased aspiration was provided in the summer of 2005 when an unprecedented number of pupils opted for the study of science 'A' levels at the local college, with the result that extra teaching groups had to be created.

The impact of the action research on the teaching staff was perhaps even more significant with changes to teaching and learning methodologies evidenced, changes to work schemes, new resources and much greater critical reflection being engaged with. The role of educational action research was seen to have value and relevance to practice and was providing a force for change.

1.7 Summary and reflection

The widespread negativity of pupils towards science education as evidenced by this research and that of others (Miller and Osborne, 1998; Schreiner and Sjoberg, 2004; Hyam, 2006) is a cause for concern for all involved in science education. Evidence that this negativity increases as pupils progress through secondary school (Galton, 2002; Osborne et al, 2003) causes further disquiet and indicates that school science education is failing to interest many pupils, especially in the physical sciences. The meagre uptake of science post GCSE also indicates that the most able pupils are ill-served by the science education that they are receiving.

Indications from this research are that pupils are 'switched off' by didactic teaching, frequent testing and lack of voice in the classroom. Many teachers are not cognisant of the special needs of able pupils and differentiation and personalised learning for these pupils is not well embedded into science classrooms. Provision for able pupils has concentrated on out of classroom contexts and had little impact on classroom teaching. The focus on classroom practice provided by this research is both much needed and long overdue (Eyre, 2007b).

There is evidence from this work and that of others (Adey, 1991; Fisher, 2004; Black et al, 2006; Watts and Pedrosa de Jesus, 2007) that teaching and learning methodologies, which promote pupil autonomy in the classroom, are more personally empowering for pupils and may promote aspiration to continue with the study of science. However pupils need to be prepared by teachers to take responsibility for their learning and this may require a culture change within the classroom. This need is reflected within the Classroom Quality Standards for Gifted and Talented Education (DCFS, 2007d), which requires that *all* teachers should engage with practices to promote good quality teaching and learning methodologies for able pupils. However if teachers are to engage with culture change within their classrooms they will need to be supported through this professional development (West, 2007). Attending out of school training courses may not be the most effective way to achieve change. This research provides evidence that supported action research within schools may be one way forward.

Chapter 2
Literature Review Part 1
The Scientifically Able Pupil

2.1 Defining the 'able' pupil.

In much of the research literature written about gifted and talented pupils the words 'able' and 'gifted' are taken to be synonymous. However some researchers have emphasised distinct differences in the meanings of these terms and in this research these terms are interpreted in different ways. Before any discussion of how pupils may be identified as able or gifted an interpretation of the meaning of these terms must be discussed.

In *Excellence in Cities* (1999b), DfEE referred to the top 5-10% of the school population as being 'very able'. This ability may be interpreted as a '*general ability*' across all subjects or a '*domain specific ability*' within one subject area. The document also referred to 'gifted' pupils but failed to define this term. However, in a later document (DfES, 2004a) gifted pupils are described as those with ability in one of the 'academic' subjects and talented pupils as those with ability in art, music, PE, sport or creative arts. Earlier DfES documentation (2002) referred to 'able pupils' as meaning those who are either gifted *or* talented and the 'exceptionally able' as the top 1% of the cohort nationally.

The term 'gifted' was first used by Terman (1925) to refer to children with high quotients of mental age to chronological age. Heller (1996) refers to 'gifted' as the top 10% in intellectual ability, 'highly gifted' for the top 5% and 'extremely gifted' for the top 2%. Thus he implies that 'giftedness' can be scored and ranked! Teare (1997) states that there is a clinical definition of the term 'gifted' accepted by a number of educationalists and this is,

"Those who are more than two standards of deviation from the mean on a normal distribution curve of intelligence." (Teare, 1997, p.25)

However, such a definition leads to further debate about what is meant, in this context, by intelligence and how it should be measured. Proponents of 'multiple intelligence theories' (Gardner, 1983; Ellison, 1984; Sisk, 1987) maintain that pupils exhibit a range of aptitudes which would not necessarily cause them to be recognised as 'intellectually gifted'. For example some of these aptitudes are described as spatial, interpersonal, creative, adaptive, social, productive and insightful. However, if all pupils exhibiting any one of these attributes were to be selected as 'gifted' then almost the whole school population would be identified as being in some way gifted. Whilst many in education would not think that this was a bad thing, devising programmes to cater for nurturing each of these abilities in school would probably prove unmanageable.

Freeman (1998) in her review of international research on educating the very able, underlines the difficulties involved in defining the terms 'able' and 'gifted' and recognises that researchers have been arguing about such definitions for nearly a century. As a consequence of this she identifies over one hundred definitions of 'giftedness', most of which refer to children's precocity in terms of psychological constructs, such as intelligence or creativity. However theories about the relationship between children's intelligence and creativity are highly controversial and much research has found only low correlation coefficients between the two (Jiannong and Fan, 1999).

An exploration of the diverse viewpoints on giftedness and creativity reveals a number of key commonalities and some crucial differences. Cohen (2003) defines giftedness as, "optimal universal cognitive development that leads to actualised or potential mastery of a domain" (p.35). Thus Cohen is describing 'giftedness' as being domain specific.

Cognitive developmental theories tend to focus on the changing way that the child understands the world as they develop. Piaget (1977) describes this as occurring through a process of equilibration, where new concepts become accommodated into the mental constructs of the individual. This re-equilibration point varies from individual to individual and will occur more readily in those able individuals who have a higher level of flexibility. The trait of flexibility in individuals with both high cognitive ability and creativity was analysed by Sternberg & Davidson (1985). Sternberg's model of creativity (Sternberg & Lubart, 1999) includes factors such as metacognition, knowledge and motivation with a key competency being a cognitive representation of the problem, giving mental access to the implicit relationships involved. Sternberg (1988) however, recognises, in his three facet model of creativity, that the cognitive facet alone is insufficient. He also identifies intellectual style (mental self-government) and personality traits as being important. Such a view implies that giftedness is an innate attribute. Conversely later research carried out in Beijing by Jiannong and Fan (1999) reported that there was a significant correlation between gifted children's creative thinking and their interest and motivation, indicating that unless the interests of gifted children were engaged their creative abilities may not be recognised.

Urban (2003) identifies creative individuals as having strengths in both high cognitive abilities and in personality. He identifies the cognitive traits of the highly able and creative to be divergent thinking and acting, a good general knowledge base and a good specific knowledge base: thus he acknowledges the distinction between general ability and domain specific giftedness. The personality traits required to effect the cognitive abilities are identified as focussing, task commitment, openness and tolerance of ambiguity. In creative thinking and acting Urban describes the problem, personality, process, product and environment as all playing a part in the outcome. Urban however, also recognises the influence of the meta-environment (society, history, evolution), the macro-environment (material, economic, cultural) and the microenvironment (family, region, socio-economics) as being influential on the performance of able children. Thus able children identified by cognitive abilities alone may fail to perform to expectation due to the influence of these other factors.

Renzulli (1977) was the first to describe the importance of motivation and creativity within his 'model of giftedness'. Like Urban, he also identifies the importance of task commitment to the outcomes for and the identification of the highly able. However, if motivation and task commitment were elements in the identification of the highly able then many of the able underachievers in classrooms would be overlooked. Thus the reliance on standardised tests alone to identify the able is unsound and will exclude those who are able but unmotivated, with little task commitment.

Guilford (1950) looked at the role of divergent thinking in the identification of gifted and creative individuals. Guilford makes the assumption that creativity is a cognitive ability which all people have or can develop. He takes the idea of divergent thinking to be synonymous with creativity. However, divergent thinking categorised as fluency, flexibility and originality is not a general trait but varies with the task i.e. some tasks stimulate some people but not others and the role of divergent thinking in the identification of the able is overshadowed by other personal traits such as curiosity, drive and personal interest. Thus Guilford is also recognising that personal interests will be an influencing factor in the choice of domain within which high ability may flourish. In a classroom situation an individual's capacity for divergent thinking will vary from task to task and be dependent not only on their ability but possibly on other factors such as classroom environment, gender (Helson,1990), family background (Dacey, 1989), age and personal interests.

Perhaps the identification of the highly able and creative is most informatively approached through theories of cognitive neuro-psychology. Geake and Dodson claim,

" People with high creative intelligence are endowed with larger than normal WM (working memory) capacities, which enable them to create more cognitive variance i.e. more links, and keep possible outcomes on-line for longer in order to weight their potential creativity." (Geake & Dodson, 2005, p.3).

They are also described as having depressed latent inhibition which permits full consideration of unconventional insights. However, such people are again also described as being highly task motivated which poses problems for the classroom situation since many classroom tasks are not of pupils' own choosing and thus their task motivation is likely to be relatively low compared to individuals who are afforded the autonomy to 'own' their task choices.

Geake, Cameron, Clements and Philipson (1996) state

"Gifted children are those whose aptitude for intellectual endeavours, including enquiry and investigation, are well superior to their age peers. Gifted children are potential scientists." (p. 41)

However, Geake et al. also acknowledge the view of Braggett (1994), in so far as gifted children may not be noticed unless they are in an environment which allows them to demonstrate their gifts. This view is supported by Taber (2007d), claiming that gifted learners may not be obvious unless they have the right opportunities and encouragement. Braggett describes this as the ***facilitative environment***, within which a key element is that pupils may work at different levels and paces. The implication here is that the pupils must have some degree of autonomy within this working environment.

Many of the researchers thus far discussed have made the distinction between the ideas of general ability as opposed to giftedness within a specific domain. Brandwein (1992) describes the idea of identifying a rudimentary nature predisposing to an intrinsic preference to science as 'intriguing'. Many research projects take giftedness as a general quality rather than being domain specific. It is therefore important that in investigating effective science education for able children, we look at both those children identified as generally able and those children who have been identified as specifically gifted in the domain of science. Poncini and Poncini (2000) found in their study into research projects in science with able children, that those who did not have a specific interest in science were not motivated to continue. However, to a large extent the tasks chosen in their study were not chosen by the children and therefore were not an expression of their personal interests. This begs the question as to whether the outcomes may have been different if the children had been given greater autonomy from the outset of the project. Ausubel and Robinson (1972, p.182) describe this as 'psychological meaningfulness'. For learning to be meaningful to an individual it must fit three criteria. It must possess 'logical meaningfulness' i.e. not a personal construction but an independent entity, not reliant on personal constructs. The individual must possess relevant ideas with which to relate the material to his cognitive structure and the individual must possess a 'meaningful learning set' i.e. the intent to relate the new ideas to his cognitive structure.

Thus in selecting the able children to take part in this study we can conclude that ideally these will be children with generally high cognitive abilities, a subset of which may be gifted within the specific domain of science. However, in some these domain specific abilities may be masked by low levels of exposure to a *facilitative* *environment* resulting in low motivation and task commitment and thus reliance on standardised test scores alone in selection, should be avoided.

For the purpose of this research the term '*gifted*' is taken to apply to those children who have been identified by teacher nomination to have a *high ability in the domain of science* and who have been placed on the school's gifted register as belonging to the top 5-10% of pupils in this area at each age group. However if the research were to be conducted exclusively upon this group of children it may lack validity on two counts

a. identification of this population is imprecise as there may be children who consistently underachieve in science for a variety of reasons
b. the sample size involved in the research would be very small

For these reasons the sample upon which this research is focussed is better described as '*able*' in that they belong to the identified 'top set' of each age group. This wider group consists of the top 10-20 % of the *general ability* grouping of that age cohort. By providing a *facilitative environment* and observing the behaviour of the pupils within it over a long period of time we can maximise the opportunity for the observation of the emergence of traits of high cognitive and creative ability within the scientific domain.

3.2 Policy and Practice in Provision for Able Pupils in Science

3.1 Identification

How do schools identify 'able' pupils? Many identification schemes involve drawing some arbitrary performance boundary above which pupils may be regarded as able and below which they are not. School gifted and talented registers are frequently compiled in this way. The introduction of the 'Excellence in Cities' (EiC) initiative in 1999 (DfEE, 1999b) required schools in EiC regions to nominate the top 5 - 10% of their intake in each year group as 'the most able'. However, this nomination was regardless of the average academic standard of the school. Thus pupils nominated as able by a low achieving school would not be comparable to those from a higher achieving school. This lack of comparability reflected an underlying socio-cultural issue (Eyre, 2007a).

Pupils from higher achieving schools were more likely to come from a higher socio-economic group (Ofsted, 1997) and usually had parents whose expectations for their children were higher than those from lower socio-economic groups. These may also be the parents who could afford any costs arising from enhancement events and fees for summer schools (Wilce, 2005). Whilst the EiC policy ensured that pupils from all socio-economic groups were represented it was not recognised that the needs of these pupils may be very different. This meant that when these diverse groups of children were brought together for enhancement activities there was still a wide diversity of ability. Not only did this undermine successful provision it also raised questions amongst teachers, parents and the pupils themselves regarding what being categorised as 'able' really meant.

Another impediment to the successful identification of able pupils was the attitudes of many teachers to the scheme. There was a widespread view that selection and provision for the 'able' was elitist (Hymer and Michel, 2002: Coll, 2007) and that funding would be better used in focussing on those pupils who were struggling to achieve a GCSE grade C pass in science. This led to unwillingness on the part of some teachers to identify 'able' pupils and funding often being 'internally redirected' within schools, despite ostensible ring fencing (Tilsley, 1981). Another factor hindering identification was that some pupils may deliberately 'hide their light under a bushel' owing to peer pressure from other pupils (Bentley, 2003). Since 'able' pupils may risk social exclusion from their peer group there was an identified risk in being labelled as such.

Some pupils who had special educational needs may also not be identified as 'able' due to their ability being masked by other factors (Bentley, 2003; Winstanley, 2007). Similarly able pupils from minority ethnic groups, where cultural values may be different to those in school, and pupils whose first language is not English, may also not be recognised (Coll, 2007). Many of the issues surrounding accurate identification arise from a lack of adequate training for teachers both in initial teacher training (McIntosh, 1993) and in continuing professional development (Lowe and Mordeci, 2003). However, there is also a need for further evaluative research into the effectiveness of current models for identification and provision within the English education system, in order to inform such training (Taber, 2007d).

In more recent years there has been a greater research focus on the most effective methodology for identifying gifted pupils (Gilbert, 2006; QCA, 2006) and much has been written about the characteristics of gifted children (Gilbert and Newberry, 2007). There have been many checklists of such characteristics drawn up to aid identification (Eyre, 1997;Welding, 1998; Wallace, 2000). However, as an alternative to reliance on attainment scores (which may owe much to work ethic) and checklists (which may not be subject specific) many schools have adopted schemes, inclusive of teacher, peer, parent and self-nomination (Eyre, 1997). But even these methods may exclude able underachievers who do not shine in class or in assessments because they do not respond to the environment in school or the teaching and learning methodology employed by teachers.

A survey conducted by NAGTY, (Campbell et al, 2006b) on 1057 gifted and talented pupils in the 11 – 19 age range concluded,

> "Almost all of this cohort (97%) state that their teachers think they are clever and have, therefore, put them forward for NAGTY membership. We should remain vigilant about the self-fulfilling aspect of this process and be aware that there may be pupils who do not presume themselves to be clever (because they have not been so labelled in school) but who have potential nonetheless, that should be brought to light." (p. 4)

An alternative to the 'diagnose and treat' model is the model of 'identification by provision' (Campbell et. al., 2004a; Freeman, 1998). The principle at the heart of this model is that when pupils encounter the right facilitative environment their potential is much more likely to be noticed than when their environment does not nurture their abilities. Thus the identification of giftedness is highly context dependent (Alexander, 2002) and will depend on both the micro and the macro-environment of the pupil.

However, since these environments are constantly changing should pupils who are identified as able at a young age be included on the gifted and talented register for the rest of their school career or conversely should those who have not been included be periodically reviewed for inclusion? Is 'giftedness' an innate attribute as suggested by Clarke (1983) or is it dependent for its emergence upon an appropriately encouraging environment as suggested by Passow (1985)? Gilbert and Newberry (2007) also maintain that ‘giftedness’ develops or is maintained through exposure to such facilitative environments and that therefore the 5 -10% model is inadequate in so far as some schools may promote more facilitative environments than others.

So what is the ‘right facilitative environment’? Under-achievement may be a learned behaviour (Butler-Por, 1993; Montgomery, 2000) and in order for a pattern of under-achievement to be avoided there needs to be high teacher expectation and excellent provision for learning. The debate then ensues as to what constitutes ‘excellent provision for learning’.

3.2 Provision

One ‘Excellence in Cities’ strand of provision focussed on school improvement in inner city areas. A strategy was identified for targeting gifted and talented youngsters in inner city schools and providing for them a special programme of extension and enrichment activities with a view to improving motivation and performance. Alongside this funding was to be found for the training of teachers in special provision for the teaching of gifted and talented pupils within schools. Local Education Authorities (LEAs) were set targets for improved pupil performance in Key Stage 3 SATs and GCSEs and improved uptake for further education at 16+.

In 2001 the Ofsted report on the early progress of EiC, ‘Providing for Gifted and Talented Pupils’ (Ofsted, 2001) was published. One of the observations of the inspectors was that many schools focussed on out-of-school enhancement activities and to have better impact these needed to be integrated with the school curriculum. In the same year the DfES White Paper ‘Schools Achieving Success’ (DfES, 2001a) set out policy on gifted and talented education. One aim was to combine in-school learning with complementary opportunities for out of school enhancement. This move was designed to improve pupil attainment and motivation and to raise teachers’ expectations of pupils. The focus was on localised provision with designated schools having co-ordinators operating under the guidance of LEAs.

In 2002 the Government set up the National Association for Gifted and Talented Youth (NAGTY), which established summer schools for scientifically gifted pupils.

However valuable the work carried out in these summer schools, it was found (Ofsted, 2003) to have little impact on practice within schools.

> *" Consistently high quality provision across subjects for gifted and talented pupils remains the exception. Many schools need to make sure that schemes of work set out what is meant by a high level of challenge and to provide guidance on ways of enriching and extending work for higher attainers. While activities outside normal lessons are often stimulating…they do not generally link well with mainstream work." (Ofsted, 2003, para. 126)*

It was in this climate that work began on the research project described in this thesis.

Since 2003 there have been numerous revisions to the model of provision for gifted education. The English Model (Eyre, 2004) set out the aim of 'integrated education', which advocated the integration of out of classroom and within classroom activities. However, the model acknowledged that there were barriers to implementation in many schools.

Research to date has indicated that there is still a wide gulf between policy and practice. The survey carried out by NAGTY (Campbell et al, 2006b) concluded that provision for gifted pupils was still limited in most schools with more challenging work being given to only 23% of pupils. Research carried out in the ROSE – Relevance of Science Education Project (Schreiner and Sjoberg, 2004) concluded that most pupils thought that the science that they studied in schools was not very challenging. More recent research carried out by collaboration between the Universities of Cambridge, Reading and Roehampton into Able Pupils Experiencing Challenging Science (APECS, 2005) indicated that the curriculum and assessment structures were amongst the chief constraints for teachers in trying to challenge the most able pupils in their classes. Whilst these research projects help to identify what is amiss in schools they do not aid teachers directly in how to modify their own practice in order to improve the situation.

Taber and Riga (2006) in the ASCEND (Able Scientists Collectively Experiencing New Demands) research programme with gifted pupils in science found that the pupils were unused to discussion and reflection and came to sessions expecting to 'be taught'. One possible reason for this was suggested by Eyre (2007b) at the World Conference for Gifted and Talented Education in Warwick,

> *"The English education system's response to the educational needs of gifted pupils has been characterised by a long trend, stretching back at least to 1978, of low expectations in the classroom and at school level and, until recently, absence of strategic policy at the national level. This trend was reinforced by unenthusiastic attitudes in the teaching profession and LEAs, either on the grounds that they lacked confidence about how to challenge such students through their teaching or that meeting their educational needs had lower priority than managing the behaviour and learning of other pupils in busy and challenging classrooms, or both. If this has not changed in 30 years using the same approach is unlikely to be any more effective now." (p. 2)*

The problem of poor teacher attitudes and preparedness is even more acute in science than in other subjects given the overall shortages of physical science specialist teachers. In order to drive development in classroom provision new initiatives for science were introduced which included: a new strand of science GCSEs published in 2004 and implemented in 2006 with a rising emphasis on applied science in the curriculum, the Secondary National Strategy for Science, the national network of Science Learning Centres and increased provision for teacher training and professional development. However, the impact of these new developments on the effectiveness of the teaching and learning practised in the classroom has yet to be evaluated. The 2006 Royal Society Report (Hyam, 2006) stated that a deeper understanding of the complex variables at play required a detailed longitudinal study into the barriers to success.

So what may be the barriers to the successful implementation of provision for gifted and talented pupils in schools? The answer to this question is complex but previous research has established a number of factors at play.

The first of these is the school science curriculum itself. Much of the science studied in schools has been 'repeating what other generations have done'. Experimental work has tended towards the verification of previously held knowledge rather than the inculcation of genuinely investigative approaches to learning and research in science (Taber, 2007d). The view of science perceived by pupils in school is very different to the view of science as perceived by scientific researchers. This school science perspective is what Renzulli (1986) refers to as 'schoolhouse' science. Poncini and Poncini (2000) also describe 'school science' as distinguishably different from 'real science'. Geake, Cameron, Clements & Phillipson (1996) explain that school science is not like real science because they serve different agendas. Whereas real science delves into the unknown and is time consuming, school science is often contrived and must be quick.

The packed content of the science curriculum has led to superficiality in the teaching of science, with time for the in depth study of concepts being ill afforded. Pupils have been 'frog-marched' through the work scheme with little time for reflection or assimilation of concepts. This has led to much didactic teaching and little pupil autonomy in the classroom (Taber, 2007d). In recognition of this the DfES has introduced a new 'slimmed down' science programme (DfES, 2007a) which is intended to reduce prescription and 'enthuse and inspire pupils, particularly the most able' (DfES, 2006b). The 'slimming' of the curriculum is intended to result in fewer topics being covered in greater depth, to enable more discussion to take place in class and to allow science topics to be embedded into contexts that are 'more relevant to the everyday lives of pupils' (Murray and Reiss, 2005). However, changing the culture in school science laboratories will not happen overnight, nor is it likely to happen simply because the Government decrees that it must. To effect a cultural change in schools will require the recognition of the fact that there are more barriers to success than can be overcome by merely changing the curriculum.

A second major barrier to success is the lack of specialist teachers in the physical sciences to enable topics in these areas to be taught 'in depth'. Effective teaching for able pupils in science requires teachers who are not only well qualified specialist science teachers but who are also knowledgeable about how to differentiate teaching to cater for the personalised needs of the able children in their classes. Such teachers are a rare breed and becoming rarer given that around 35% of these experienced teachers are due to retire in the next ten years. The Government has recognised the problem and has put into place a number of initiatives to assist in recruiting and retaining more science teachers. These include a 'Golden Hello' payment to attract more science teachers into the profession, support for Continuing Professional

Development (CPD) through the setting up of Science Learning Centres in 2004 and the introduction of retraining programmes for pre-initial teacher education, the Physics and Chemistry Enhancement Programmes (TDA, 2003) and for in-serving teachers, the Science Additional Specialism Programme, (Science Learning Centres, 2007). In the Science and Investment Framework (DfES, 2006b) it is stated that,

> "A good supply of high-quality science teachers is crucial to achieving results in the classroom. Ofsted has found that the quality of science teaching is related to teachers' initial qualifications. Where the match between the teacher's qualifications and the subjects they taught was thought to be excellent/good by Ofsted, the quality of teaching was excellent/very good or good in 94% of schools." (p. 44)

However, given that there are too few graduates in physical sciences for the required recruitment pool other strategies have to be found. A student review of the science curriculum (Murray and Reiss, 2003) found that a large number of pupils identified 'teachers who know what they are talking about' (p.10) as fundamental to quality learning in the classroom. The influence of well informed teachers was also reinforced by Ofsted (1998).

> "When teachers are thoroughly in command of their subject, they are able to adapt their teaching to the responses of the pupils, to use alternative and more imaginative ways of explaining, and to make connections between aspects of their subject and with pupils' wider experiences, so capturing their attention and interest. The teacher's ability to answer spontaneous questions is an important factor in generating enthusiasm for the subject." (p. 23)

This robustness in specialist subject is even more important when teaching gifted children as these are the pupils most likely to ask searching questions related to subject matter but the needs of able pupils go even further than this. Eyre (2007a) maintained that it was the responsibility of all teachers to become adept in strategies for teaching gifted children but this cannot happen without specialist training (Coll, 2007; Taber, 2007d). Other researchers take the opposite view, that not all teachers can or should be teachers of the most able pupils, since certain teaching styles may not lead to the kind of facilitative environment conducive to allowing able pupils to explore their abilities (Mandell and Fiscus, 1981). In 2005 NAGTY developed a PGCE+ (plus) programme, which gave newly qualified science teachers specific training in catering for the needs of able pupils in science classrooms. This programme was a success locally but was funded for only two years.

> "In comparing myself with my NQT peers I felt better equipped to deal with not just G&T students, but across the board – particularly in respect of strategies to involve students in their own learning, in questioning techniques and in expectations." (PGCE+ teacher quoted in Meatyard, 2007, p.8)

Despite the success of this programme for newly qualified teachers its impact upon school science departments was found to be less successful and the programme did not continue beyond 2006. Instead funding was directed into CPD for in-serving teachers. The efficacy of such CPD is yet to be proven and opinion is divided on the best way to achieve the desired outcomes. Previous studies examining the way teachers implement and adopt change as a result of CPD have not been encouraging

> "Teachers will not take up attractive sounding ideas, albeit based on extensive research if these are presented as general principles which leave entirely to them the task of translating them into everyday practice." (Black and William, 1998, p.15)

Unless CPD is made explicitly relevant to classroom practice it is unlikely to have the desired impact and this is only one obstacle to effecting change within the classroom. Pedder (2006) explains,

> "In order to skilfully and successfully promote learning how to learn, teachers need to learn new practices and to learn how to develop and sustain the relationships that are expressed through them." (p. 2)

Thus teachers need to accept that they themselves must become learners (George, 2003). One impediment to this is that because science teachers are in such short supply, existing ones are unlikely to be released from school in order to engage in further learning (George, 2003). Even if farsighted Head teachers were to allow such teachers to be released there are few good quality supply teachers to facilitate this process? Perhaps, as advocated by a DfES report (2001b), a model of 'in-house' training is needed where researchers and teachers need to collaboratively engage in action research together towards improved practice? Perhaps such collaborative approaches may be more effective in winning the 'hearts and minds' of teachers and effecting a real change of culture in the classroom.

At the brunt of all the rhetoric on policy and provision are the teachers. This can often be lost sight of amongst all of the educational and political debate. Apart from the issue of how well equipped are teachers by their training and/or professional development to deliver effective teaching in the science laboratory, there are also other barriers that impede successful outcomes. A third barrier identified by research (Eyre, 1997, 2007a) is that teachers' expectations of pupils are generally low. George (2003) asserts that teachers need to provide challenging tasks and high interest activities and that it is essential to 'promote motivation by giving learners control over their learning' (p.21). To drive higher teacher expectations and higher standards of provision the 'National Quality Standards in Gifted and Talented Education' (DCFS, 2007c) were drawn up in 2007. These and the accompanying 'Classroom Standards in Gifted and Talented Education' (DCFS, 2007d) were devised as self-evaluation documents to help teachers to work towards improved provision for learning. But 'excellent provision for learning' also involves reducing prescription in the classroom. The new science programme based on 'how science works' claims to do just this but this claim is dependent upon a new philosophy of learning permeating the science classroom.

The lack of knowledge and confidence amongst science teachers on how to specifically nurture the most able pupils in science has led to an over-reliance on 'enhancement' activities as the main provision for able and talented pupils in school. The provision of these activities whilst benefiting pupils, did to some extent allow teachers to pass the responsibility for nurturing their able pupils onto 'experts'. If able pupils were provided for by sending them off to enhancement activities then teachers were reprieved from having to analyse their teaching and learning methodologies critically and this allowed them to continue to 'teach to the test', which they viewed as most effective for achieving the high attainment figures for which they were held accountable. By spoon-feeding pupils in how to answer test questions performance figures remained high but this was at the cost of not allowing pupils to develop their own study skills. These are just the skills most vital to able pupils if they are to develop their domain specific abilities (Poncini and Poncini, 2000; Lee, 2003).

Another barrier presented by the over-reliance on enhancement activities for the provision for able pupils was that it required the pupils to be motivated enough to want to attend these activities. The ‘not cool to learn’ culture that pervades many schools may have acted as a disincentive for some pupils who would rather not attend than be subjected to negative peer pressure. Nor may pressure come only from peers. For certain socio-economic groups parents do not encourage able pupils from attending these out of school events for a number of reasons. Amongst these was a concern that pupil expectations may be raised by such events beyond what could reasonably be supported by the family (Eyre, 2007a). In areas of social deprivation school pupils may be expected to support families either by practical or financial means and ‘out of school’ time may need to be directed to activities other than ‘enhancement activities’.

Eyre (2007b) declares,

> “When G&T really works pupils are at the centre of the learning process taking responsibility for their learning. This is a personalised approach and in sharp contrast to the type of cohort led provision in which the G&T cohort are seen as being a homogeneous group with common needs and common issues.” (p. 2)

If it were possible for the type of approach to learning in which pupils were engaged on enhancement days to become embedded into the teaching and learning methodology adopted within the school classroom, then the accessibility to such learning may become more available to all able pupils, including those able underachievers overlooked because they have not experienced an environment facilitative in encouraging their abilities. To achieve this would require a culture change in schools and at the heart of such a culture change must be more effective approaches to teaching and learning for able pupils.

Chapter 3
Literature Review Part 2
Teaching and Learning in Secondary Science

3.1 Disaffection with science education

The growing body of evidence that a significant proportion of able pupils in secondary schools are disaffected with the study of science as prescribed by the National Curriculum has been a concern amongst educationalists for a number of years. In the report, *Beyond 2000: Science Education for the Future* (Millar and Osborne, 1998), conclude that,

> *"The National Curriculum for England and Wales has failed to meet the needs of contemporary society, much less anticipated the needs of future society." Hodson (2003, p. 649)*

In another seminal report on Creative and Cultural Education, (NACCCE, 1999) a committee chaired by Ken Robinson reported that,

> *"Creative and cultural education is being poorly served by the National Curriculum. The cumulative impact of successive changes in structure, organisation and assessment since its introduction have eroded provision for the arts and humanities, and for creative approaches in other curriculum areas including science." (p. 5)*

Such a body of evidence substantiates the view that science education in secondary schools is at best misdirected and at worst lacking in effectiveness. At the heart of the matter is what is actually taking place within school science laboratories and how the teaching and learning taking place can be linked, not only to outcomes of attainment but also to outcomes of improved attitudes towards the study of science and aspirations to continue with such study or with science related work beyond compulsory school age.

Diane Montgomery (2003) is of the view that, for able pupils, teacher-led lessons which require writing, learning and recalling cause pupils to lose motivation as they have little involvement in making meaning for themselves from the lesson content.

Urban (2003) recognised the restrictions of classroom practice in his considerations on divergent thinking in the classroom and asks,

> "Does anything happen in school that could be named divergent thinking? Or is learning only regurgitation of accumulated knowledge that has been mediated by textbooks or teachers?" (p.102)

Passow (1982) called for the development of critical and creative thinking, heuristics and problem solving and affective interpersonal communication and social skills to improve thinking and learning for able pupils. Freeman (1998) describes how lessons which fail to engage able pupils will result in boredom, disenchantment with learning, daydreaming, challenging the rules and disturbance. Such pupils may also fail to develop 'the discipline of study' leading educational disablement.

Piaget's (1964) viewpoint on the purpose of education was that it should produce individuals "who are capable of doing new things, not simply of repeating what other generations have done – men who are creative, inventive and discoverers" (p5). Does current science education encourage this? The indicators are that perhaps it doesn't.

Research attempting to identify the reasons for the underachievement of able pupils in secondary schools was carried out by Michael and Kathryn Pomerantz (2002). In their analysis they found that the pupils were 'switched off' by excessive copying, sitting passively, a lack of relevance and variety, dull lecturing, lack of pupil voice and poorly planned lessons, particularly those of supply teachers. Their research concluded that hands on practice, creative activity, adult orientated work, mentoring, multi-media work and a study skills emphasis improved motivation. Most importantly ownership of the task and the empowerment which that brought, was found to be a strong motivational factor.

> "There is a power imbalance and Able Underachievers do not feel they own the problem or are responsible and empowered to do something about their underachievement and lack of interest in academic subjects." (Pomerantz and Pomerantz, 2002, p.57)

These viewpoints indicate that perhaps the reasons for the disaffection of pupils with school science may be less to do with the content of the science curriculum and more to do with the way in which it is taught. Teachers may be focussing on achieving attainment targets rather than on fostering genuine understanding of the science that they teach.

In 2003 Murray and Reiss, following up on previous research by Osborne and Collins (2001), reported on a web-based survey carried out by a collaboration of the London Science Museum, Planet Science and the Institute for Education. Pupils responding to the ‘Student Review of the Science Curriculum’ (Murray and Reiss, 2003) enthusiastically made the case that there was a place within the science classroom for debate of controversial science issues and a need to understand the causes and implications of scientific events impacting on the world around them. However, these pupils also acknowledged that the teaching methodologies that they enjoyed the most were not necessarily those that they regarded as the most ‘useful and effective’.

A wider research project carried out in 2004 looked at attitudes to science education worldwide. The research carried out in the ROSE – Relevance of Science Education, project (Schreiner and Sjoberg, 2004) targeted 14 – 15 year old pupils in 22 countries across the world and found that most pupils thought that, although school science was not particularly difficult, it was less interesting than other school subjects. The ROSE research reported that the relative unpopularity of science was stronger in the modern western countries than in the more traditional eastern countries. This may indicate that the reasons for the current relative unpopularity of science may lie outside school curriculum issues.

Later research, commissioned by the Economic and Social Research Council as part of the Teaching and Learning Research Programme (James, M. et al, 2006), focussed on how to improve ‘learning how to learn’ (LHTL). This research was carried out in 17 secondary schools across five Local Authorities. The research suggests that it is the quality of the educational experience provided by the teacher that is the dominant factor in determining the attitudes of the pupils (Gilbert, 2006). In an associated article Black et al. (2006) report that in order to help pupils to become more effective learners teachers should start from the established understanding of how children learn and explain that these learning principles are contravened when teachers ‘teach to the test’. Indeed the authors go further in stating that such an approach,

"....risks damaging good natural habits of learning by emphasising extrinsic success on performance tasks instead of supporting the genuine development of understanding." (p.8)

However 85% of the 'Planet Science' survey respondents said that they thought that the teaching and learning that they experienced in the classroom was exam-led (Murray and Reiss, 2003). Whilst this remains the case pupil voice in the classroom is likely to remain suppressed and skills in reasoning and problem solving through collaborative discussion will fail to be developed (Mercer, 2000, pp. 149 – 159). Pedder (2006) emphasises that teachers must learn new practices if they are to successfully promote pupil learning in the classroom and that a new relationship needs to evolve between pupil and teacher. Sisk (1987) states one of the essential roles for teachers of able pupils is as facilitators to guide independent study. This is not the same as letting them 'make it on their own' but requires sensitivity and judgement on the part of the teacher as to when to allow a pupil space to think alone and when to offer guidance.

In *Beyond 2000: Science Education for the Future,* Millar and Osborne (1998) recommend that teachers use a wider range of teaching and learning approaches in order to empower pupils by allowing them to access a basic understanding of the ways in which science and technology develop and are influenced by the driving economic, environmental and political forces of the day. The Scottish Consultative Council on the Curriculum (SCCC, 1996) refers to this as *scientific capability*. They define this by explaining,

"A person who is scientifically capable is not only knowledgeable and skilled but is also able to draw together and apply his/her resources of knowledge and skill, creatively and with sensitivity, in response to an issue, problem or phenomenon." (p. 15)

One way of achieving this is by *contextualising* the science curriculum. By acquiring knowledge and applying understanding in the context of a real world issue the science becomes more personally relevant to the pupil and their motivation to understand the principles at stake rises. By engaging in and developing expertise in *scientific enquiry* confidence can be developed and self esteem built in order that pupils will begin to feel that they have viewpoints which are important regarding a wide range of 'real world' science and technology. In other words pupils will gain a 'voice' in their science education.

The need for pupils to engage with the principles of *scientific enquiry* in an endeavour to bridge the gap between 'school science' and 'real science' were also identified in the Beyond 2000 report,

> *"There is a lack of variety of teaching and learning experiences leading to too many dull and uninspiring lessons. Sometimes routine practical work is used where other learning strategies might be more effective. Even investigations, an innovative practice introduced by the National Curriculum itself, are in danger of succumbing to routine teaching as a consequence of perceived assessment requirements." (p. 3)*

What changes in pedagogy will be necessary to bring about such a culture change in the science classroom? Traditional science has dealt with given 'knowns'. Some teachers may feel intimidated by the sense of 'loss of control' that may be produced by approaching science lessons from the perspective of investigating 'unknowns'. Fears regarding the possible detrimental effect of such an approach on attainment scores will need to be allayed.

Such fears are not only present in teachers but also in pupils who have become indoctrinated into the 'teach to the test' mentality and may themselves resist learning that does not count towards their attainment scores. Lakin and Wellington (1991) reported that pupils can feel discomforted by change and insecure in the classroom when the onus for their learning is suddenly thrust upon them.

> "They don't expect reading and discussion or drama and role-play – they do expect Bunsen burners and practical work. They don't want to find out that science is not a set of facts, that theories change, and that science does not have all the answers – they want the security of a collection of truths which are indisputable." (p. 187)

Thus effecting culture change in the science classroom is bound to be an uphill struggle. In order for teachers not to feel threatened by the change and for pupils not to feel insecure a great deal of underpinning support may be required. However Miller and Osborne (1998) consider that this change is unlikely to be brought about unless the assessment driven curriculum is changed.

> *"As long as the assessment system continues to reward disproportionately the kinds of learning which are best achieved by a narrow range of rather uninspiring and dull classroom activities, then we see little prospect of genuine improvement in the quality of our science education, or in the enjoyment of teachers in teaching it, and learners in learning it." (p. 5)*

As long as pupils are driven by the agenda of frequent testing and performance related teaching the cost will be demotivation (Gilbert, 2006) and a failure to engage with long term meaningful learning. Nor is this phenomenon peculiar to the English education system. Renzulli et al. (2007) describe a similar problem in the American education system where too frequent testing is leading to a lack of 'authentic learning',

> *" Over-prescribing the work of teachers has, in some cases, lobotomised good teachers and denied them the creative teaching opportunities that attracted them to the profession in the first place." (p. 45)*

Miller and Osborne (1998) stressed the importance of positive teacher and pupil attitudes towards classroom science as being influential on pupils' confidence, ability to make informed decisions and ability to make sense of scientific media reports. Ofsted have reported a link between pupils' attitudes to science and how actively involved they are through scientific enquiry with making decisions and expressing views (DfES, 2006b) Whilst these findings are indicative of a correlation between positive attitudes and pupil attainment they do not establish any definitive link between a good pupil attitude to science and high achievement in the subject. However there *is* some research evidence to assert that this may be the case. In 1999 research commissioned by the International Association for the Evaluation of Educational Achievement (IAEEA, 1999), which tested the attitudes towards science of 12 year old pupils and correlated them with the level of pupil achievement across 43 countries, found that there *was* a clear positive association between attitudes to science and achievement in science. The logical conclusion therefore is that if pupils' attitudes to science education can be improved then this will ultimately lead to improvements in pupil attainment.

In recent years the image of science has suffered from disturbing environmental disasters, social changes and considerable ethical concerns. Science has acquired a political dimension to which the school science curriculum has not responded by addressing the 'bad press' and disaffection, which has coloured the public image of science. So why is it so important that we change the culture of our secondary science classrooms? The answer to this question lies in accurately anticipating the needs of the citizens of the future as far as their understanding of science is concerned. Hodson (2003) makes the case that whilst scientific literacy is a fundamental requirement for citizens of the future, so also is the ability to understand the nature of science and its theoretical frameworks, to be aware of the applications of science and to be able to use science in everyday problem solving. Hodson also highlights the case for '*intellectual independence*' stating that without this capability citizens are 'easy prey to dogmatists, flimflam artists, and purveyors of simple solutions to complex problems' (AAAS, 1989, p.13)

Brandwein (1992) states that for able pupils to develop their scientific talents they need experience in a scientific activity 'outside the normal curriculum'. How much better would it be if by increasing teacher awareness and skills the curriculum could be adapted to include 'scientific activity' within the normal classroom? Renzulli's (1992) theory of the ideal acts of learning describes ideal interactions between the individual learner, the teacher and the curriculum. Renzulli notes that ideal learning needs both a rich curriculum <u>and</u> passionate teachers. By bringing some of the principles and practices from enrichment activities into the classroom we may more closely approach Renzulli's ideal. In this way we may also avoid many of the accusations of elitism that have been directed toward enrichment provision for the gifted and also some of the problems of inadequate identification procedures for the gifted.

3.2 What constitutes effective teaching and learning?

How are we to judge what is an 'effective teaching and learning methodology' in secondary science? Whilst many teachers would assume that a pupil achieving high grades in science SATS and GCSEs has had an effective science education others may think that this is more open to debate. Murphy et al. (2001) consider the most commonly accepted measure of effectiveness to be the ‘holy grail’ of end of Key Stage (KS) test results and define two effective teaching models, the social constructivist model distinguished by the collaborative relationship between pupils and teacher and the positivist authoritarian model, within which science is represented principally as knowledge to be acquired. Murphy et al. cite both of these models as being effective for attaining high test results but question whether in the latter model the learning acquired has any real meaning for the pupils. The extent to which each model is likely to stimulate and motivate pupils is also presented as a key consideration with the inference that the latter model, whilst widespread in use, is unlikely to promote sustained interest and motivation.

Positivist approaches to science education have been widespread in use since well before the introduction of the National Curriculum. Popper (1968) put forward a ‘rationalist’ view of science and emphasised a commitment to the scientific method in the search for scientific ‘truths’. Kuhn (1970) criticised such an extreme positivist epistemology towards empirical science and stated that by necessity all knowledge must be interpreted relative to existing paradigms. Thus attempts to ‘discover the truth’ are therefore always influenced by the frame of reference of the observer. This inevitably leads to a number of conflicting ‘truths’ depending on the viewpoint of the learner. Only by social discourse can a consensus of opinion be reached upon which ‘truths’ can be widely accepted as universal and which can only be accepted subject to limiting conditions. It is in this way that science knowledge has been constructed since the days of Copernicus.

Kuhn’s viewpoint is relevant to the science classroom in so far as it becomes a necessary part of the learning process for pupils and teachers to be able to argue, reflect on and discuss their relative opinions. If teachers only impart knowledge without allowing pupils to be socially constructive in building their models of understanding then it is unlikely that their cognisance will be meaningful. In such a scenario pupils will be inclined to ‘switch off’ and may even become resentful that their voice is not being listened to (Warwick and Stephenson, 2002). Black (1998) maintains that the pursuit of coverage of the curriculum and the necessity for pupils to perform well in external tests dominate what teachers believe to be important in the classroom and that these are the drivers responsible for much that can be recognised as positivist in their approach to teaching and learning, wherein even practical science lessons may become mere verifications of pre-existing knowledge. Warwick and Stephenson (2002) reinforce this view,

> " For the majority of pupils, rather than making science meaningful, the practical work they undertake is at best illustrative, rarely allowing the opportunity to investigate their own ideas. Actual experiments are dismissed if they fail to support the 'accepted' scientific wisdom. At the same time, 'what should have happened' explanations take precedence over any critically reasoned discussion of findings. The consequence is that practical activity, rather than inspiring awe, wonder, excitement and curiosity, becomes purposeless and de-motivating." (p. 147)

Murphy et al. (2001) identify a type of teacher who represents science only as 'knowledge to be acquired'. However they question whether such 'learning' has any real meaning, depth or durability for pupils. Tobin et al. (1990) are in agreement with this view,

> "There is little evidence that the majority of science teachers are concerned with the extent to which students understand what they are to learn or with implementing the curriculum to emphasise student understanding of science. Rather, the findings of research suggest that most teachers feel constrained to prepare students for tests and examinations and cover science content from text books. This practice deprives many students of opportunities to learn with understanding." (p. 3)

Such viewpoints resonate with those voiced by Miller and Osborne (1998):

> "There has been a general acceptance that learning science involves more than simply knowing some facts and ideas about the natural world, and that a significant component of science curriculum time should be devoted to providing opportunities for personal inquiry." (p.2)

In rejecting the positivist stance Miller and Osborne explain that learning in science should include a search for reliable explanation, skill in evaluation, interpretation and analysis and practice in constructing argument based upon evidence. Their idea of 'effective teaching and learning methodology' is one, which is inclusive of a variety of activities with which learners engage, allowing for a 'range of tasks better matched to individual pupils' current capabilities and their interests' (p. 5).

Such a 'constructivist' approach to teaching and learning has its roots as far back as Socrates, who in dialogues with his followers asked directed questions, which caused them to reflect upon weaknesses in their understanding. In more modern times perhaps the rise of constructivism can be identified with the work of George Kelly (1955). Kelly was a psychologist who developed the theory of 'constructive alternativism', which explained that reality is always experienced from one or another perspective leading to alternative constructions. However, true to his philosophy, Kelly recognised that if his theory survived the next ten or twenty years *without modification* then it would be disproved. However Kelly need not have feared for there have been many modifications to his theory since its first inception.

Jean Piaget (1952, 1969, 1972), working in the field of cognitive development, theorised that the development of intellect happened through the processes of adaptation and organisation. By such arguments Piaget declares a constructivist epistemology. Adaptation is a process of assimilation and accommodation wherein external experiences become integrated into the mental models formed by the individual. Piaget defined four major periods of cognitive development in the human as the sensorimotor, the pre-operational, the concrete operational and the formal operational and associated each stage with age ranges within which children's learning methodology could be chiefly identified by the criteria describing each period. National Curriculum attainment levels are still loosely related to Piaget's theoretical stages of development and ascribed to similar age ranges.

Piaget was a constructivist in so far that he maintained that knowledge is actively constructed by the learner. Jerome Bruner, a contemporary of Piaget, went further in maintaining that this active construction of learning relies on new concepts being formed which are based on the existing understanding of previous knowledge. Thus Bruner advocated that the curriculum should be organised in a spiral manner so that the student continuously builds upon what they have previously learned (Bruner, 1960, 1966). Lev Vygotsky (1978) introduced the contention that learning was a social process and developed a theory of social constructivism. Vygotsky was critical of the assumption made by Piaget that it was possible to separate learning from its social context and argued that all cognitive development was a product of social interactions (interpsychological), which occurred first followed by internalisation of learning (intrapsychological) by the individual. Vygotsky defined a Zone of Proximal Development (ZPD) within which children may be assisted in their understanding by social interaction aiding them to construct new knowledge. The role of the teacher within social constructivism was to 'scaffold' the learning of the pupil by providing stimuli to enable them to build on prior knowledge and internalize new information (Raymond, 1999:176). Thus Vygotsky is contradicting Piaget's theory that development precedes learning and maintaining that learning is a necessary precursor for development.

Ernst von Glaserfield (1990, 1992) developed a theory of radical constructivism which viewed knowledge as something which is personally constructed by individuals and allied himself with Piaget's view of knowledge construction by intrinsic internalisation rather than Vygotsky's view of extrinsic assimilation by socialisation.

> "Knowledge is the result of an individual subject's constructive activity, not a commodity that somehow resides outside the knower and can be conveyed or instilled by diligent perception or linguistic communication." (von Glaserfield, 1990, p.37)

What this implies is that knowledge cannot be conveyed simply by words unless the concepts of the listener are linguistically compatible with those of the explainer. For meaningful learning to occur the learner must actively construct new information onto existing mental models. However, such preconceived models may be invalid or incomplete and this may hinder the ability to assimilate the new information with the existing structure. It is when the incoming data is 'non viable' within the existing knowledge framework that cognitive dissonance arises and the individual is required to construct a new model to assimilate the new information. The new constructions of knowledge must be 'viable' in order for them to survive and thrive within the adapted concept framework of the individual. This is summed up by Ausubel

> "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." (Ausubel, 1968, p. vi)

However ascertaining what the learner already knows is perhaps the easier task and it is in the interpretation of 'teaching accordingly' that many of the problems lie.

Research carried out by Lorsbach and Tobin (1997) indicates that teachers' beliefs about how children learn are what determine their practice. Teachers who ascribe to the positivist epistemology are more likely to adopt didactic, teacher-centred teaching and learning methodologies and teachers who believe in constructivist approaches are more likely to engage with child-centred teaching and learning methodologies. However, there are some teachers who may profess to hold constructivist beliefs and yet are revealed by their practice to be closet positivists (Fischler, 1993). When teachers are under pressure it is often the case that they revert to teacher centred teaching in order to 'complete the work scheme' and constructivist principles go by the board. Research indicates (Lorsbach and Torbin, 1997) that it is the personal epistemology of teachers, formed from their own past experiences and often unverbalised, which guides their practice.

However, constructivist approaches should not be regarded as a universal panacea to cure all ills in the classroom. Critics of constructivist approaches maintain that pupils can often construct meanings that fit with *their* experiences and expectations and may often construct meanings different to those intended by the teacher (Driver, 1989). This can result in a separation between 'school science' and real world experiences. A common example of this is in the interpretation of Newton's Laws of Motion, where pupils are quite ready to accept that a resultant force on an object results in a change of velocity when in the classroom but when outside believe that in order for any object to keep moving at the same velocity a force must be acting (since if it wasn't the object would slow down!). However, unless teachers are prepared to *listen* to the thoughts of pupils and construct meaning to their learning through social interaction such dichotomies in pupils' thinking are unlikely to become evident and the correction of misconceptions will remain unresolved. If the classroom climate for behaviour management requires pupils to work in silence and do only as they are instructed then the opportunity for teachers to understand the thinking of pupils is not presented (Caprio, 1994) and pupil misconceptions are likely to perpetuate. Effecting a culture change in classrooms may involve teachers in feeling threatened by a 'loss of control' in the classroom and thus many teachers may feel intimidated and resistant to change.

A second criticism of the constructivist approach to teaching is that it is elitist, most successful with children from privileged backgrounds with committed parents and access to educational resources. Whilst it is almost certainly true that such children are more likely to be in supportive environments than children from less privileged backgrounds, it would be discriminatory to offer constructivist teaching and learning methodologies only in ‘middle class’ schools and positivist, objectivist teaching in ‘working class’ schools. Surely the perspective of educators should be focussed on how to provide all children with the right facilitative environment within their classroom and school, within which they can access the resources and conditions that they need to thrive educationally. Actively involving and encouraging parents to be part of their children’s education can be possible in many social contexts and not to offer constructivist approaches to any sector of society on the basis of socio-economic grouping would do many pupils a great disservice.

Another criticism of constructivism is that it may be subject to the ‘tyranny of the majority’ in which some pupils may conform to the consensus rather than voice their own thoughts. Rather than this being an argument against constructivism it could be viewed as an argument *for* autonomy. Encouraging greater autonomy for pupils means encourages teaching and learning methodologies which allow each individual to take responsibility for their learning and not abrogate this to others, be that a peer group or indeed their teacher! However encouraging pupils to take responsibility for their own learning is not to deny that a considerable amount of guidance may be necessary on the part of the teacher towards this end (Duit, 1994). Unless teachers themselves are guided upon how to accomplish this it is unlikely to happen spontaneously.

One common strategy amongst science teachers is to arrange a cognitive conflict by using conflicting empirical evidence (Scott, Asoko and Driver, 1992). However, even when pupils recognise such a conflict they do not readily give up their previous conception unless the new learning is made meaningful within their own conceptual framework (Duit, 1994). This requires that teachers firstly appreciate what that conceptual framework is and this they can only do by interaction with the pupil. This then leads to an hermeneutic cycle of understanding in which new concepts firstly coexist alongside old concepts until eventually they become integrated into a new modified conceptual framework (Jung, 1986).

So what is the evidence that constructivist approaches to teaching and learning work in so far as they result in a depth of understanding of the subject and a motivation for further study on the part of pupils? Guzetti and Glass (1992) offer reason for optimism.

> “ Based on the accumulated evidence from two disciplines [reading and science education], we have found that instructional interventions designed to offend the intuitive conception were effective in promoting conceptual change. The format of the strategy (e.g. refutational text, bridging analogies, augmented activation activities) seems irrelevant, providing the nature of the strategy includes cognitive conflict.” (p. 42)

Ambrose et al. (2003) also report metacognitive training to be effective in nurturing cognitive abilities and advocate that one way to do this is by encouraging children to share how their minds work. Poncini and Poncini (2000) report from their study into pupil scientific research that constructivist strategies resulted in greater writing fluency, increased accuracy, improved laboratory technique and the development of peer teaching within the group of pupils under study.

> “ Active student participation in scientific research provided opportunities for students’ controlled learning or metacognition. We believe that the students were responsible for their learning skills because they appreciated the importance of science, the need to test hypotheses and that science as an experimental discipline produces information for other scientists.” (p. 47)

In the CASE (Cognitively Accelerated Science Education) Project, Adey and Shayer (1994) report that the success of the project was a direct consequence of the pupils’ ability to think about the nature of their own thinking. The project proved successful for middle ability pupils in scaffolding their progress towards higher levels of cognitive acuity and the benefits did not just show up in their performance in science but also in their performance in subjects across the board. The effects of the CASE Project proved to be long term in that pupils’ improvements in thinking skills persisted throughout their secondary education, as evidenced by a measured improvement in GCSE scores, above previously expected levels.

However CASE is only one of a number of initiatives designed to facilitate cognitive learning. Teachers have been the recipients of a number of theories and initiatives based on ideas regarding how the brain assimilates information, including thinking skills enhancement, left brain / right brain theories, multiple intelligence theories and assorted theories about ‘learning styles’. Whilst many of these have proved to have some foundation, there have also been wide criticisms. Claxton maintains that raising standards does not necessarily depend on the creation of ideal learning environments but on persistent encouragement for young people to think of themselves not just as ‘knowers’ but as ‘finder-outers’ (Claxton, 2005). In constructing their own knowledge through personal enquiry they ‘learn how to learn’ and can set themselves an enjoyable level of challenge. Consulting pupils about their perceptions of science and giving them choice in the direction of their learning, enhances motivation and contributes to the development of a wider range of teaching strategies (Flutter and Rudduck, 2004). Evidence from New Zealand (Coll, 2007), where a much more pupil centred national curriculum is in operation suggests that a constructivist based curriculum results in greater flexibility in learning programmes. However, this requires the continuous professional development of teachers who may be inexperienced in both constructivist philosophy and methods.

In order for teachers to take on board such professional development they must firstly be convinced of the advantages of constructivist approaches over other classroom methodologies. What evidence is there that a paradigm shift on the part of teachers will result in improved learning for their pupils? Fisher (2004) observes,

> “The quality of pupils’ work can improve dramatically when they have a chance to develop their thinking skills and have time to explore, to play with ideas, solve problems with others and get feedback on creative tasks.” (p. 2)

Further evidence suggests that children learn more and can enjoy learning more than when they are passive listeners, that their learning is transferable to other settings and that by gaining ownership of what they learn they engage with initiative, invest personal time, develop creativity and are more likely to retain knowledge gained. By grounding learning activities in real world contexts constructivist approaches succeed in engaging pupils’ interests and stimulating their curiosity. Such teaching and learning methodologies also promote social and communication skills, encourage articulation of ideas, collaboration on tasks and enhance negotiation skills. However, they require the setting of tasks that do not have clear ‘right’ answers (Taber and Corrie, 2007) and this increases planning time for teachers. How realistic an expectation this is for every teacher in every classroom is questionable. Where the range of ability within the classroom is large teachers will need to practise fully their skills of differentiation in order to ensure that both the struggling and the able are supported to achieve their full potential.

A study carried out by Galton (2002) into primary/ secondary transfer revealed that there was still a heavy reliance (> 50%) by secondary teachers on ‘whole class teaching’. This was at the expense of individualised interaction. Despite the curriculum shift towards ‘scientific enquiry’ the reality in the classroom was that little had changed over the last two decades. Galton concludes that if science teaching remains dominated by teacher instruction and demonstration then part of the reason why pupils are disaffected with science education may lie in the kind of teaching that they receive. There is an increasing recognition amongst science educators that science education is, to some extent, a product of its time and place (Hodson, 2003). Today’s pupils are not content with dull and unstimulating teaching methodologies when their lives outside school are filled with stimulating activities. If other school subjects offer greater stimulation, interest and motivational activity then they will turn away from science and towards those other subjects.

3.3 Effecting culture change in classrooms

So what needs to be done to switch pupils back on to science? There is no one ‘quick fix’ solution and to suggest that there may be would be naïve and fly in the face of much research into a number of problem areas.

The first of these is the curriculum itself. The national science curriculum (DfEE, 1999) consists of four main areas SC1 ‘Scientific enquiry’, SC2 ‘Life Processes and Living Things’ SC3 ‘Materials and their Properties’ and SC4 ‘Physical Processes’. Each of these areas contains a Programme of Study (POS), which forms a curriculum model for that subject area. These programmes of study contain many facts and concepts alongside process skills and identified interlinking relationships. The recent introduction of the Secondary National Strategy (DfES, 2007a) has imposed another layer of prescription on top of the demands of the basic curriculum as teachers are now also required to take on board the 'Every Child Matters' agenda for personalised learning. This requires that teachers consider more than just knowledge transfer in their classroom but also consider,

> "…developing positive and supportive relationships by creating conditions for learning, which form the overall context within which a teacher's knowledge, understanding and skills are applied and the learner's progress can be maximised." (p. 2)

Whilst this is a laudable aim and certainly a step in the right direction, creating these optimum conditions for learning will require effecting a culture change in most classrooms. Before any such culture change can be effected teachers will need to be convinced of the need for change. For many teachers who are achieving good pupil performance figures by positivist methodologies this may take some convincing.

The National Strategy describes four 'domains of pedagogy' as subject and curriculum knowledge, teaching repertoire of skills and techniques, teaching and learning models and conditions for learning (DfES, 2007a). Whilst the objectives set out by the National Strategy have been carefully researched and shown to be effective in improving teaching and learning in the classroom, in pilot projects with motivated teachers what has been less well researched is the process by which such objectives may be achieved across the board. What strategies can be used to enable *all* teachers to do what good teachers were doing anyway? Changing the culture in classrooms may take more than government edicts. Many teachers struggle with differentiating for ability in the classroom (OFSTED, 1994) and these are likely to struggle even more with the personalised learning agenda, since this requires not only differentiating for ability but also for affective qualities including personal interests, confidence, communication skills, aspirations and attitude to learning. The Secondary National Strategy states that,

> " The curriculum should not only provide all pupils with sufficient understanding of science for their role as scientifically literate citizens but should also excite young people to study science further. The new Key Stage 4

> curriculum and the new Science GCSEs have these principles in mind." (DfES, 2007a, p.47)

However, it is unlikely that a change of curriculum alone can be successful in switching pupils back on to science. It will also require teachers to become convinced of the need to embrace such changes and to reflect upon how such changes can be effected within their own classrooms.

Teacher attitudes are therefore the second problem to be overcome before changes in classroom culture may be achieved. How can teachers be persuaded to let go of some of their 'tried and tested' teaching and learning methodologies and embrace new ways of communicating in classrooms? Perhaps one method for achieving this may lie in getting teachers to analyse, through action research, the role of dialogue exchange in their classroom. Scott (2007) discusses the role of classroom dialogue in 'coming to an understanding of ideas' and advocates the use of extended talk in making learning more meaningful for pupils. Scott analyses classroom talk in four categories interactive/ authoritative, interactive / dialogic, non-interactive/ authoritative and non-interactive/ dialogic and estimates that in most classrooms it is the interactive/ authoritative talk which makes up over 90% of communication. This is usually question and answer sessions of the type that require the pupils to guess what response the teacher wants them to give. However, Scott maintains that by using a flow of different types of classroom talk for different purposes at different points within a lesson a much more meaningful intercourse takes place with a place for all four types of classroom talk, used rhythmically to open up ideas and then draw discussions to conclusion. Scott also recognises that changing the practice of teachers towards such ends is challenging as few teachers will identify the problem or feel a compulsion to effect a shift in practice.

This view is reinforced by Watts and Pedrosa de Jesus (2007) in their analysis of classroom questions, which found that most of the questions asked in the classroom are asked by those who know the answers rather than those who do not. By repressing pupil questioning creativity is stifled in the interests of routine and 'progress' against the work scheme (Rutland, 2005). Watts and Pedrosa de Jesus (2007) exhort teachers to use creative, reflective and critical questioning to challenge the thinking of pupils and make their learning more meaningful. However, creating such a 'climate of enquiry' requires teachers to plan thoughtfully and welcome and give time for pupil questions within their lessons. This 'letting go and handing over' philosophy can be scary for teachers who feel that good behaviour management requires tight control and such a change in practice will not be easily achieved. This point is reflected upon by Eyre (1997),

> "The desire to demonstrate that all children have covered the required content, concepts and skills has, in some cases, led to an emphasis on teaching at the expense of learning: a preoccupation with what pupils are being given to do rather than what they are learning." (p. 43)

Research carried out by Campbell et al. (2006a) identified four principal conditions required in classrooms for personalised learning to be practised effectively. The first of these was that the teacher needed high levels of expertise in their subject. For science teachers this may be problematic, as many may have to teach outside their own specialist subject due to shortages of teachers of physical sciences. The second condition was that classrooms exhibited high levels of on-task behaviour and pupil self-motivation. Again this may be another problematic area in many schools where behaviour management is a major issue. The third condition was that the philosophy that knowledge is tentative, contestable and revisable should permeate the lesson. This is unlikely to be the case with positivist, authoritarian teachers and may require a major paradigm shift in many classrooms. The fourth condition required was that relationships within the classroom should be informal but structured with pace and direction clearly controlled by the teacher. Whilst this may be the case in the more pupil compliant, middle class schools within which Campbell et al (2006a) carried out their research, it may well not be the case in all schools and the extent to which the findings of the research are generalisable to other more challenging contexts is questionable. Thus there may be more impediments to constructivist teaching and learning methodologies becoming embedded into all classrooms than those demonstrated by this research.

As long ago as 1994 Ofsted identified good provision as occurring when teachers are operating securely and encouraging pupils to think, reflect and seek challenges in their tasks. Ten years later a QCA (2004) publication on 'Implications for teaching and learning from the 2004 KS3 Science tests' urges teachers to encourage children to evaluate inferences from scientific information, apply knowledge in unfamiliar situations and practise writing descriptions and explanations in order to enhance their classroom performance. Thus it would appear that teaching and learning in most classrooms has changed little within this ten year period. So what new proposals are being offered to ensure that progress is better in the next ten years?

The 2006 'Science and innovation investment framework 2004 – 2014' (DfES, 2006b) reports that pupils attitudes to science are affected by how actively involved they are in the classroom through scientific enquiry, making decisions and expressing views and recommends that 250 after school science clubs should be set up from 2006 for KS3 pupils with interest and potential in science. Thus there is widespread recognition that pupil autonomy, pupil dialogue and pupils taking responsibility for their learning are key to future progress. However, the danger in the setting up of science clubs is that it again takes the emphasis for learning away from the ordinary classroom and relies on accurate selection of those pupils who may have 'interest and potential in science'. There may be many children in unstimulating classrooms that have this potential but are not included in selection for such clubs. Thus it must surely be preferable to focus primarily on provision in the classroom. The Secondary National Strategy has as one aim 'to identify and promote effective practice in interactive teaching including imaginative use of practical work' (p.47) but does not outline how such practice is to be identified and promoted. There is clearly a need for educationalists from within schools, research establishments and other agencies to work together to support such identification and promotion of good practice.

Eyre (1997) identifies a number of key indicators for good classroom provision including, differentiated pace, high teacher expectation, secure classroom management and identified learning outcomes. Montgomery (1998) underlines the importance of teaching good study skills alongside the development of thinking and problem solving skills. Wittrock (1994) proposed a 'generative model for teaching', which used pupil metacognition to help pupils become more proficient in learning. This required teachers to have clear, contextually relevant objectives, to have a good understanding of pupil preconceptions, use models to develop pupils' understanding and for teachers to realise that learning is a generative process which uses metacognition to solve problems. The use of modelling to assist pupil learning has also been advocated by Grevatt et al. (2007), who describe the successful use of action research amongst a group of teachers to help them to develop challenging science teaching through modelling. The researchers describe the methods used to be most valuable in extending the work of able learners within the classroom. However all of these approaches require pupils, to a greater or lesser degree, to accept responsibility for their own learning and this can only happen if pupils are given some autonomy over the direction of their learning in the classroom.

The 1999 Robinson Report (NACCCE, 1999) on 'Creativity, Culture and Education' concluded that if teachers wanted pupils to think creatively then it required teachers to teach creatively.

> "Teaching for creativity aims to encourage autonomy over the ideas being offered; authenticity from decisions based on ones own judgement; openness to new ideas, methods and approaches; respect for each other and for emerging ideas; and fulfilment in the creative relationship. Above all there has to be a relationship of trust. This can encourage a sense of responsibility for learning, leading to self-directed learning involving goal setting and planning and the capacity to monitor, assess and manage oneself." (NACCCE, 2000, p. 6)

Whilst there is much to be applauded in the report what it describes is an ideal condition in schools. What the report does not do is to assist teachers and school managers to move forward from what are commonly non-ideal conditions towards this ideal.

The Robinson Report identifies a third obstacle to changing the culture of the classroom and that lies in the status of learning amongst pupils and the ethos of many schools. When the culture of 'it's not cool to be clever' persists in schools, teachers face an uphill struggle to engage pupils in autonomous learning practices. The values and practices that teachers and pupils bring to the classroom are both derived from and embedded within the ethos of the school (Campbell et al, 2006a). Thus it is essential that schools work towards creating a culture within them wherein success can be celebrated. George (2003) suggests that in the interests of creating such an ethos for learning it is necessary that schools provide high interest activities, give pupils prompt and frequent personal feedback, have high expectations and promote motivation by giving learners control over their learning. Another important factor identified by Sisk (1987) in the creation of a positive ethos in school is the development of pupils' self esteem. Sisk maintains that this can be aided by identifying the areas of interest of individual pupils and allowing them to pursue a project in that context through to its completion. By demonstrating their knowledge and ability in one area their attitude to other areas of school life may be lifted and individual aspirations raised. The Secondary National Strategy (DfES, 2007a) also identifies the importance of mutual respect in building a school ethos for positive learning. This demands that pupils' views must be listened to and taken seriously by their teachers, only then can teachers expect reciprocal treatment from their pupils. Thus constructivist principles are in alignment with the 'respect agenda', which is rising to the fore in current political debate. However, the teaching workforce consists of a significant number of teachers who have operated in a didactic, positivist fashion for a number of years.

The fourth impediment to be overcome in the interests of changing classroom culture is to get all teachers to accept that as well as teachers they must also be learners. Changes in family structure, in technology, in youth culture, in peer pressures and in society's expectations have created a complex undercurrent of conflicts and desires in young people. Many teachers may be out of tune with this and fail to appreciate that the contexts of life for their pupils are very different from their own. Constructivist teaching moves away from the idea of the teacher always being the 'knower' and the pupil the 'learner'. It very often may depend on teacher and pupil co-constructing knowledge and working in a collaborative way. Research has shown (Duit, 1994) that teachers are not usually ready to adopt constructivist teaching and learning processes without considerable distortion. However, if they are to do justice to the needs of their pupils, including the needs of their most able pupils, then they will need to embrace the fact that their own learning needs to be continuously developed. Initial Teacher Education is just that, *initial*, and for teachers to cope with the fast pace of change in society they must also accept that they have learning needs every bit as valid and urgent as that of their pupils.

3.4 The special needs of able pupils

To what extent is constructivist pedagogy suitable for able pupils? For those pupils who have already been identified as having a proclivity for science there may well exist a greater knowledge base and more advanced skills than would be demonstrated by the average pupil. In addition many able pupils will already posses an intrinsic motivation to continue to develop their understanding (Geake et al, 1996). Many pupils may engage in scientific investigations of their own volition outside of school lessons and take great interest in creative projects of their own construction. But this will not be the case for all able pupils. It falls to the teacher to be able to open doors for some of these able pupils and to ensure that these doors stay open for others. One way of doing this is to encourage all able pupils to exploit their abilities through scientific enquiry.

Poncini and Poncini (2000) believe that by providing able pupils with the opportunity to carry out real scientific research, their cognitive skills in all areas may become better developed. Their experience suggests that 'real science' cultivates scientific thinking and improves the capacity to learn amongst able pupils. West (2007) agrees with this view but laments the fact that the type of 'practical work' contained within most school schemes of work does not constitute authentic scientific enquiry. West maintains that opportunities for pupils to demonstrate creativity are lost because school practical work, all too often is closed and offers no scope for problem solving.

> *"Working with large numbers of gifted learners in the context of Summer School and Master Class activity it is clear to us that problem solving approaches embodying students' own investigations provide an excellent vehicle for supporting the needs of these learners. Unfortunately it seems that generally this type of provision involves students being removed from the usual teaching environment and placed into some kind of specialist arena." (West, 2007, p.179)*

The provision of 'enhancement activities' for able pupils has been in widespread use since 1999 when the 'Excellence in Cities' (DfEE, 1999b) initiative began. The National Strategy for Key Stage 3 (CEDS, 2004) states that it is vital to enrich and extend the curriculum for pupils who are gifted in science. One strength put forward for enhancement activities is the opportunity for able pupils to work with other like-minded individuals. However, there has been little research into how effective this strategy has been in advancing able students. Hewston et al (2005) suggest two reasons why this is the case. The first of these is that the diverse range of enhancement provision makes any systematic evaluation difficult and the second that there are very few criteria against which to evaluate the effectiveness of such programmes. The extraction of able pupils from their schools for enhancement activities has been observed to result in them becoming estranged from their peer group in school in some cases (Eyre, 2002). Also since enrichment support varies from area to area the quality of pupils' experiences becomes something of a postcode lottery. Ofsted (2001) have suggested that enhancement courses have been successful in raising pupils motivation and self-esteem but have not offered any evidence that they enhance pupils' attainment. Research to date (Eyre, 2002; Teare, 1997) has suggested that in the interests of equity and effectiveness more emphasis should be placed upon stretching able pupils in the classroom by using more innovative approaches to teaching and learning.

One such innovation has been the introduction of context-based courses as an alternative to the traditional content-based offerings from GCSE examinations boards. Such context-based courses begin with a relevant context and introduce scientific concepts as the context is explored. One reason for the introduction of such courses was that teachers were citing 'lack of time' for open-ended tasks when delivering content-based courses (Kind, 2007). In the view of Montgomery (2000) traditional courses have lead to,

> " …a cadre of teachers who are educationally illiterate and pupils who are becoming repositories of fact but who lack the ability to put their knowledge to any useful real-world purpose…. The highly able and the more creative are rejecting such 'schooling' and are switching off." (Montgomery, 2000 pp. 130 – 131)

Evidence that context-based courses may be more appropriate for the needs of able pupils is discussed by Bennett et al (2005) in their study of over two hundred chemistry teachers teaching on the Salter's Advanced Chemistry course. The study reports the advantages to be the presentation of greater challenge and the promotion of independent study skills. However, problems encountered in the delivery of such courses have been recognised in the difficulty experienced by teachers adjusting to a different kind of pedagogy (Bennett et al, 2005), resulting in the need for ongoing support for teacher development (Van Tassel-Baska, 1998). Further to this, Kind (2007) reports that the benefits of such courses have been evidenced primarily in middle ability pupils rather than high ability pupils and that such courses have not resulted in increased recruitment onto 'A' level science courses. Thus it would seem that the success of such courses for able pupils lies with the extent to which teachers are able to adapt their teaching practices in order to incorporate challenging and stimulating classroom activity and facilitate able pupils towards the attainment of skills for independent learning.

The inclinations of able pupils in science towards independent learning have been documented in previous research. Vygotsky (1978) explains that able pupils display greater proclivity for independent learning because they possess more extensive zones for proximal development than less able pupils. Ausubel and Robinson (1972) described the enthusiasm displayed by able pupils when engaged on scientific investigation and reported that these pupils did not require instruction and worked effectively unaided. Sato (1995) describes an ideal differentiated curriculum for the able as containing in depth learning of a self-selected topic within the area of study designed to aid the development of independent study skills. However, the danger exists that teachers will interpret such statements as meaning that able children can be 'left to go it alone' and that their special needs as able learners will be neglected. Thus when describing the ideal differentiated curriculum it should be made clear exactly how ability in a subject area should be differentiated for.

Differentiation refers to,

> *" …the process by which curriculum objectives, teaching methods, assessment methods, resources and learning activities are planned to cater for the needs of individual needs." (George, 2003 p. 105)*

Research into ideal conditions for learning for able pupils confirms that pupils are more successful when they are in classrooms where the teacher has catered for their needs through differentiated planning (Ehlers and Montgomery, 1999; Tomlinson, 1995). Nor is such differentiation to be considered only in the case of the mixed ability classroom but in all classrooms since there will always be a diversity of ability in any classroom, even within a class, which has been selected on the basis of ability (Hewston et al, 2005). Teare (1997) describes a differentiated curriculum for the able as consisting of a number of areas to which the teacher must give some thought when planning lessons. These include

- Differentiation by task: tasks for able pupils must be open-ended and more difficult than tasks for others in order to create a climate for challenge;
- Differentiation by pace: able pupils must be required to work faster than others;
- Differentiation by resource: resources and worksheets must differentiated for the different abilities in the class;
- Differentiation by outcome: tasks should allow individuality of response in their outcome;
- Differentiation by dialogue: language used with able pupils must be appropriate to their ability to understand complex constructions;

Eyre (1997) maintains that differentiation by task, outcome, resource and support are important but that good provision requires consideration of greater subtleties and that sometimes good differentiation is opportunistic in that it requires the teacher to be reactive to the needs of the moment, as those moments present themselves within the classroom. However, Eyre also appreciates that it is difficult for teachers to do this when they are under-confident in their subject which may be the case for some of those teaching physical sciences. This kind of inflexibility can be detrimental to able pupils.

“ Curiosity cannot be put back in a box and revisited later, especially not where young children are concerned.” (Eyre, 1997 p. 40)

Another impediment to appropriate differentiation is the guilt that some teachers feel when they spend lesson time on the most able rather than the least able pupils (Eyre and Fuller, 1993) Teachers’ perceptions are that the needs of the least able are deserving of a greater proportion of teacher time and this operates to the detriment of the more able pupils in the class. Eyre (1997) suggests that this impediment may be overcome by improving classroom organisation and the use of other adults in the classroom. O'Brien (2003) maintains that one aspect of classroom organisation which can assist able pupils is to look at the working groups within the class. By grouping the most able children together some of their interactions with each other can serve to stimulate higher level work. Thus the teacher is less likely to feel guilty about giving some class time to the group rather than to just one individual. However, one disadvantage of this can be that other members of the class resent the creation of a 'top group' from which they are excluded and that this can be socially divisive.

Wallace (2000) maintains that the key to good differentiation in the classroom lies in the quality of teacher questioning. Ofsted (1994) found that most teachers do not extend their able pupils by the use of thought provoking questioning and identified this as an area for development in the professional development of teachers. Another method for stimulating pupil response and debate identified by Levinson (2007) is to introduce controversial socio-scientific issues into the classroom. Levinson maintains that activities based on socio-scientific issues offer opportunities for differentiation by task, by support and by outcome and describes how the ability of pupils to analyse resources and synthesise arguments is supported by this activity. Pupils may get better exposure to the complexities of such issues by the utilisation of 'expert scientists' in the classroom. Sisk (1987) describes how the use of such expertise gives pupils insights into how scientists think and provides opportunity for pupils to understand the rigour of scientific methods. However many such encounters take the form of enrichment activities (Newberry and Gilbert, 2007) and as such the link with classroom activities is weakened unless preparatory work and follow up work take place around the event. If pupils are extracted from lessons for their encounters with experts and teachers are not included in the encounter then the impact on the teaching and learning for able pupils in their classrooms will be minimal. Whilst able pupils will find such activities enjoyable and stimulating an opportunity is lost to model 'real science' and the principles of true 'scientific enquiry' with their teachers and this is to the detriment of not only the able pupils that they teach but also all the other pupils taught.

Perhaps the most explicit form of differentiation for able pupils lies in the creation of Individual Education Plans (IEPs). Teare (1997) describes the use of such plans as the means to deliver effective provision on an individual pupil basis. IEPs consist of action plans containing targets and review dates so that the teacher can monitor individual pupil progress. However, the routine use of such IEPs can become mechanistic and hard pressed science teachers may find it difficult to consult with able pupils on an individual basis regarding their progress in science. One advantage of the use of IEPs is that the pupil's education in school can be mapped against their out of school activities in order to make their total experience more meaningful. However, in order for IEPs to be used effectively teachers will need to be convinced of their benefits for able pupils and supported by training in effective methods of use and the time management skills called for by their use. Thus the special needs of able pupils cannot be considered in isolation from the special needs of their teachers. Geake et al (1996) maintain that an important aspect of differentiating for able pupils is increasing teacher awareness of the nature and nurture of 'giftedness'. If *all* teachers are to be effective teachers of the able pupils in their classrooms then the professional development of *all* teachers must be an essential pre-cursor to effective provision for their pupils.

3.5 Initiatives to promote teaching and learning for able pupils

Research projects designed to inform initiatives to promote better teaching and learning for able pupils can be categorised into those which gather information principally through researchers, those which gather information through working with pupils and those which gather information through working with teachers. There will inevitably be some overlap between these three categories in any research project.

In 2002 educational psychologists Kathryn and Michael Pomerantz (Pomerantz and Pomerantz, 2002) conducted interviews with 26 pupils, identified as able underachievers across eleven schools in the East Midlands. One area of focus was the thinking and learning factors that these pupils identified as affecting their academic progress. One of the key findings of this study was that able underachievers did not feel empowered to do something about their underachievement. The limited repertoire of study skills that they had acquired throughout their schooling did not allow them to express their creativity or access independent learning and the majority accepted boredom as a major part of school life. The conclusions of the study were that able underachievers need creative and practical approaches to learning in lessons. They need to be challenged at the levels of synthesis and evaluation and to be exposed to a range of study skills. These able pupils felt that school offered them little of relevance to their lives and were generally unmotivated by their lessons.

The issue of pupil motivation was examined in a subsequent study by The Royal Society for the encouragement of the Arts (Bayliss et al, 2003). The RSA developed a competence framework consisting of five categories of competence: learning, citizenship, relating to people, managing situations and managing information. This created a radical departure from the normal way of working within the National Curriculum and introduced a competence-led curriculum for key stage 3 in five pilot schools. The introduction of such a curriculum resulted in a dramatic change in the working practices of teachers. Pupils spent more time with fewer teachers and did not move around the school as much. This resulted in different demands on teachers and closer relationships with their pupils.

The findings of this research were that students became more confident and motivated and that behaviour improved. This resulted in less staff time being used up in dealing with behaviour issues. Pupils in project groups took more responsibility for their work and teacher-pupil relationships became more negotiative. Teacher morale improved and there was a sense of 'restored professionalism'. However, some teachers found it difficult to adapt to the pupil-centred lessons and reported that they found this way of teaching much harder work. Teachers also felt a sense of loss at no longer being allied with their subject specialism and discomforted at the thought that non-specialists were teaching their subject areas. The benefits for the pupils of this way of working included improved achievement, attendance and a more positive attitude towards homework. However, the project did not extend into key stage 4, where greater subject identity may be needed to prepare pupils adequately for GCSE. Perhaps the most important lesson to be drawn from the study is that pupil ownership of task and professional support for teachers, informing new ways of teaching and learning in the classroom, can have clearly beneficial outcomes.

In 2004 a large scale survey into the Relevance of Science Education (ROSE) (Jenkins and Nelson, 2005) surveyed 14 to 16 year old pupils about their science education both within the U.K. and in other countries worldwide. Although 61% of the U.K. pupils found science interesting only 21% said they would consider a career in science, indicating that current models of teaching and learning do not inspire aspiration for further study. It was the expectation of pupils that their teachers should provide a diversity of classroom activities, including scientific enquiry and discussion which were relevant to their everyday lives. The extent to which able pupils were able to appreciate key features of scientific enquiry was investigated by a collaborative project between the Universities of Cambridge, Reading and Roehampton, known as APECS – Able Pupils Experiencing Challenging Science (APECS, 2005). Part of this project involved PGCE trainees in interviewing top set key stage 3 pupils in two schools regarding their understanding of the terms 'theory', 'hypothesis', 'experiment' and 'model'. The conclusion of the study was that the pupils were unclear about the meanings of such terms and that teachers adopted their use on the often false assumption that pupils understood what they meant. Thus a communication gap between teachers and their pupils concerning crucial terms in scientific enquiry was revealed.

The work of researchers in these four research projects between 2002 and 2005 has indicated that able pupils may underachieve for a number of reasons. Lack of ownership of task, poor study skills, poor teacher – pupil relationships, lack of voice and little understanding of the nature of true scientific enquiry have resulted in a loss of motivation on the part of pupils to further their study of science. Perhaps by looking at other projects which have focussed directly on working with pupils, we may begin to comprehend what it is that would motivate pupils to such further study.

Problem based learning (PBL) has evolved from early use in medical schools in the 1970s in Canada. It incorporates both the presentation of an ill-structured problem and self-directed learning on the part of pupils (Maker and Schiever, 1982). The criteria which must be fulfilled in order for a methodology to conform to the principles of PBL are that firstly it must be central not peripheral to the curriculum. Secondly PBL is focussed on questions that involve central concepts of the discipline. It must also involve pupils in a constructive investigation which is pupil driven. Also PBL projects must mimic real science as opposed to school science with the direction of the investigation in the hands of the pupils not the teacher. The assumptions underlying the principles of PBL are that learning is more effective when it is 'hands-on', problem solving is motivational for pupils and that by learning to think critically attitudes to learning become more positive.

PBL is thought to be particularly suited to the needs of able pupils due to its open-ended structure. The role of the teacher in PBL is to act as a facilitator to encourage pupils to voice their thoughts and to discuss the thoughts of others. This often requires skills in Socratic questioning. Such a change in role can often be problematic for teachers who are more used to taking the lead in lessons (Maker and Schiever, 1982). Research in Illinois into the use of PBL for high ability mathematics and science pupils, involving pre and post testing, has found that there was a benefit to pupils in long-term retention (Gallagher et al, 1992) but for able pupils there was no advantage in terms of attainment compared to traditional methods of learning (Gallagher and Stepien, 1996), although analytical skills were found to have improved.

A British study into PBL in mathematics is reported by Boaler (1997). This study also used pre and post testing on an experimental and control group who were similar in background and ability. At the end of the first year Boaler found no differences on attainment tests but at the end of three years there were three times as many project based pupils as traditional based pupils attaining the highest grades on national tests. Also the ability of the project based group to apply their knowledge to novel situations was considered to be much higher. In addition, the attitudes of the project based pupils to learning mathematics were noted to be much more positive than those of the traditional based pupils. However, implementing PBL was not without its challenges. Pupils found it difficult to generate appropriate questions and to manage their time effectively. Pupils sometimes lacked the social skills for effective collaboration and lacked some of the necessary background knowledge. Research designs were often inadequate which increased the pressure on the teachers to intervene. Teachers were presented with a number of dilemmas, including whether to structure pupils' time and whether to guide pupils to 'correct' results when they appeared to be on the wrong track. Classroom management and control issues were also encountered and skills in how to use technology for cognitive purposes were sometimes lacking. One finding of the study was that it proved to be just as necessary for teachers to be supported by each other to attain new teaching skills as it was for pupils to be supported by teachers to attain new learning skills.

A second contemporary initiative requiring teachers to acquire new skills which was more widespread in schools during the early 1990s, was Shayer's Cognitive Acceleration through Science Education (CASE) project (Shayer, 1996). This consisted of special lessons delivered by science teachers during the first two years of secondary school. The lessons were designed to utilise the pupils' ability to think deeply about science phenomena that they directly experienced. It was observed that pupils participating on the programme ultimately achieved higher GCSE scores than would have been predicted on the basis of their prior attainment scores. Such results were also generalised across a wide number of schools. However Shayer reports that not all science teachers adapted to the new teaching and class management skills required. Teachers were asked to teach some science lessons based on the reasoning behind different aspects of science and to focus other science lessons on exemplifying such reasoning patterns. Teachers were also expected to change their classroom strategies to focus to a much greater extent on child-centred methods. Where teachers were able to embrace all aspects of the methodology the results were very positive for their pupils but not all teachers had the flexibility to adopt the new methodology and Shayer recognised that many teachers would need greater support in 'developing the necessary art' (p. 15)

A third school-based initiative taking place in Australia during the late 1990s short circuited the problem of pupil outcomes being influenced by teacher inflexibility by only using the teacher in a consultative capacity during the programme. Poncini and Poncini (2000) describe research undertaken, in a school setting during pupils' lunch breaks, into doing 'real scientific research'. University researchers administered this project and the pupils selected for the project were regarded as amongst the most scientifically able in the school. However, the pupils were not allowed to self-select their project and this resulted in a loss of motivation for some pupils.

Pupils were given a novel scientific problem to investigate and given an initial 'method' to proceed with. Pupils then worked in pairs to devise an hypothesis, construct their apparatus, take measurements and evaluate their data. The pupils showed good analytical skills and adapted experimental techniques but, in many cases, did not possess the necessary prior knowledge to interpret results meaningfully.

The new skills acquired by engagement with the research did impact upon learning methodology in pupils' regular lessons and accuracy and writing fluency increased. However, there were no discernable effects upon pupils' attainment scores or on teaching methodology. In addition, no long term effects of the project were evaluated and impact on changes in teaching and learning methodology within the school classroom was not demonstrated. Thus the research could be viewed as an evaluation of an 'enhancement activity', despite its school setting, rather than an initiative that impacted upon classroom teaching.

A fourth research project, which also could be categorised as an enhancement activity evaluation, grew out of the APECS (APECS, 2005) research into pupils' appreciation of key features of scientific enquiry. The ASCEND (Able Scientists Collectively Experiencing New Demands) project developed an after school programme of enrichment work for able 14 – 15 year olds held at the University of Cambridge Education Department (Taber and Riga, 2006). It utilised PGCE trainees to facilitate able pupils as part of a research and development project. Pupils were given tasks with overall aims but a minimum of guidance was given on exactly how to perform the investigation. Pupils were responsible for organising their own time and research design. Some were uncomfortable with this level of ownership as it was unfamiliar territory and where necessary the trainees had to provide more support.

Pupils reported that they enjoyed the depth of thought that they were required to engage with, the interactivity of group work and taking responsibility for their learning. However for some this level of ownership was intimidating and they expressed a desire for more guidance. Finding the balance between 'challenge' and 'scaffolding' emerged as an issue for the trainee teachers involved in the programme (Taber and Riga, 2007). Conclusions from the research emphasised that able pupils do have the process skills to tackle true 'scientific enquiry' but that these are often under-utilised in the classroom. Further able pupils actually enjoy engaging in 'in depth' thinking in preference to the superficial encounters with science topics to which they are frequently exposed in the classroom. Another significant benefit to the pupils was seen to be the association with other able pupils in the 'adult' environment of the University.

What these four research projects clearly demonstrate is that able pupils have capacities that are not generally exploited in classrooms. They are able to engage in critical thinking, analysis of problems, collaborative working, metacognition and take responsibility for their learning. They may have under-developed organisational and communication skills and need scaffolding in these areas. However, a major impediment to good classroom provision for able pupils would appear to be the lack of ability and/or willingness of some teachers to embrace child centred teaching and learning methodologies. Perhaps an examination of a number of teacher-focussed research projects may throw some light on why this is the case.

Eyre (1997) maintains that it is the teaching approach that seems to be the important factor in improving learning for able pupils. Eyre (1999) describes how, in a small scale research project, a group of twelve teachers were brought together to identify the main issues in creating good provision. Amongst the conclusions of the study were four key proposals; the first was that most provision would be through differentiated classroom provision, the second was that all lesson planning should include extension opportunities, the third that enhancement activities should be encouraged but not used as a substitute for classroom provision and lastly that all provision in school should be monitored by senior management. This served to raise the profile of provision for able pupils and LEA advisors were charged with supporting teachers in how to create challenge in their subject areas.

The implementation of the new LEA policy began in 1990 and at first not all teachers were enthusiastic. Many regarded such provision as elitist and some did not want to take on the extra work. However, the enthusiasm of a few proved infectious and gradually sceptics were won over. Although the models for provision adopted by each school were unique one common factor identified as being influential on success was the support from senior management. It was also found that whilst many schools felt confident in providing enhancement through extra-curricular clubs many teachers were much less confident about differentiating in the classroom. It was felt that the exam driven emphasis on competence at the expense of excellence had de-skilled teachers in providing for the most able pupils.

LEA subject advisors brought teachers together for discussion regarding the characteristics of good classroom provision. However, this approach was reliant on good quality thoughtful teachers who were confident in their subject expertise. Mechanistic teachers were found to be less able to be responsive in the classroom and make adjustments when needed. A continuous need for training was also identified as essential to allowing teachers a respite from the relentless demands of their classrooms and give them time to be reflective regarding their own practice. The recommendations emerging from the study were that for effective provision to be implemented teachers must be made aware of the needs of able pupils, become familiar with various models of provision and be confident enough to adapt the models to their own professional practice. Above all teachers need to become more skilled in the principles and practices of classroom differentiation. This has implications for the Initial Teacher Education of all secondary teachers.

A more recent (DfES, 2007b) study (The Eight Schools Project) into Assessment for Learning (AfL) focussed on how to develop the independent learner. Here again the value of teachers working collaboratively was identified as a major contributor to success. Classroom dialogue was also found to be a key indicator to the quality of the interactions taking place within the classroom and the nature of different kinds of dialogue for different pupils was also identified as influential on differentiation in the classroom. 'Top down' approaches from senior management were found not to be effective in winning the hearts and minds of teachers, although they did set a clear expectation of the need for improvement. Exemplars of good practice need to be shared in order that weaker teachers could perceive the ideal and be supported in working towards improved practice. It was also recognised that training course alone were insufficient to embed good practice in classrooms and that more innovative approaches e.g. coaching, networking and collaborative planning needed to support training.

The eight schools involved in the research project adopted an 'action research' approach to improvement. This was found to be both appropriate and effective in moving teachers forward from planning for teaching to planning for learning. The expectations from teachers of what pupils were capable of were raised and it became clear that instead of being passive recipients of information pupils could perform at much higher levels when they were enabled to become autonomous learners. If teachers shifted their focus from objectives to outcomes and criteria for success in lessons it impacted upon the number of pupils achieving those outcomes, the quality of the outcomes and the engagement and motivation of the pupils. Effective teaching only happens when pupils are learning and by focussing the emphasis of teachers away from the routines of 'teaching' and towards the outcomes of learning they were better able to appreciate how to move such learning forward. Another outcome of the project was for teachers to gain a growing realisation that continuous professional development is an ongoing process and best achieved 'on the job'. Through the project, teachers developed as reflective practitioners and came to an understanding that if they were to assist their pupils in becoming independent learners then it was required that they should also become independent learners (DfES, 2007a).

The findings from the Eight Schools Project had synergy with those from a wider project into Learning How to Learn: in Classrooms, Schools and Networks (James et al, 2006). This was a four year (2001 – 2005) development and research project involving researchers from four Universities working across five Local Education Authorities. One conclusion from their report was that,

" Emphasis should be placed on classroom practices that have the potential to promote pupils' autonomy in learning." (Black et al, 2006, p.13)

However the report also recognised that simply presenting teachers with a list of strategies was unlikely to bring about change (Marshall et al, 2006a). It was important that teachers viewed themselves as agents for change rather than passive recipients of government strategies. One way to enhance this sense of 'agency' was found to be 'teacher inquiry',

" If teachers find difficulty implementing this set of practices (and our data suggests they do), and if promoting learning autonomy is a central strand of learning how to learn then 'inquiry' (teachers' uses of and responses to different sources of evidence from more formal research and their own inquiries, together with their collaboration with colleagues in joint research and evaluation activity) is likely to be an extremely useful and important strategy supporting the classroom promotion of learning how to learn." (Pedder, 2006 p.14)

This approach to teacher development was also found to be successful in the research into using 'Thinking Frames' (National Teacher Research Panel, 2006). The 'Thinking Frames' research used materials designed to help in visualising how a learner can use thinking skills to apply scientific modelling in order to form their own explanations of concepts. The teachers involved used collaborative discussion to help to inform and interpret their own action research.

Thus it would appear from the evidence to date that teachers do experience difficulty in implementing differentiation for able pupils in the science classroom and in promoting autonomous learning. This difficulty stems from teachers being unprepared by both subject expertise and pedagogical training to be confident in these areas. The situation is compounded by pressure to produce good examination performance figures, often at the expense of real learning and by the whole school issues of behaviour management and pupil work ethic. Science teachers, senior managers and other education professionals need to work collaboratively towards enabling their pupils to become confident, motivated, independent learners. The research to date would seem to indicate that one possible way forward is for science teachers to engage in supported action research within their own classrooms with a view to improving teaching and learning for the scientifically able pupils in those classrooms.

Chapter 4
Literature Review Part 3
Autonomous Learning for Able Pupils

4.1 Defining autonomous learning

George (2003) describes autonomous learning as a process of being able to organise personal knowledge acquisition whilst maintaining concentration and motivation. Betts (1985) describes the autonomous learner as an individual who has the ability to be responsible for the development, implementation and evaluation of their own learning. In the opinion of Diezemann and Watters (2000),

> "It is also clear that autonomy involves the capability of working independently and collaboratively and having the disposition to explore ideas and challenge assumptions, often in the face of resistance." (p. 16)

Thus the consensus of opinion appears to be that autonomous learners take responsibility for their learning, organise the resources that they require for that learning and welcome challenging (but not overly challenging) tasks. In the classroom 'autonomous learning' applies to the degree to which pupils are allowed to make decisions regarding the direction in which they wish to take their learning and the form of the activities, which they undertake to promote that learning. Whilst autonomous learning may be a behaviour learned through a number of contexts, of which the classroom is only one, there is concern amongst both educators and employers that many children are leaving school without the necessary skills for independent learning that they need to equip them for life in either the workplace or further education. The Secondary National Strategy (DfES, 2007a) recognises this problem and recommends that,

> "Pupils need to move from being passive recipients of what they are being taught, to develop as independent learners who take responsibility for their own learning and are empowered to make progress for themselves." (DfES, 2007a p.10)

The empowerment of pupils through ceding to them some decision making powers about their learning will require a fundamental change in the mindset of teachers and consequent changes in classroom methodology. However, such a change is fundamental to raising motivation and aspiration towards science education. If we are to attract more of our most able pupils towards the continuance of study or work in scientific fields it is a change that is both necessary and overdue.

4.2 What are the advantages of autonomous learning for able pupils?

Evidence from previous research (Gunstone, 1988) has indicated that many able pupils show a preference for autonomous learning. One of the major benefits put forward (Kanevsky, 1990) for promoting autonomous learning for such able pupils is that they find having 'ownership' of tasks in the classroom more motivational than the usual teacher directed learning methodologies. Delcourt et al's (1994) research reported that able children are more intrinsically motivated and rely less on teacher feedback because they have a greater repertoire of knowledge and skills relevant to the concept being taught and a greater desire to develop their understanding and take responsibility for their learning. Rea (2003) explains this preference within his *theory of the motivated mind*,

> "The motivated mind is motivated by the playfulness of the creative thinker and the seriousness of the critical thinker. The motivated mind is able to speculate and imagine divergent possibilities as well as to analyse and evaluate these possibilities for their convergent usefulness. The motivated mind is impelled by the desire to find novel challenges and compelled by the need to master these challenges." (p. 211)

Fundamental to achieving the 'motivated mind' is enabling pupils to feel a sense of control over their own learning. Research undertaken by Rimm (1995) into the reasons why able pupils underachieve found that they tended to have a low sense of being in control of their own learning and often expressed the fault for their underachievement as belonging to factors outside their control. Martin (2002), in his analysis of research and practice concerning motivating able pupils states that,

> *"Another way to enhance the students' sense of control is by giving them greater input into decisions that affect them. Choice and input can encompass students contributing to content, methods by which that content is delivered and indeed the methods and criteria for (authentic)*

> *assessment. This not only increases their sense of control, it also provides them with a greater sense of responsibility and empowerment and develops their critical thinking and decision-making skills, skills vital beyond the classroom." (p. 29)*

Wittrock (1994) identified motivating factors for able pupils to be taking responsibility for learning, believing that they can and will succeed in mastering understanding and experiencing frequent success. Pintrich (1989) also recognised the importance of success in motivation. He maintains that a person's motivation to do a task is a product of their expectancy of task completion, the perceived value of the task and the emotional reaction to the task. However the negative attitudes of pupils towards science in school are an obstacle to motivation. How such negative attitudes may be turned around will require teachers to change the emphasis of their lesson away from their 'teaching objectives' and more towards 'meaningful learning outcomes' for their pupils. Handy (1993) explains that dissatisfaction arises when pupils experience a gap between their self-perception and their ego-ideal. Motivation arises when pupils are given the opportunity to work towards their ego-ideal.

Hogan (1999) reported that, in science lessons, pupils' motivation and learning orientations are influenced by changes in their epistemological beliefs about science as they become more cognisant about classroom culture and the purpose for learning. Pintrich et al (1993,) maintain that instructional settings designed to allow students to take responsibility for their learning processes may be more meaningful and significant for them. This is reinforced by Brown et al (1989), who maintain that the context is integral to what is learned,

> "What is learned is inseparable from how it is learned." (p.32)

By allowing pupils to have greater autonomy over selecting the contexts for their learning then the science concepts that they acquire will become more meaningful for them. Not only is learning enhanced in the right context but also by giving the child the facilitative environment within which they feel secure enough to give expression to imaginative thoughts, without ridicule, they gain greater confidence in their decision-making processes. In trying to identify pupils' pathways from their existing conceptual structure towards new science concepts Pintrich et al (1993) recognise contextual, motivational and cognitive factors as affecting the process of conceptual change. The motivational factors identified include pupils' personal targets, personal interests, and the perceived usefulness of the learning. By allowing pupils to make decisions over which aspects of their lessons they find personally interesting, important and useful and by encouraging them to develop these aspects, pupils may be led towards meaningful understanding of the science concepts involved. If this results in enhanced motivation as suggested by Pintrich et al., then consequential links may be established between autonomy, motivation and enhanced cognitive skills.

Much of the literature on metacognitive training implies that it is an effective tool for stimulating the minds of able children (Shore et al, 2003). By giving these children the opportunity to share how they are thinking with others, they are helped to structure their own mental constructs and to demonstrate the personal nature of their thinking processes. Reflecting on mental links and cognitive pathways strengthens these links and pathways and aids the thinking skills of the pupil. Thinking skills can then be better applied to new contexts and concepts in the future. Shore et al. conclude that it is vital that pupils learn the habit of spontaneously making interconnections without prompting or teacher intervention. They describe the effect of giving pupils, 'What if…' scenarios and classroom brainstorming games upon their ability to make creative links in their knowledge base. This is a demonstration of the power of the decision-making process, since the pupils have the freedom to create imaginative and unusual ideas of their own. Also asking pupils to evaluate lessons and offer suggestions for improvement can provide insights into the value judgements that they are making.

If these findings are generalisable over a wide context then perhaps it is the constraints that teachers experience towards successfully promoting pupil autonomy, that play some part in the lack of motivation on the part of pupils to continue with science education. It is important to understand both what these constraints are and what the benefits to pupils may be if the practice of promoting pupil autonomy is to become more widespread in the science classroom.

4.3 What are the impediments to the implementation of autonomous learning?

If autonomous learning has been demonstrated to enhance pupil confidence, motivation and meaningful comprehension, then why is it not embedded into the teaching and learning methodology of most classrooms? There is evidence of a number of possible reasons why teachers have not widely adopted these methodologies in their day to day teaching.

The first of these is the perception that autonomous learning may disadvantage pupils' attainment because the methodology is incompatible with the content of the pupils' programme of study. Research carried out by Olsen et al (1996) examined the conflicts, which may arise between pupil autonomy and pre-ordained science and recognises the dichotomy that exists between the expectations that pupils arrive at the pre-ordained scientific outcomes whilst learning to act as empirical scientists. These conflicts were identified as the mismatch between autonomous practices and the official curriculum; the possibility of autonomous practical experiments producing the 'wrong' results and the extent to which teachers were prepared to allow pupils to 'struggle' towards knowledge. The implicit danger in adopting autonomous learning practices is that some concepts may not be effectively accessed by such constructivist approaches because the concepts requiring construction are so far outside the pupils' experiential base that the probability that they will spontaneously construct them is very low (Geake et al, 1996).

Whilst the emphasis on pupils' own activity may empower pupils to take responsibility for their own learning and enable them to become autonomous practitioners, it may also deny that a sound basis of pre-existing knowledge may be necessary before such activity can take place. This pre-existing knowledge can be both an asset and an impediment to learning. Interpretation of new information is done with reference to pre-existing knowledge and sense-making processes. Incoming sense data may be so rich that in order to interpret it a personal 'filter' is applied to reduce the richness to certain facets, regarded as important by the pupil. As each pupil applies their own viewpoint their previous conceptions will influence their new perceptions. This will lead the pupils to have different learning experiences to one another and certainly different to that expected by the teacher, who has his own personal interpretations. Thus autonomous learning may not be successful in guiding the pupils from their previously held conceptions to the science conceptions that the teacher regards as the desirable outcome.

The second possible reason why teachers may be reluctant to adopt autonomous learning practices is because they may clash with the existing classroom culture and attempts to implement autonomous learning become distorted. In many classrooms 'guided discovery' can end up as teacher direction. Modelling and questioning are the most frequently used forms of scaffolding by teachers (Rosenshine *et al*., 1996). However the more the questioning moves down the continuum from open ended to closed questions the more that 'guidance' begins to resemble didactic teaching. In '*The Learning Cycle'*, Lawson, (1989) describes scaffolding in three phases 'exploration', 'term introduction' and 'concept application' to achieve conceptual change. This example of a constructivist teaching sequence affords opportunities for the pupils to make their own experiences and construct their own meaning. Arguments against this sort of approach are that it is too time consuming and may lead students in the wrong direction. However, in the view of Lesgold (1989), if we wish children to be more creative in the classroom then we must allow them the time for 'musing' in order to create the new pathways required to access higher level concepts. This is a high risk strategy for teachers because they are gambling that extra time invested in the promotion of autonomous learning practices will be 'won back' at some later stage as the pupils become more effective learners. Many teachers will not take the gamble and will continue to teach didactically in the belief that their 'tried and trusted' methods are the most effective for ensuring examination success.

A third danger with autonomous learning is that it carries risks to the pupils' self esteem, since there is a heightened risk of getting concepts 'wrong'. Risk, innovation and creativity carry with them the potential for mistakes. Diezmann and Watters (2000) reinforce the need for an accepting culture,

> "To be creative, an individual requires intellectual autonomy, expertise and a culture supportive of unconventional thought." (p. 6)

However, the process of conceptual change is not only affected by cognitive factors but is also deeply influenced by affective and emotional factors, which cannot be controlled within a classroom environment. The importance of relationships to the development of a 'classroom climate' within which effective learning can take place was recognised by Hay McBer (2000). Ireson and Hallam (2005), in their research into the effects of ability grouping on pupils' liking for school, reported that it was psychologically important for pupils to feel affiliation to and support from their teacher and that this provided a basis for the development of the autonomous learner. Thus it was important that teachers allowed pupils to feel competent in their studies and celebrated their successes.

A person's motivation to do a task is a product of their expectancy of success, the perceived value of the task and their emotional reaction to the task (Good and Brophy, 1994). Task productivity is dependent upon all of these factors as well as natural curiosity and the view of the pupil that their work is a personal object of ownership. However, the acquisition of science acuity is gained by actually doing science (Hodson, 1992) and this can only be achieved by allowing pupils decision-making powers in the laboratory.

A fourth obstacle to implementing autonomous learning practices is that, as much as the pupils value the autonomy afforded to them, this does not mean that they are ready to take the responsibility for their learning. Most pupils are so unused to having the onus for the development of their learning placed upon them that they find that they do not have the tools to structure such learning when given the autonomy to do so. Previous research (Renzulli and Gable,1976; Zimmerman & Martinez -Pons, 1990), has found that although self-directed study is successful with able pupils, not all of these pupils have the strategies in place to self-regulate their work. This is something of a sad indictment of the provision for able scientists in schools. Lee (2003) explains that the lack of experience of teachers in teaching 'study skills' stems from the failure of initial teacher education to teach these skills explicitly. When able pupils are taught how to use strategies of goal setting, planning and self-evaluation other research has shown (Scruggs & Mastropieri, 1998) that they become able to transfer these strategies to new tasks. However, it may be argued that since able children rely less on mechanistic study skills to learn, that they possess fewer independent study skills than other children. Many highly able children are capable of making intuitive leaps in understanding and find it difficult to have to break down each small step in their reasoning process in order to explain it to others. When such children are challenged with a novel situation, wherein they have insufficient prior knowledge to make the intuitive leap, they are then less well equipped to approach the problem through the systematic steps that less able children are used to having to apply to a wider range of learning situations. A comparison of the approaches of Rosalind Franklin and Crick and Watson to the discovery of the structure of DNA is illustrative of the difference between the systematic methods of highly able scientists and the intuitive leaps of the creative, gifted approach.

Despite these impediments there are many teachers who aspire to embrace more autonomous learning practices and embed them within their classroom teaching. However for many these remain aspirations and not realities. Those teachers who recognise that there is a gap between their values and their practices cite a number of constraints to explain this. Amongst these are the nature of the examination system, the demands of the curriculum, mixed ability classes, the passivity of pupils and the tension between desirable lesson outcomes and what is practically possible. These teachers need support and assistance from senior managers and the wider educational community in order to bring their working practices closer to their aspirational ideals.

4.4 Previous initiative to promote autonomous learning

A number of previous research initiatives have addressed both the views of teachers and pupils regarding the effectiveness of autonomous learning on the achievement of conceptual understanding. Taylor and Fraser (1991) conducted a 'Constructivist Learning Environment Survey' to assess supportive classroom climates for learning. They assessed these on the basis of autonomy, prior knowledge, negotiation and pupil-centeredness. However, they also recognised that didactic instruction may well be effective in achieving learning if pupils' needs and conceptions are addressed. Their conclusion was that ideally teaching and learning is best effected by a range of different types of lessons, having a continuum of degrees of pupil autonomy, some didactic owned by the teacher to freer, investigational work owned more directly by the pupil.

Tretten and Zachariou (1995) used the self reports of 64 teachers to analyse the positive benefits of autonomous learning upon attitudes towards learning, work habits, problem solving capabilities and self esteem, in four elementary schools. They found that,

> "Students, working both individually and cooperatively, feel empowered when they use effective work habits and apply critical thinking to solve problems by finding or creating solutions in relevant projects. In this productive work, students learn and/or strengthen their work habits, their critical thinking skills, and their productivity. Throughout this process students are learning new knowledge, skills and positive attitudes." (p. 8)

Whilst there is little dispute that didactic teaching can be effective in achieving learning, there would seem to be a consensus of opinion that it is autonomous learning practices that produce mature work habits, self reliance and motivation for further study. Poncini & Poncini,'s (2000) study into pupils' engagement with scientific research investigations, observed that once able pupils were given ownership of tasks, there was evidence to suggest that they would spontaneously increase the complexity of the task to satisfy their own curiosity. This was observed to produce greater drive and determination on the part of the pupils. Whilst drive and determination may be attributable to individual personality traits, the observation that they are evidenced more frequently in an autonomous learning environment gives insight into the way that such a facilitative environment may affect the way that pupils operate.

However, similar research (Thomas, 2000), involving pupils carrying out scientific enquiry through Project Based Learning (PBL) reported an absence of planning and self-monitoring skills on the part of inexperienced, young problem solvers. Thomas emphasises that PBL is not teacher-led, scripted or packaged. Pupils work autonomously to define and seek a solution to the problem posed for them, investigating leads, asking for additional information, analysing data, etc. Pre and post test analysis for control and experimental groups showed that the experimental group had better knowledge of factual content and an increased ability to critically analyse situations. Thomas concludes that some studies of PBL report unintended and beneficial consequences i.e. enhanced professionalism and collaboration on the part of teachers and increased attendance, self-reliance and improved attitudes towards learning on the part of the pupils. Teachers at the end of the PBL project reported that the positive benefits for pupils included improved attitudes towards learning, work habits, problem solving capabilities and self-esteem. They also reported that learning was maximised if the context for learning was relevant to the pupil. At the end of the work 82% of pupils reported increased motivation and 93% reported increased interest in the topic. This is a powerful endorsement of autonomous learning practices. However, it is of interest that this study also found that the profound effects of the research had impacted also on the teachers and that a supportive school environment was one which allowed teachers time for reflection, mutual feedback and collaborative discussion.

Research carried out by James, et al (2006) into Learning how to Learn (LHTL) found that from a sample of 558 classroom teachers 80% felt that there was a gap between what they practised and what they valued with regard to the promotion of pupil autonomy. Many felt under a constraint to meet performance targets in a way that was not conducive with their beliefs about learning. In an analysis of teachers' views on how they utilise assessment for learning (AfL) within their classroom it was found that best practice was characterised by teachers holding strong convictions that the promotion of pupil autonomy was inherent to their beliefs about learning. Such teachers also felt a personal responsibility in motivating pupils to learn. The 'AfL 8 schools project' carried out between 2005 and 2006 (DfES, 2007b) also found that fundamental to developing AfL in the classroom is developing the independent learner and urges teachers to work collaboratively towards developing those areas of AfL that will promote autonomous learning. The project focussed on the use of AfL in eight secondary schools across a wide geographical area. One of the key messages from the research report was that in promoting learning autonomy teachers need to develop classroom dialogue by promoting 'focussed discussion'. The project also reported that engaging pupils in evaluation skills helps them to develop as reflective learners. However, it was recognised that such changes in pedagogy are unlikely to be brought about by training events alone and that for change to happen the focus needs to shift from theory to application in the classroom. The project used an action research methodology and reported that this had resulted in the teachers involved in the project becoming more reflective practitioners and more able to evaluate their own practice.

"Teachers were getting under the skin of AfL and understanding why different strategies help pupils learn and how they might develop them in their

lessons so that they were able to develop as independent learners themselves." (DfES, 2007b p. 49)

Pedder (2006) in reporting on the LHTL research, discussed the finding that the promotion of pupil autonomy was a 'necessary condition' for helping pupils develop an increasing repertoire of learning strategies and the judgement of how to apply them appropriately to a range of different learning situations. However, the research also reported that only 21% of the teachers in their sample practised the promotion of learning autonomy to a degree that was in line with their educational values. If this figure is typical of all teachers in secondary schools there remains much work to do on the part of educational researchers to convince secondary school teachers that they have a responsibility to prepare their pupils not just for examinations but also for a life beyond school, a life in which they will need to take the responsibility for their own future learning. Teachers must teach pupils the necessary skills to do this if they are to adequately equip them for adulthood.

4.5 How can teachers promote autonomous learning?

In order to equip the citizens of the future with an understanding of scientific concepts perhaps the time has come to allow them to take more decisions in the classroom and have greater influence over the learning practices with which they engage (Taber, 2007c). By affording to pupils more autonomy in the classroom perhaps teachers can again ignite the spark of curiosity and interest in the study of science that pupils seem to lack.

Therefore teachers need to be aware of a range of approaches from radical constructivism through to didactic instruction and to consider which point on this continuum best serves the needs of the pupils before them. For most pupils some 'scaffolding' of learning by the teacher may be needed (Vygotsky, 1978) and it is likely that the need for this scaffolded learning will increase as the ability of the pupil decreases. It will lie within the professional judgement of well informed teachers to decide whereabouts on the constructivist/ positivist spectrum they place their teaching for each group taught. Indeed, ideally this differentiation may be needed for each pupil taught and by using autonomous learning methods we can involve the pupils themselves in this. Thus the role of the teacher in guiding students towards tasks within their 'zone of proximal development' (Vygotsky, 1978) is important and although the students are given autonomy over their learning, the role of the teacher will necessarily evolve as they guide pupils through the learning process.

The balance between 'scaffolding', 'instruction' and 'autonomous learning' will require some experimentation and will be different for different pupils. Underlying it is the essence of the relationship between pupil and teacher. Unless pupils can view their mistakes as acceptable on the journey to improve their understanding they may suffer a loss of self-esteem. Thus it becomes evident that, from a psychological perspective, the affective aspects of teacher-pupil relationships need to be considered in striving towards the development of autonomous learning (Ireson and Hallam, 2005). Re-defining the role of the teacher to become more of a facilitator is the key strategy to promote an environment which promotes discussion, allows pupils to make propositions, justify their thinking, challenge the thinking of others and seek alternative explanations. This view is underlined by Betts and Kercher, (1999),

> "A facilitator guides, questions, and supports, but does not direct, specify or restrict." (p. 64)

The degree of autonomy afforded to children in the classroom may be analysed by observation of the dialogue, interactions and activities of the teacher and pupils within that classroom and the balance of ownership of the learning and teaching strategies utilised within the lesson. The balance of ownership of the learning and teaching strategies will form a continuum ranging from those in which the teacher maintains total control of the course of the lesson to those in which the pupils are allowed complete freedom to determine the course of the lesson. This balance of ownership may vary at times within each lesson and also between lessons for the same teacher and pupils. It may also vary for a teacher encountering different groups of pupils and for pupils encountering different teachers. Teachers will also need to recognise that the needs of their most able pupils are every bit as valid and as deserving of attention as the needs of their weakest pupils.

Geake, et al (1996) observed the strong parallels between the cognitive characteristics of the most able pupils and research scientists. They pose the question,

> "How do we, as teachers of science, strengthen the motivation of gifted children to embark on careers as scientists?" (p. 49)

Perhaps the answer to this lies fundamentally in allowing pupils to do 'real science'. This may involve teachers in allowing pupils to design their own science investigations, providing sufficient background knowledge to enable them to proceed and then standing back and waiting to be asked before further intervention. By getting the pupils to ask the questions teachers can be sure that these questions are meaningful for the pupils. This can be built upon by discussing what questions real scientists ask and how they may go about finding out the answers. One way to overcome the difficulties of teaching concepts which are far outside the pupils' experiential base, may be an approach wherein the fundamental questions faced by the originators of these concepts and theories is put to pupils for them to muse on. By this means the precognisant ideas of pupils could be compared to those of the original scientists. By using this approach pupils learn at first hand the process of hypothesis modification in the light of higher level knowledge i.e. *they learn to be scientists.*

Chapter 5

Research Design

5.1 Research design: a dilemma

At the outset of this study decisions regarding the choice of the most appropriate research methodology were of major concern. On the one hand quantitative methods had the advantage that they could access a wide set of opinions by the use of questionnaires and thus may yield more generalisable findings but they were traditionally associated with a positivist paradigm. The disadvantage of this was that the researcher only gains information about the specific questions asked and this may be too narrow a stance to gain a full perspective of the complexities of the situation. On the other hand qualitative studies, whilst being regarded as more constructivist and naturalistic, held the danger that in order to be manageable they would, by necessity, be small scale and run the possible risk of having limited generalisability. In order to inform the final decision on which research methodology to adopt, it was first thought to be helpful to look at the research done previously in similar fields in order to establish the advantages and disadvantages of the various methodologies employed by previous researchers.

Another reason for such a review was that areas of focus might be suggested, which were deserving of study, but which had received scant attention from previous researchers. This might perhaps illuminate a starting point for the research. Also the findings of previous researchers could be critically analysed for weaknesses in methodology, which may have influenced the inferences drawn from the project. By postulating alternative hypotheses more ideas may be generated for the starting point of this study.

5.2 Methodologies employed in previous research

Previous research projects into the effectiveness of educational provision for able pupils have approached the task through a variety of different research methodologies. The methodology chosen needs to be ‘fit for purpose’, in other words, the chosen methodology must adequately address the objectives of the research project. Thus research carried out with the objective of finding statistical trends and demographic analysis will use very different methodology to research which aims to probe the reasons for situations arising or reflect upon how people feel about those situations. However, even once the objectives of the research are clearly understood decisions will still have to be taken regarding the best methodology to apply in order to obtain the most accurate understanding of the situation under scrutiny.

This is exemplified by a large-scale research project into ‘Learning how to learn in classrooms, schools and networks’ (LHTL) carried out by the Teaching and Learning Research Programme (Marshall et al, 2006b). This project focussed on pupils’ learning skills in 23 primary and 17 secondary schools across 5 Local Education Authorities in England. The project also studied the role of networks, including electronic networks, in supporting the dissemination of the knowledge and skills of learning how to learn. Such a large-scale project required the adoption of different research instruments in order to adequately probe for the required data. The diversity of methods used was wide. The research took place at three levels.

At the level of the classroom, pupil questionnaires were used to gather information from pupils from within the 40 schools. Given the large sample of pupils involved, the questionnaires provided the only manageable means of obtaining a cross section of the views of the pupils at various times throughout the project. However, the disadvantage of questionnaires is that they cannot be prompted for further explanation of responses and they frequently do not provide the rich detail that helps researchers to ‘flesh out’ the bones of an issue. Thus the questionnaires were supplemented by pupil interviews, classroom observations and videotaping. The data sought by these means was both factual and attitudinal in nature. In addition performance data on the children was analysed from records held by the school and the DfES.

At the level of the school, teachers were surveyed and interviews were carried out to provide further detail regarding views and opinions. At the level of the network, teachers were asked to draw organisational maps displaying their view of their role within the networks of which they were a part. Head teachers and school co-ordinators were interviewed and LEA officials also were asked to map out their perspective of the operational network of the educational systems within their authority. Over the course of four years the whole research team met monthly, forming a focus group which could reflect upon research progress and explore the relationship between the three levels of the project. Whilst such rigour in triangulation of research methods is exemplary, it required a large team of researchers with complementary skills in both quantitative and qualitative methods. Such an approach is more difficult for a lone researcher working within a limited time frame without the funding for a research team.

A second large-scale research project into 'personalised learning' (Pollard and James, 2004) funded by the Economic and Social Research Council (ESRC) for the Teaching and Learning Research Programme used a qualitative approach to pupil and teacher consultation. However this project found that the process of consulting pupils is fraught with methodological problems. Many of the teacher-researchers cited time and space in the curriculum as two of their major constraints. They found that group interviews could also be dominated by the articulate, self-assured, 'middle class' pupils, who have greater linguistic competence and social confidence. Measures had to be taken to ensure that the more hesitant had an opportunity to contribute. The authenticity of the consultation process was also found to be at issue, as pupils will quickly judge whether they have a genuine voice or whether the process is a tokenistic one. The tokenistic viewpoint can also be confirmed if pupils cannot see their opinions as being an agent for change. Best practice is demonstrated when respondents are treated equitably and can see that their views are making an impact upon policy.

Electronic survey methods are becoming a more dominant quantitative methodology since the rise of more extensive electronic communication. The 'Student Review of the Science Curriculum' (Murray and Reiss, 2003) describes a web-based questionnaire of 55 questions targeted at key stage 4 pupils. In six weeks 1493 responses were obtained, which demonstrated this to be a highly effective method for gathering large sample quantitative data. The high profile given to this survey by the media gave the pupils concerned the sense of having participated in something of significance. The findings from this survey were influential on the review of the Key Stage 4 science curriculum by the Parliamentary Select Committee on Science and Technology, which gave the exercise great authenticity in the eyes of the pupils who had contributed (Murray and Reiss, 2005). However, such electronic surveys require a means of electronic access to the target sample and a facility with the manipulation of large databases. This can act as a barrier to success unless the researcher is both privileged by and proficient with such knowledge.

Another qualitative approach to gathering data on educational viewpoints makes use of seminar and discussion. One of the most influential pieces of research within the last ten years, in science education, leading to the pivotal report *Beyond 2000: Science Education for the Future* (Miller and Osborne, 1998) made use of this methodology. The aim of these seminars was to consider and review the form of science education for citizens of the future. The advantage of the seminar method was that, by discussion and reflection,, views were elicited which were both reactive and responsive to the dynamic of the interactions taking place between those who had deeply held viewpoints on the matters under discussion. This contrasts with the questionnaire method, where respondents may not have thought deeply about or even particularly care about, the issues under question. This discursive approach relies on the participation of other interested parties to the research.

Seminars can often be used to initiate a research programme as was the case with the APECS (Able Pupils Experiencing Challenging Science) research (Taber, 2006). The seminar series explored how models and modelling in science could help to develop work that would challenge the most able. From this a 'curriculum model' was developed and trialled by teacher trainees. To gather data on how effectively the model could be implemented, it was necessary for the trainees to conduct structured interviews with pupils. This is problematic. Pupil responses may be influenced by hearing the responses of others which can affect the reliability of the data. Since the trainees were inexperienced in interview technique a rigid schedule was used, which may have constrained the depth of the responses, especially as the interviews were not recorded but relied on contemporaneous note taking.

The evaluation of interventionist research projects is complex and requires complementary evidence to be gathered by a number of different methodologies, in order to gain the fullest possible picture of the situation under scrutiny. Taber and Riga (2006) describe such a process in the ASCEND (Able Scientists Collectively

Experiencing New Demands) project. A programme of after school enrichment activities was held at the University of Cambridge for year 10 secondary pupils. Data was gathered in the form of notes taken by observers, audio recordings and pupil feedback from open-ended questionnaires. Whilst this methodology has the distinct advantage of the richness of detail that can be accessed, this advantage must be balanced against pragmatic considerations of the considerable amount of time required to field code observational data, dialogue and open responses in such a way that systematic analysis can take place.

A more straightforward way of gathering attitudinal data on the views of pupils and teachers is by the use of attitudinal questionnaires that make use of 5-point Likert scales. Such a quantitative methodology was used by Ireson and Hallam (2005) in research into ability grouping and its effect on pupils' self-concept and perceptions of teaching. This large-scale project sampled across 45 secondary schools aimed to ascertain both attitudinal information and factual information by the use of questionnaires. Samples within each school were chosen carefully to represent the desired target populations. The pupil questionnaire included scales for self-esteem and self-concept, pupils' liking for school and their perceptions of mathematics, English and science lessons. Questionnaires constructed in this way are vulnerable to the influence of phrasing in the questions as this can influence whether someone, for example, simply *disagrees* or *strongly disagrees*. Also there can be a tendency in such five point scales for respondents to avoid the extremes of response and for the 'middle' option to be taken when they haven't really thought about the issue or feel that the information requested is too personal to reveal. For this reason some questionnaire designs use only a four-point scale.

Another possible way of evaluating interventionist research projects is by the quantitative analysis of outcome as represented by data gathered on attainment scores held on the school database. However, it is difficult to establish causal links between the intervention and the outcome since very often there are many influential factors at play, which are difficult to isolate from the interventionist strategy. The same argument may also be applied to the increasingly popular use of 'value-added scores', which take into account the starting point of each pupil at the beginning of the intervention. Such a methodology was used by Shayer (1996) in an evaluative research project into the long-term effect of cognitive acceleration on pupils' school achievement. Science teachers had experienced a programme of in-service training for the preceding five years before the assessment of their pupils' performance on 'Piagetian Reasoning Tasks'. These tasks had been pre-tested on a sample of 14,000 children during the seventies and were found to be good predictors of future learning. Shayer made the claim that the intervention resulted in an improvement in grades across all subjects at both Key Stages 3 and 4. He substantiated this by saying that improved grades had been produced by many teachers working in a great variety of schools, which was more reliable than a 'hot-house' research project.

This stance by Shayer is rather dismissive of research which takes place as case studies within more limited contexts and he attempts to undermine the generalisability of such research. However, there have been many such research projects, which have contributed greatly to understanding particular issues surrounding best practice in the classroom. Kathryn and Michael Pomerantz (2002) undertook a qualitative research project into the causes of underachievement and possible remedial interventions for able pupils within a single secondary school in Nottinghamshire. Before they embarked upon this they examined a great deal of quantitative evidence from previous research and in their turn they expressed their doubts of the worthiness of generating numerical data alone. This they summed up by quoting,

" What can be counted might not count. What counts might not be countable."
(Albert Einstein[1])

The Pomerantz research again used an open response interview schedule which was subsequently field coded. They then analysed the responses to highlight the reasons quoted by pupils for their dislike of the classroom. The dominant themes emerging from this research were those of the lost opportunities to use talents, the poor communication between teachers and pupils, the lack of perception of problem ownership and the apathy brought about by an over-reliance on restricted teaching methods.

[1] The origin of this quote is in dispute. It appears to have been on a sign that hung outside Einstein's office at the Institute for Advanced Study. Though it may not have been written by him, it is nonetheless generally attributed to him, and must have received his approbation.

This methodology was also used in another small scale project in St Marylebone School in Westminster (Hunter, 2003) where pupils' views on their gifted and talented programme were sought. This involved a fifteen minute interview with each pupil. This was unique within the school as classroom teachers, of all subjects, would have been teaching the pupils but may never have had the time for the one-to-one conversation that would reveal their learning needs. As a result of this research exercise, the whole structure of the monitoring of able pupils within the school was changed and the model held up as an exemplar to other schools within the Local Education Authority.

Similar findings were described by Galton (2002) who used an observational methodology to establish that when sustained interaction between pupils and teacher occurred, it was far less likely to occur in science than in any other school subject. Galton presents the results of his research as a series of illustrative anecdotes but he maintains the reliability of his findings by also including statistical data on his observations. Again the research was conducted on a small sample of primary school year 6 children, who were subsequently followed into year 7 in the secondary school. By using a longitudinal study, Galton captures some of the rich detail which evolves through a sequence of descriptions of lessons and which could not be captured within a mere 'snap-shot' questionnaire.

The research described in this section, undertaken mostly within the last ten years in England, is relevant to the context of the English educational system. But what can methods used by international researchers teach us about the strengths and weaknesses of research methodology used in other countries?

Methodology used in international research has many similarities with that used within the English educational system. The five point Likert scale was used in an international survey (IAEEA, 1999), which investigated evidence for a link between attitudes to school science and achievement. In this survey 12 year old pupils in 43 countries were asked for their degree of agreement with five statements about science in school.

- I like science
- I enjoy learning science

- Science is boring
- Science is important to everyone's life
- I would like a job that involved using science

It was found that mostly there was a positive correlation between attitudes towards sciences and science achievement in all countries except Taipei, Hong Kong, Japan and Korea. It is interesting to note that the statements used in the attitudinal survey are kept short and unambiguous in order to minimise the possibilities of misinterpretation. Also both positive and negative statements were used. Most usually attitudinal questionnaires of this type will use pairs of positive and negative statements about the same issue. Thus if a child agrees with the positive statement and disagrees with the matching negative statement then the internal validity of the question pair can be tested. By pre-testing the questions on a small sample of similar characteristics to the target sample, the questionnaire can be tested for the internal validity of its questions by establishing a consistency score for responses to matching positive and negative statements about the same issue. Sometimes the phrasing of negative questions can catch respondents out if the negative logic becomes too complex to follow, particularly when double negatives are used in statements. Such questions may have to be discarded or replaced within the questionnaire at the pre-test stage.

A similar methodology was used in the ROSE (Relevance of Science Education) project (Oversby, 2005). This was targeted at 14-15 year old pupils across 22 countries. This used a four point Likert scale, thereby eliminating the 'middle' option and not permitting respondents to 'sit on the fence'. Findings from such large samples, whilst certainly robust in reliability may be limited in informing the researcher about the reasons for the trends observed and therefore may be open to misinterpretation. The findings from the ROSE (2004) project indicated that pupils in most 'modern western' countries feel that school science has not inspired them to become interested in science as a career. This contrasts with pupils from 'traditional asian' countries, who aspire to scientific careers. However the research does not explain *why* this may be the case.

A similar trend in pupil 'switch off' had also been noted in the USA. In a programme designed to motivate pupils and 'switch them back on' to science, an approach of project based learning was trialled (Thomas, 2000). The methodologies used in this research were diverse. Scores in standardised tests were analysed pre and post intervention, performance on problem solving tests were also analysed. Alongside this a three-year longitudinal study was conducted, which used research instruments to probe pupils' capabilities, achievements and attitudes. This was used for pupils from age 13 to 16 and required the researcher to observe lessons, interview students and teachers, analyse questionnaires and administer assessments. In addition this research used performance tasks to assess pupils' acquisition of specific skills that were the focus of project activities. The wealth of detail obtained by such methods gives researchers a more robust evidence base from which to postulate theories regarding the causes for pupil disinterest in science and perhaps assess some interventionist strategies to turn this around. The downside of such a study is the diversity of research skills required for its analysis. Mostly research of this nature relies on a team of researchers with complementary skills rather than a single person.

From reading the methodology described within the previous studies, it was becoming evident that the research methodologies required to effectively carry out this research project would also need to be diverse in nature. Whilst questionnaire would be the most effective method for surveying the views of large samples of pupils and teachers, this method alone was unlikely to provide the 'thick description' (Geertz, 1973) that would enable an interpretation of the underlying causes of the problems perceived in science education for able children to be arrived at. Nor would questionnaire alone serve as a means by which a possible interventionist strategy could be adequately evaluated.

In order to obtain the fullest picture possible of the views of pupils and teachers regarding the way that science is taught to able pupils it would be necessary to do more than merely survey them. Thus the research methodology for the project was a mixed methods sequential design consisting of two phases. Phase one would consist of a survey of pupils and teachers across more than one school in the Local Education Authority. This phase would also involve interviews with LEA staff and school senior management with a view to identifying key issues affecting the current state of science education for able pupils in local schools. Since there was no way of knowing what these issues were before the interviews were held, a 'concept identification' approach was felt to be necessary in order to allow the emergence of these key issues through the research process. The value of this approach is that concepts for further exploration emerge from interview and whilst this may be open to flaws in interpretation, it does present a sounder starting point than a mere postulation of the researcher's gut feelings.

In order to establish some convergent validity between the two phases, any theories derived from phase one, would need to be further probed in phase two of the project. Therefore in the interests of manageability phase two would be designed as an action research project in one school, where by means of classroom observation, classroom intervention, individual and group pupil interviews, teacher interviews, pupil and teacher surveys, pupil performance data and a science teacher focus group the 'thick description' of all the factors interplaying to influence the learning and teaching of able pupils in science could be evidenced.

5.3 My research design: the mixed methods approach

A mixed methods research design is defined by Tashakorri and Teddlie (2003) as a design, which combines the qualitative and quantitative approaches into the research methodology of a single study or multiphased study. Mixed methodology has emerged in recent years as a 'third methodology' alongside quantitative and qualitative methodology. However it's birth as a respected research methodology has not been without labour pains.

One of the stumbling blocks to the acceptance of mixed methodology has been that traditionally quantitative research has been viewed as embedded in a positivist paradigm and qualitative research in a constructivist paradigm. The research perspectives underpinning these clashing paradigms were viewed by some to be irreconcilable (Tashakorri and Teddlie, 2003) and the conflicting arguments put forward by their protagonists were referred to as the 'paradigm wars' (Gage, 1989). The main objection to the idea of mixed methodology was described by the 'incompatibility thesis', which maintains that research processes cannot be divorced from the philosophical assumptions that researchers bring to their enquiries (Cresswell and Tashakorri, 2007).

The argument put forward was that there was necessarily a link between research epistemology and method and that a philosophy that held that a truth was out there to be discovered (positivism) and a philosophy, which maintained that knowledge, was a human construction (constructivism) were basically at odds with each other.

However Denzin (1978) had many years previously discussed the idea of 'across methods triangulation' involving both quantitative and qualitative methods. In this discussion mixed methods was viewed as the collection and analysis of two types of data rather than the integration of two approaches to research. In reviewing the history of the development of mixed methods as a research methodology, Tashakorri and Cresswell (2007) distinguish between 'studies that utilize two types of data without serious integration and those that integrate the findings of the quantitative and qualitative strands' (p.4). A 'pragmatic approach' (Morgan, 2007) emerged from the ideas of John Dewey (1933) and George Herbert Mead (1934). Howe (1988) also advocated pragmatism as a means of reconciling conflicting paradigms and establishing an alternative paradigm. This view was reinforced by Patton (1990), who stated,

> " In short, in real world practice, methods can be separated from the epistemology out of which they emerged. One can use statistics in a straightforward way without doing a literature review of logical-positivism. One can make an interpretation without studying hermeneutics. And one can conduct open-ended interviews or make observations without reading treatises on phenomenology." (p. 90)

A number of researchers (Howe, 1988, Patton, 1990, Tashakkori and Teddlie, 1998) have advocated pragmatism as a valid alternative paradigm for mixed methods research. The latter suggest,

> " Study what interests and is of value to you, study it in the different ways that you deem appropriate, and utilize the results in ways that can bring about positive consequences within your value system" (p.30)

This 'bottom-up' approach is attractive to some researchers because it allows them to attach a new methodological idea to their preferred methods. In a later study (2003) the same authors reinforce the benefits of the pragmatic approach by emphasising that pragmatists consider the research question to be more important than the either the method used or the paradigm underlying that method. They reject the either/or attitude regarding positivism and constructivism and adopt a ‘compatibility theory’. The stance is that in the pragmatic research frame any contradictory ontological or epistemological assumptions are less important than ‘situational responsiveness and a commitment to an empirical perspective’ (Greene and Caracelli, 1997, p.9). By utilizing the complementary strengths of different research methods the disadvantages of the weaknesses of each may be minimised. These weaknesses are identified by Rocco et al. (2003) as the ‘interpretive gap’ between the researcher and the data in qualitative research and the inability of quantitative methods to access the ‘structural complexity of human knowledge’ (Loef, 1990). Tashkkori and Teddlie (2003) also make the case that mixed methods research can answer research questions that other methodologies cannot, provide stronger inferences and allow a greater diversity of different views to be presented. The integration of quantitative and qualitative methods allows findings to be viewed more credibly and answer a broader and more complex range of research questions, which may also be generalisable to wider contexts.

One reason explained by Scwandt (2000) for the resistance to the widespread adoption of mixed methods research may be that often researchers are viewed as ‘expert’ within their own preferred methodology and resist acquiring ‘novice’ status by engaging with a research method, which is not their forte. Schwandt put forward the view

> “So the traditional means of coming to grips with one’s identity as a researcher by aligning oneself with a particular set of methods (or by being defined in one’s department as a student of “qualitative” or “quantitative” methods) is no longer very useful. If we are to go forward, we need to get rid of that distinction.” (p. 210)

An article by Rocco et al. (2003) identifies a need for ‘research courses that demonstrate quantitative and qualitative data collection and analysis techniques, followed by instruction in how and when to mix methods in the various stages of a research design’ (p. 611). The authors make the case that this would lead to greater sophistication in research design, involving both philosophical and political decisions.

Punch (1998a) makes the case that whilst quantitative research has been primarily concerned with verifying theories and qualitative research with generating theories there is no reason why these outcomes cannot be achieved by the opposing methodology. Tashkkori and Teddlie (2003) agree with this viewpoint,

> "A major advantage of mixed methods research is that it enables the researcher to simultaneously answer confirmatory and exploratory questions, and therefore verify and generate theory in the same study." (p. 15)

Evidence of mixed methods research in educational contexts are often implicit rather than explicit, with many researchers utilising mixed methods without explicitly identifying that they are doing so. One exception to this is May (1999) who used mixed methods literature to support the decisions that he made into the research design for a study on the effectiveness of training for research. May used statistical analysis of pre and post tests but also used qualitative data to 'illuminate quantitative data' (p. 1108). Another example of the utilisation of mixed methodology, for a doctoral thesis, was exemplified by Stevens (2002). Stevens' research hypothesis was that the introduction of a 'distinguished educator' would have an impact upon effective teaching within a school. Stevens used an experimental design, where some schools were allocated a 'distinguished educator' and some were not. The research methods used were analysis of attainment scores, observations, interviews and documentary analysis. By using mixed methods Stevens was able to both confirm her original hypothesis and explore in greater depth the mechanisms impacting upon effective teaching.

The above example illustrates the use of mixed methods within a simultaneous design but one of the most useful applications of mixed methods (as in this study) uses a sequential design where inferences made at the end of one phase of the research lead to the questions for and the design of the second phase. Cresswell and Tashakorri (2007) describe the compatibility of such designs,

> "In a sequential mixed methods design, a researcher may begin with a quantitative survey (embracing a post positivist perspective) to answer a theory-driven research question and move into collecting qualitative focus group data (embracing a constructivist perspective) in response to a qualitative question.

> Such a shift in worldview has been demonstrated in current research and is not unrealistic." (p. 306)

In this study the pilot phase is a predominantly (but not exclusively) quantitative phase and the action research phase is predominantly (but again not exclusively) qualitative. Phases of research which integrate both quantitative and qualitative methods within each phase, may more accurately be defined as 'mixed model' designs (Tashakorri and Teddlie, 2003). These designs employ concurrent triangulation within a sequential explanatory strategy (Cresswell, 2003). Such methodological triangulation utilises two separate paradigms to impact upon a single research task. If the findings of the two phases of the research reinforce each other, the convergent validity of the research as a whole is greatly strengthened. Convergence is demonstrated when researchers look several times at the same issue, maybe looking each time in more detail and arrive at more informed but similar conclusions each time (Heron and Reason, 2001). However, Morse (2003) views the ad hoc mixing of methods as a threat to validity because she maintains that the researcher must maintain the assumptions of each paradigm in use and this leads to conflict in interpretation of inference.

The issue of validity is important and because it means different things within quantitative research compared to qualitative research it is necessary to reflect upon what it means in the context of this research. The basic understanding of valid research is that it actually addresses the question that it set out to address and that the inferences drawn from the research honestly reflect the interpretations of all those involved. The validity of each phase of the research is discussed within the relevant, subsequent chapters and related to the methodology employed during that phase of the research. The convergent validity between the two phases is discussed within the conclusion where inferences from the research are examined. Tashkorri and Teddlie (2003) underline the importance of the 'quality of inference'

> "We believe that the ultimate advantage of using mixed methods is in the quality of inferences that are made at the end of a series of phases/strands of study. As such we distinguish the "results" of a study from the "inferences" that are made from that study. Results are the outcomes of data collection and data analysis. Inferences are based on the investigator's interpretations and expansion of such results." (p. 35)

Indeed the authors go further in suggesting that the term 'inference quality' is synonymous with 'internal validity' (or 'causal validity', Cook and Campbell, 1979) in so far as it describes the accuracy with which both the inductive and deductive conclusions from an enquiry are drawn. Furthermore they define a term 'inference transferability' to be synonymous with external validity or generalisability of results to other contexts. They defend this position by stating that external validity and transferability are similar because both processes involve assessing the degree to which conclusions may be extrapolated beyond the research study. Whilst this point is worthy of consideration it must be remembered that good inference quality is unlikely to follow from poor data quality and therefore rigour in obtaining valid data cannot be underestimated. This is termed by Cook and Campbell (1979) as the 'construct validity' of the research and is further discussed in the relevant chapters describing each phase of the research. For quantitative and qualitative researchers the theoretical validity of the research has rather different meanings. In the former case it is construed as the degree to which the interpretation of the findings is consistent with the known theories (positivist view), whereas in the latter case it is more concerned with the degree to which the interpretation of the findings fit the data (constructivist view). As a means of reconciling these differences it may be more informative to look at the consistency of the design quality of this research with regard to three criteria

- Within-design consistency: is the design consistent with the research question? Are the inferences consistent with the data? Are the inferences consistent with the research question?
- Conceptual consistency: are the inferences obtained within the various parts of the study consistent with each other? Are the inferences consistent with that of other external research findings?
- Interpretive consistency: is there agreement amongst those involved in the study on the interpretation of the findings?

The consideration of these three criteria will provide a structure against which a final evaluation of the research project may be assessed at its conclusion.

Chapter 6

Phase1: The Pilot Study

6.1 Rationale for the Pilot Study

Since the introduction of the National Curriculum for Science in 1989 there has been a steady reduction in the numbers of pupils going on to study science post 16, particularly physical sciences (DfES, 2006a). Previous research into the reasons for the disaffection of young people with science education (Murray and Reiss, 2005) has revealed that many pupils do not find the science that they study in schools stimulating or interesting. The Royal Society at its March 2006 conference iterated a need for an interdependency of research, reform and practice and called for "a relevant, high quality, sustainable evidence base to inform policy and practice and reverse the declining popularity of the sciences post 16" (Hyam, 2006 p. 6). If such a reliable evidence base is to be compiled it will require contributions from a numbers of researchers in the field. Thus the need for research projects of this type is well established.

The pilot study was carried out in the summer of 2003 in Staffordshire, after the Excellence in Cities programme had been in place for 3 years. Its aim was to gather information from pupils and teachers about the impact of the programme for science education in terms of pupil and teacher attitudes to school science and the teaching and learning strategies adopted to deliver the science curriculum.

The objective of the pilot study was to investigate the practice in place in three secondary schools. The research examined two areas

a. The attitudes to science education of both pupils and teachers
b. The outcomes of the programme in terms of applied teaching and learning strategies and impact on pupils and teachers

6.2 Research methods for the pilot research

The pilot study was embarked upon by utilising a mixed methods approach. By this means an understanding of the intrinsic culture of the school context can be arrived at, which is complementary to the etic, extrinsic viewpoint of the quantitative researcher.

The criticism that naturalistic methods may be influenced by researcher reactivity and possibly not generalisable to a wider population is addressed by the reinforcing evidence of the quantitative data. Whilst it may not be possible to attribute causality to any relationships observed by quantitative methods, the triangulation achieved by the utilisation of mixed methods may strengthen the case for firmer conclusions to be drawn.

Thus, for the pilot study the two main research methods utilised would be the use of surveys, carried out using the research instrument of the questionnaire, for pupils and teachers and ‘conversations’ with educational practitioners utilising the research instrument of the unstructured interview. At LEA and school senior and middle management level, the interactions required were small in number and thus data collection by interview was manageable. At teacher and pupil level the number of respondents was considerably larger and thus the interview method was ruled out. The most cost effective method of gathering data from these groups would be by questionnaire.

Although unstructured interviews can be more difficult to analyse they can often be more revealing. The structured interview is useful when the researcher is aware of what she does not know and is in a position to frame questions that will supply the knowledge required, whereas the unstructured interview is useful when the researcher is not aware of what she does not know and is reliant on the respondents to tell her (Lincoln and Guba, 1985).

It was decided to begin with open-ended, informal interviews with the Local Education Authority’s Regional Science Advisor and Able and Talented Co-ordinator. The aim of these interviews was to learn what initiatives had been put into place in schools to help to promote science education amongst able pupils and to select possible suitable schools within which to conduct the survey. It was necessary that these interviews should be unstructured in order to allow a free discourse on the policies and practices adopted by the Education Authority towards the science education of able children. Open ended interviews allow respondents an opportunity to express their definition of the situation (Silverman, 1993).

In carrying out these interviews a number of preliminary considerations had to be dealt with. The issue of informed consent was contentious. Each respondent was informed of the purposes of the interview and not only consented but was eager to have their say on issues that were very pertinent to their day to day work. However, consent also had to be sought from the Education Authority Senior Management Committee, which introduced an element of accountability for the respondents and may have rendered them unwilling to say anything detrimental about their employing establishment and the researcher needed to aware of the sensitivities of the respondents in framing her questions.

Unstructured interviews, for the purposes of setting the agenda for the research, can be subject to a great deal of researcher bias as the choice of questions, responses and even the body language of the researcher can all be influential on respondents (Cohen et al., 2003). The advantages of using the interview method at an early stage are that the interviewer can follow up points, seek clarification and check interpretations of answers for validity on the spot. The influence of politics on the interview responses had to be borne in mind. It was in the interests of the Local Education Authority to appear to be successful regarding the progress of nationally funded initiatives in education for able children and this may have engendered a 'rose-tinted' spin (Somekh, 2006) on some of the interview responses given.

The interviews were recorded by the taking of contemporaneous notes as it was felt that the presence of a tape recorder may have been intimidatory and resulted in the respondents speaking less freely about their true feelings on an issue, particularly if they seemed to be critical of their employer. However, the danger of bias creeping in to recording procedure has to be averted and an effort made to ensure that *all* issues raised by the respondent are recorded by the researcher and not just those with which she has empathy. In order to reassure respondents, assurances on the confidentiality of the interview exchanges were given. Whilst the interviews proved a useful starting point it was recognised that they were highly subjective and had low validity since respondents may have used the opportunity to convey hidden agendas via the researcher. Also people's experiences can only be recounted in interviews and whilst this may reveal their interpretations and understandings that is not necessarily the same as an organisational construction of reality. From these interviews a selection of schools was made within which surveys could be taken. Again, the choice of these schools may have been political on the part of the individuals concerned, as representing schools which they desired a closer look into, rather than schools which were a truly representative sample across the whole LEA.

Issues to be probed in surveys were also suggested in these interviews and these had to be analysed for relevance to the research objectives rather than pursued without question, since again hidden agendas may have been at play. One way of increasing the validity of the information gained from these interviews was to compare it with information obtained from interviews with senior science staff in schools. This comparison establishes ‘convergent validity’ (Cohen et al., 2003). Thus it was decided that in addition to merely surveying schools, more structured interviews should be held with senior science staff within schools in order to compare the issues raised as concerns by them with those raised by Education Authority staff.

The region was divided geographically into three cluster groups, each with a cluster leader. The Heads of the schools within these clusters were then invited to volunteer for the pilot. The reports of each of the cluster leaders were read and a school selected from the number of volunteering schools within each cluster. The criteria for school selection were that each school should have a similar socio-economic intake and a similar academic achievement profile, as judged from SATs and GCSE attainment scores but that they should each belong to a different cluster group for ‘Excellence in Cities’ initiatives. This ensured that the three schools had similar pupil profiles but had each experienced slightly different approaches to teacher training in the teaching of able pupils and in the types of initiatives pursued at pupil level.

A visit was then made to each of the schools and a more structured interview conducted with the Head of the Science Department. The purpose of this interview was to find out the issues relating to the teaching of gifted pupils in science, which were important to the school. The choice of a semi-structured interview technique was chosen at this point in the interests of achieving some comparability between the responses from the three schools and reducing interviewer bias. However, there was still some scope at the end of the interviews for the respondents to add any other issues, which appeared to be relevant to their school situation. From these interviews a number of common issues emerged. These issues centred around poor attitudes to differentiated science education for able pupils due to an aversion to 'elitist treatment' by teachers and pupils, poor take up of continuing professional development in teaching able children due to time restrictions, financial constraints and low teacher morale and a lack of diversity in classroom practice leading to overly didactic teaching methodologies being used by science teachers. Arising out of these interviews the two focal objectives for the data required from the questionnaires were established as:

- Attitudinal data on science education in schools from both pupils and their teachers.
- Comparative data on the applied learning and teaching strategies in the classroom as perceived by pupils and teachers.

Questionnaire design can be problematic for a number of reasons. For each question that is posed the researcher must consider the justification for the question, whether it needs to be broken down into simpler questions and whether the respondents have the information necessary to answer the questions. The way in which a question is worded can greatly affect the way in which it is answered (Oppenheim, 1992) and issues of emphasis and technicality need to be addressed. The ordering of questions can also lead the respondent along lines of thought, which may influence their answers and the type of response asked for can greatly affect the quality of the analysis that is possible (Oppenheim, 1992). Even the presentation of the final questionnaire can influence the number and quality of the responses obtained. Major issues to be addressed in questionnaire design are those of reliability and validity. Reliability refers to consistency, to obtaining the same result again. Validity tells us whether the question or item really measures what it is supposed to measure (Oppenheim, 1992).

Both teacher and pupil questionnaires were designed to consist of two parts. Part A, in each case, was concerned with factual information. By contrasting the responses of both pupils and teachers the construct validity of the responses to questions regarding classroom practices could be strengthened. Also some of the factual information requested could be verified from the school databases. The majority of questions in this section were highly structured, allowing the respondent a limited choice of responses. However, earlier interviews had revealed that a motivating factor for respondents was the allowance of some scope for them to express their feeling about certain issues more fully and for that reason this section of the questionnaire contained some open-ended questions regarding perceptions of constraints on learning and teaching in the science classroom. In order to analyse these responses quantitatively the replies had to be analysed, grouped and field coded into a limited number of categories. Free response questions can inevitably introduce coding error (Sudman and Bradburn, 1983) but they have the advantage that respondents are required to think more deeply about their responses than is the case in limited category responses.

Part B of the questionnaire was attitudinal. The design of attitudinal questionnaires introduces particular problems due to the personal nature of the questions. Leading questions and loaded words are to be avoided if results are to be undistorted by the personal bias of the researcher (Oppenheim, 1992). Responses to attitudinal questions can also be influenced by prestige bias or respondent embarrassment. In order to maximise reliability a technique of using sets of questions, rather than individual questions was used. In such sets of questions those which test the same underlying attitude can be phrased in a positive or a negative manner. This helps to reduce the effect of respondent acquiescence. As explained by Oppenheim (1992),

> "Sets of questions are more reliable than single opinion items; they give more consistent results, mainly because the vagaries of question wording will probably apply only to particular items, whereas the underlying attitude will be common to all the items in the set." (p. 73)

Critics of attitudinal questionnaires maintain that such research instruments can only investigate the feelings and opinions of respondents at a superficial level and that many respondents do not consider their responses in sufficient depth for the information to be reliable. However this methodology has been widely used by many respected researchers. Ireson and Hallam (2005) conducted research into the effects of ability grouping in school on pupils' self concept and perceptions of teaching. Their work analysed these effects in terms of motivation, attitudes towards school and self esteem. The methodology for this research used attitudinal questionnaires and the outcomes of the research are highly positive. Their work demonstrates that although attitudinal research can be fraught with problems, the theoretical validity of responses may be strengthened, by using both structured response and free response questions.

One important consideration in devising questionnaires of this nature is the necessity for pre-testing in order to establish the internal validity of the question structure. One way of circumventing this problem is the adoption of pre-existing questionnaires, making only minor modifications to suit the new situation. In order to maximise the internal validity of the attitudinal questionnaire used in this study, it was decided to adopt with minor revisions the structure of an attitudinal questionnaire, designed to discover pupils' attitudes to school science, as described by Misiti, Shrigley and Hanson (1991).This used a response code consisting of a five item Likert scale and had been trialled in Pennsylvania's middle schools amongst fifth, sixth and seventh graders. The practice of adopting pre-existing questionnaires is advocated by Sudman and Bradburn, (1983) as it has the advantage of short cutting the pre-testing process. The questionnaire chosen had been subjected to rigorous testing and reduced to 23 questions from an original selection of 81. Those questions that failed to be selected were rejected on the grounds of readability, reliability ratings, internal consistency and 'evaluative quality' for the attitude object under test. The questions were also analysed for gender group validity and cross cultural validity by comparing outcomes with population norms when the questionnaire was given to different gender groups and when translated into Spanish and given to Hispanic students. In conclusion the test authors stated that,

> " The science attitude scale for middle school students passed several tests suggesting some degree of validity. The reading level of the statements was checked. Known groups testing, cross-cultural data, high item – total correlations, and tests for evaluative quality suggest a valid scale" (Misiti, Shrigley and Hanson, 1991, p.538)

For the purposes of this research exercise the 'americanised' language of the original questionnaires had to be modified for the context of the English recipients. Once the questionnaire had been re-constructed it was still necessary for it to be pre-tested on a small sample so that any problems in questions' wording or conceptual understanding might be revealed. Therefore the teacher questionnaire was pre-tested on a convenience sample of academic colleagues with science teaching experience and the pupil questionnaire was pre-tested upon a second convenience sample of the children of the colleagues. The feedback in both instances indicated that the questionnaires were easily understood, clearly worded and contained little threat to the respondent. The questions asked were found to be both relevant and unambiguous. Each questionnaire was timed to take approximately 15 minutes as any longer may have introduced ‘respondent fatigue’ and result in poorer quality responses.

One central issue concerning the administration of the questionnaires was that of sampling. The pupils chosen for the samples were the entire Year 9 (age 14) cohort from each school. This was a target sample of approximately one hundred pupils from each school. This year group was chosen because they were at a pivotal point, where they were beginning to think about subject choices for GCSE and future career paths. Within this year group some of the children had been categorised as scientifically able by external tests and some of the children had been categorised as scientifically able by assessments internal to the school. The choice of the entire cohort helped to satisfy two problematic areas.

Firstly, it became unnecessary at the point of sampling, to distinguish between ‘able’ and ‘less able’ pupils and secondly, it avoided the ethical problem of some children feeling ‘left out’ and undervalued. Many Heads of School had taken great pains to ensure that able children were not regarded as elitist and it was felt that the questionnaire would be better accepted within the schools if it was given to all the children in the year group regardless of their categorisation. Details of those pupils on the ‘gifted and talented register’ could be obtained from the school separately from the questionnaire responses, along with the performance data on all of the pupils sampled.

Another ethical issue, which needed to be addressed was that of informed consent (BERA, 2004). Denscombe and Aubrook (1992) imply that questionnaires given to school children within lesson time may subject children to undue pressure since their natural inclination during school time is to do what they are told to do. Thus their conclusion is that the pupils are not really demonstrating freely their consent. However, the questionnaires used explained clearly the purposes of the survey and each participant in the survey was asked to sign their consent to participation. Some children did not consent and these results were not used. This indicates that the concept of informed consent was understood and that although the questionnaires were completed within school, the pupils were not unduly pressured to comply with responding to the questionnaire. Another ethical consideration was that of the use of pupil time. Time, in which the argument may be made, that the pupils should have been engaged in learning activities. In defence of this one must ask to what extent the questionnaire itself may have been a learning opportunity for pupils. Pupils were asked to reflect upon their learning processes and thereby engage in metacognition. This it may be argued is in itself, an important learning skill.

The first somewhat surprising reaction of school staff to the proposed research, involved an element of suspicion that it was an evaluative exercise that would reflect upon the schools and their own performance appraisal. Despite assurances of confidentiality many of them found the task threatening and regarded it as some kind of inspection exercise. The result of this was to raise an awareness of the politics of fieldwork (Denzin and Lincoln, 1998). In order to allay fears about the motives of the survey, it was necessary for the researcher to offer reassurances and explanations of the research motivation to science departmental meetings.

The final task in this first phase of the research project was the analysis of the data obtained from the questionnaires. The method of sampling had produced a high response rate and consequently a wealth of data to be analysed for trends and correlations. Given the wide-ranging nature of the questions asked in both parts of the questionnaire, there were many possible variables which could be analysed for interconnecting relationships.

The only way to handle this large amount of data was to use computational analysis. The first stage of this involved some degree of data reduction, coding data in such a way that it may be more easily handled by mathematical methods. Initially simple spreadsheet tables can be used to look for possible trends and underlying patterns by producing scatter plots but greater rigour is required before conclusions can be drawn regarding the correlation of variables.

More sophisticated statistical analysis using SPSS (The Statistical Package for the Social Sciences) was used to investigate the correlation between different variables. However, a degree of caution must be used in ascribing any causality to relationships demonstrating high correlation coefficients. This is because in any analysis there may be other, measured or unmeasured, variables affecting the results (Field, 2000) Also if there was a causality, correlation coefficients tell us nothing about the direction of that causality.

Scrutiny of regression line plots and the data residuals can give a picture of the quality of fit between two variables. More complex analysis of multiple regression can portray the interrelationships between a number of variables and indicate which factors play the dominant role in the outcome variable.

Thus, by these means, an attempt can be made to gain insight into the relationships between some of the independent (but possibly co-dependent) variables e.g. ability set, gender, experience of teacher training, preferred learning activities, self esteem and the possibly dependent variables of positivity of attitude and aspiration.

6.3 Analysis of the findings of the pilot study

The data gathered from the three schools used in the pilot study was analysed initially using simple scatter plots and then in more detail by using SPSS analysis. Before any detailed data analysis could be entered into, it was important to look firstly at the quality of the data obtained from the sample under study.

Across the three schools used, data was gathered from 100 year 9 pupils. By analysing the responses to the twenty three questions put to the pupils, a score for each pupil could be determined which indicated their positivity towards school science education. A histogram was plotted showing the frequency of each positivity score and this was looked at firstly to determine whether it formed a normal distribution. When a normal curve was displayed on the histogram, it could be seen that the distribution of the histogram conformed to the shape of the normal distribution displayed by the curve.

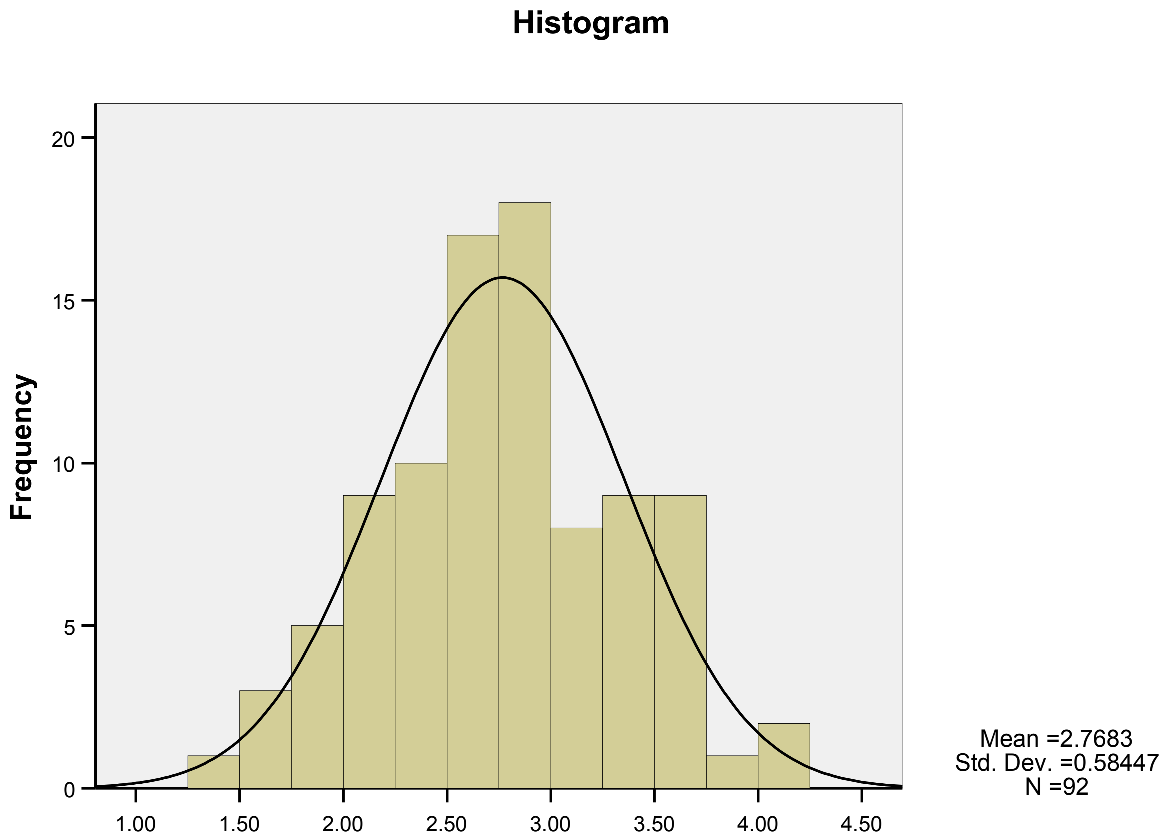


Figure 6.1 Frequency distribution of pupils' attitudes scores for all 3 pilot study schools

To check this, further tests were performed on the data to determine if there was any skewness or kurtosis present. Skewness gives an indication of the degree to which the scores predominate at one end of the scale and kurtosis measures the sharpness or shallowness of the peak of the distribution and is related to the standard deviation. A normal distribution would have zero skew and zero kurtosis. The scores on both counts for this distribution were so small as to be insignificant, indicating that the data fell within acceptable limits for testing as a normal data set. However, to further verify that the distribution was normal a Kolmogorov-Smirnov test was performed. This compares the set of scores on the sample to a normally distributed set of scores with the same mean and standard deviation. If the test is non-significant ($p>0.05$) it tells us that the distribution of the sample is not significantly different from a normal distribution. In this case the p value was 0.2 confirming that this was normally distributed data set. As a final check a Q-Q plot was obtained. This plots the values that you would expect to get if the data were normal (expected values) against the values actually seen in the data set (observed values). The expected values are a straight diagonal line, whereas the observed values are plotted as individual points. If the data is normally distributed, then the observed values should fall exactly along the straight line. In this instance the observed values followed the line of expected values very closely, except for only two outlying values. All of these tests therefore indicate that this is a sound data set for further analysis.

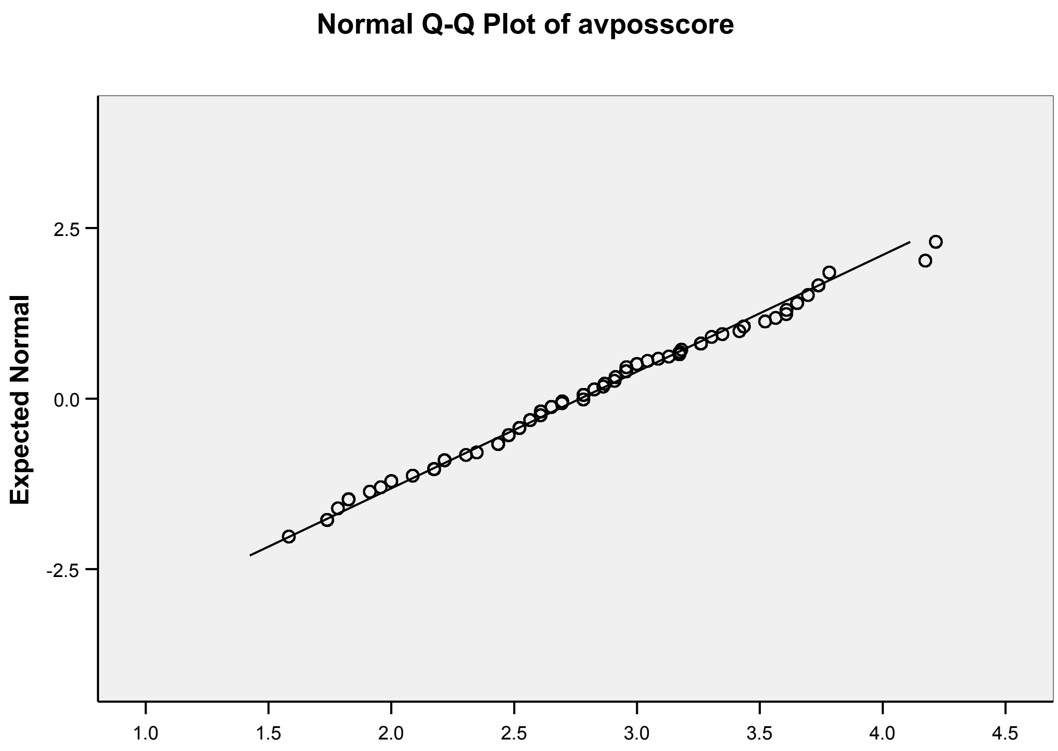


Figure 6.2 Q-Q plot. Test of closeness of fit of pupils' attitude scores to that of a normal distribution

6.3.1 Reliability and validity

The reliability of the data was tested in order to ascertain the internal consistency of the questionnaire, essentially that all of the items in the test were measuring essentially the same thing i.e. positivity towards science. One way to do this is to split the test into two comparable halves and then to correlate scores on these. This is called the split-half reliability. However the reduced size of the two halves will result in an underestimate of the true reliability and this can be corrected using the Spearman-Brown formula. In this instance the Spearman-Brown coefficient was 0.902, which indicates that the internal consistency of the questionnaire was high. A second reliability test, the Cronbach's alpha test incorporates all possible splits in a single formula and includes test items scored either dichotomously or continuously. The coefficient of equivalence, α is essentially a measure of the degree of consistency within a test. In this instance the value of α was 0.894, above the generally acceptable level of 0.7 indicating high reliability and that no items in the test required deletion.

However, it must be remembered that a test that has high reliability does not necessarily have high validity. Therefore it is essential that the research analysis maintain a strong theoretical link with the research objectives. The most direct form of validation is to compare the results obtained with those from another similar test or with those obtained from other previous research.

The test from which this questionnaire was developed originated from work done by Robert Shrigley at Pennsylvania State University (Misiti, Shrigley and Hanson, 1991). The first generation of the test was used in 1968 and then redesigned in 1983 for use with Egyptian fifth-grade students. The third revision upon which this questionnaire is based was developed in 1991 and used on grades 5 to 8 in Pennsylvania middle schools. The questionnaire was subjected to validity tests including, known groups validity and cross-cultural validity. The known groups testing confirmed that when analysed for gender, the positivity to science of boys was higher than that of girls. This was a finding known to the researchers from previous work and also one demonstrated by the questionnaire used in this study. By comparing the actual pattern of the relationships obtained in the data analysis with the expectations, as described in previous research, the construct validity of the questionnaire can be assessed. The cross- cultural validity was also found to be good when the questionnaire was translated into Spanish for Puerto Rican students and thus it can be inferred that its use with British school children should not suffer from cross-cultural changes.

6.3.2 Data Analysis

6.3.2.1 Correlation

Whilst some of the variables used in the analysis may be regarded as continuous, some such as gender, were categorical or used small range responses. Thus it was decided that non-parametric testing would be used alongside parametric tests in the data analysis. The Pearson Product-Moment Correlation Coefficient can be used for most continuous (parametric) measures and the Spearman's Rho Rank Correlation tests used for ordered (non-parametric) data. Both tests were used in analysing many of the variables studied.

6.3.2.2 Ability sets

The first step in analysing specific features of the data was to do a simple scatter plot of the positivity for each science set within each school. Each dot on the scatter plot represents the positivity score of a pupil. It can be seen from the number of dots below the zero line that in general pupils across all ability groups in all three schools are negative about school science.

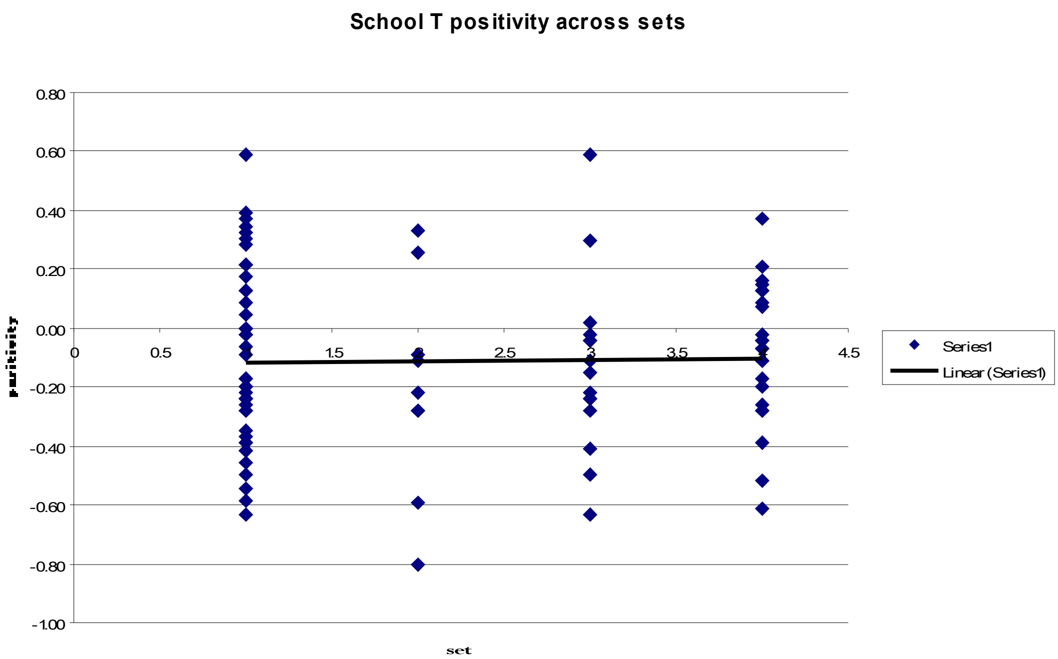


Figure 6.3 Positivity scores for pupil across all sets in pilot study school 'T'

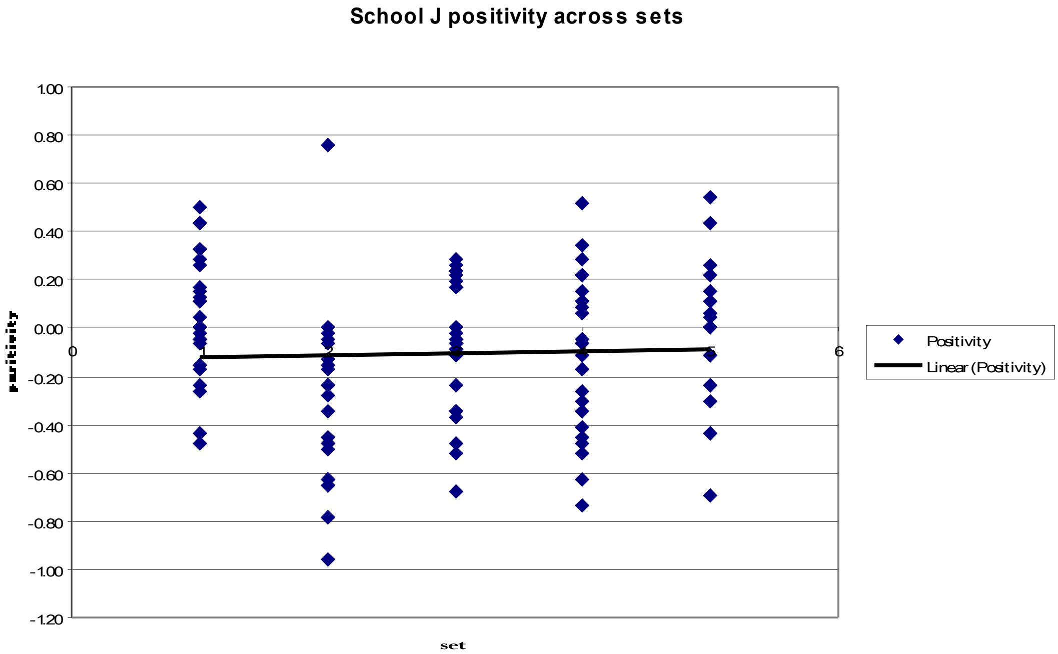


Figure 6.4 Positivity scores for pupil across all sets in pilot study school 'J'

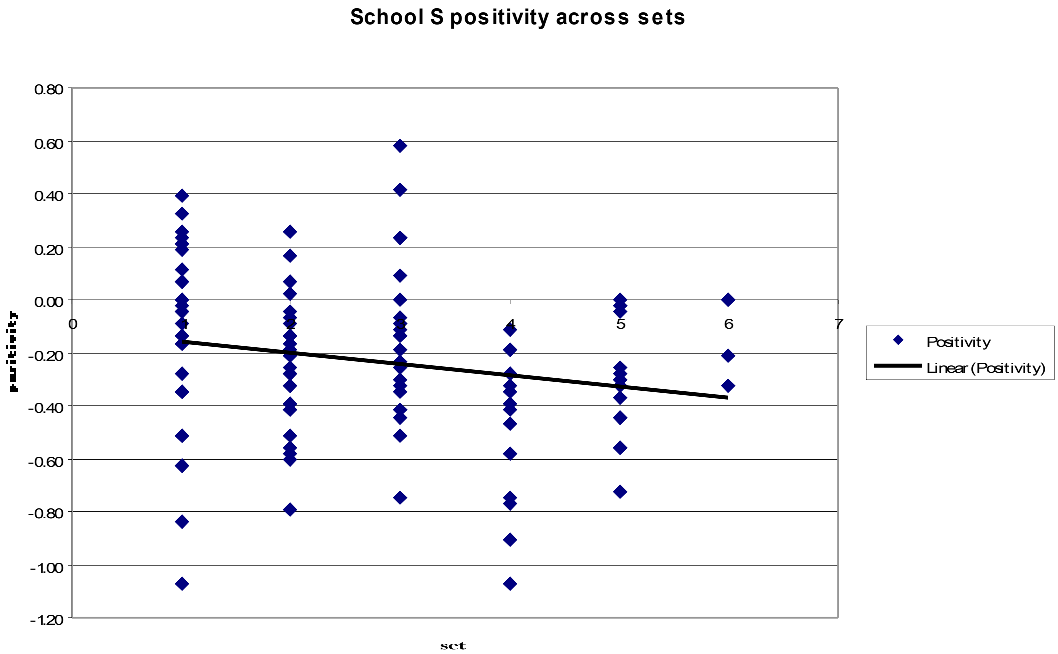


Figure 6.5 Positivity scores for pupil across all sets in pilot study school 'S'

6.3.2.3 Gender

A simple scatter plot of positivity versus gender appeared to indicate that there may be a difference in the attitude to science between girls and boys. In order to test if the difference in positivity between genders was significant the data was subjected to a test of significance. If gender were unrelated to positivity then the probability of the two being related would be 0%. However, certainty of this nature is rare in statistical analysis and a level of significance is usually set at a point at which the relatedness of two variables is accepted. This is commonly set such that if the probability of a statement being true is less than 5% ($p<0.05$) then the statement is regarded as untrue (the null hypothesis). Conversely if the probability that two variables are related exceeds 95% ($p > 0.05$) then the statement is regarded as true (the experimental hypothesis).

Since gender is categorical data the non-parametric Mann-Whitney U test was carried out on the gender data. This is an assumption-free test, used to establish whether the difference in the means of two independent samples is statistically significant. The most important figure in the results ($U = 794$, $z = 1.872$, $p= 0.061$) is the probability value and this shows ($p> 0.05$) that there is no significant relationship between gender and positivity. However, p very close to 0.05, indicating that this result is approaching significance. This infers a probable dependence of positivity towards science on the gender of the pupil with boys being more positive than girls.

6.3.2.4 Aspirations

It may be expected that pupils who have positive attitudes towards science also have aspirations to study science further beyond GCSE and/or get a science related job in the future. However, this is not necessarily a foregone conclusion as some pupils continue to study science beyond GCSE, despite not being terribly positive about school science, because it is required for entry to some higher education course or for a particular career. On the other hand some pupils who may be very positive about school science will not continue it beyond GCSE because they perceive it to be hard to get high grades in at ‘A’ level or because they do not regard scientific careers to be as lucrative as others. It is important to establish whether there is a correlation between positivity to school science and aspiration to continue with science beyond age 16, since if this can be established it may have implications for improving the numbers of pupils continuing with science to sixth form and university.

Item responses about the pupil aspirations involving science in the future were analysed alongside their scores on positivity to science. A Pearson Product-Moment Correlation Coefficient was calculated giving values ($r = 0.401$, $p<0.001$, 2 tailed test). ‘r’ measures the extremes of perfect agreement and perfect disagreement by the values of +1 and –1 respectively. The positive value of $r = 0.401$ shows a good measure of agreement. The results also show that there is a less than 1% probability that a correlation coefficient this big would have occurred by chance. The two tailed test was used since the direction of the relationship between aspiration and positivity could not be determined and caution must be taken in ascribing causality, in either direction, to the relationship between positivity and aspiration by this result alone. Also it is important to remember that causality cannot be assumed because there may be other measured or unmeasured variables affecting the results. Since there were only 5 response levels to this item a non-parametric Spearman’s Rho Rank Correlation test was also performed on this data giving the result (Rho = 0.377, $p < 0.001$, two tailed test). This works by first ranking the data and then applying Pearson’s equations to those ranks. The p value for this relationship indicates that we can be 99% sure that this correlation has not occurred by chance. Therefore we can conclude that the data demonstrates a positive relationship between positivity to science and the aspiration to continue with its study beyond 16 or to work in a scientific field.

6.3.2.5 Subject Difficulty

If pupils are negative towards school science could this be because they find the study of science harder than other subjects in school? Items asking pupils to rate their perception of difficulty of biology, chemistry and physics in school were analysed alongside positivity scores to see if there was a correlation.

The findings for biology gave a Pearson Product-Moment Correlation Coefficient ($r = 0.092$, $p= 0.390$, 2 tailed test), which indicated no correlation between the perception of difficulty of biology and the pupils positivity to science in general. A Spearman’s Rho Rank Correlation test result (Rho = 0.082, $p = 0.442$, two tailed test) also indicated that even if the data was ranked there still was no relationship between how positive the pupils were towards school science and their perception of difficulty of the biology that they studied.

However, the findings for chemistry did show a correlation. The Pearson Product-Moment Correlation Coefficient ($r = 0.300$, $p= 0.004$, 2 tailed test) indicated that there was significant ($p < 0.05$) agreement between the pupils' perception of difficulty of chemistry and their positivity to schools science in general. A Spearman's Rho Rank Correlation test result (Rho = 0.251, p = 0.017, two tailed test) also indicated that even if the data was treated as non-parametric there was a greater than 95% chance that this correlation had not occurred by chance.

When the results for physics were analysed a similar correlation was found, Pearson Product-Moment Correlation Coefficient ($r = 0.285$, $p= 0.007$, 2 tailed test) and Spearman's Rho Rank Correlation test (Rho = 0.228, p = 0.031, two tailed test). This shows a strong relationship ($p < 0.05$) between the pupils perception of difficulty of physics and their positivity of attitude to school science overall.

The question arising from these results is why are physics and chemistry perceived as more difficult than biology. Is this to do with the intrinsic nature of biological sciences compared to physical sciences or is it to do with the way in which the physical sciences are delivered in school, which is making pupils feel less positive towards school science? If the latter is the case then could changing the way in which these subjects are presented in school change attitudes to school science?

If the pupils' perception of difficulty of science subjects does influence their overall attitude to school science, is this any different for those pupils identified as gifted in science? It might be expected that if these pupils find science easier than others they should not have their attitudes to science negatively influenced by finding the subjects difficult. In order to try to determine this, a subset of the previous data was analysed for those pupils appearing on the school's gifted register as having ability in the scientific domain.

This data was subjected to ANOVA (analysis of variance) testing. ANOVA tests can be used to analyse situations in which there are several independent variables. ANOVA gives information regarding how these independent variables interact with each other and what effects these interactions have on the dependent variable (positivity). An ANOVA test produces an F-ratio, which is a measure of the ratio of the variation explained by the model to the variation explained by unsystematic factors. It can be thought of as the ratio of the experimental effect to the individual differences in performance. Any value less than one will represent a non-significant event since individual differences will be having a greater effect than the experimental effect.

When this analysis was run for chemistry $F(4,90) = 1.007$, $p = 0.408$, indicating no strong relationship between perception of difficulty and positivity to science. The Pearson Product-Moment Correlation Coefficient ($r = -0.072$, $p = 0.489$, 2 tailed test) confirmed this. Similarly for physics $F(2,91) = 0.865$, $p = 0.691$ and the Pearson Product-Moment Correlation Coefficient ($r = 0.029$, $p = 0.781$, 2 tailed test), both indicating a high probability of no correlation between perception of difficulty and positivity to science. Thus it would seem that for those identified as gifted in science positivity to science is not influenced by a perception that chemistry and physics are difficult.

However, when the data for biology was analysed the ANOVA results $F(3,90) = 2.037$, $p = 0.096$ do indicate a relationship between positivity towards science and the perception of difficulty for gifted pupils. This correlation was confirmed as probably true ($p < 0.05$) by a Product-Moment Correlation Coefficient ($r = 0.280$, $p = 0.006$, 2 tailed test). This may mean that the perception amongst gifted pupils that biology is the easier of the sciences does produce greater positivity.

The evidence suggests that those pupils who perceive science, particularly physical sciences, as difficult are less positive than those who find science easy. The majority of pupils are finding school biology much easier than the physical sciences. So why are the physical sciences perceived to be so much more difficult than biological sciences?

6.3.2.6 Teacher Specialism

Could it be that the subject specialism of the teacher and possibly their confidence in subject delivery is influential on the pupils' perception of subject difficulty and consequently their attitude to school science. Data was collected regarding the science subject specialisms for each class teacher in the survey and tests of significance performed on this data, Pearson Product-Moment Correlation Coefficient ($r = 0.017$, $p = 0.872$, 2 tailed test) and Spearman's Rho Rank Correlation test ($Rho = 0.033$, $p =$

0.752, two tailed test). Neither of these tests revealed any probability of significant correlation between pupil positivity and the teacher's subject specialism. Also the data indicated that the teacher's specialism makes little difference to the pupils' perception of difficulty of the subject discipline at key stage 3. Thus it would appear that the subject specialism of the teacher is not a factor influencing the positivity of the pupils' attitudes to science education and we need to look elsewhere for more influential factors.

6.3.2.7 Parental Background in Science

Another avenue explored was whether it may be the scientific background of the parents which has an influence on the positivity of the pupils towards science. Data was gathered concerning whether the pupil's parents had occupations which were scientifically orientated. When this data was subject to significance testing, Pearson Product-Moment Correlation Coefficient ($r = -0.116$, $p= 0.273$, 2 tailed test), Spearman's Rho Rank Correlation test (Rho = -0.077, $p = 0.471$, two tailed test) and ANOVA $F = (2,89) = 1.606$, $p=0.207$ it was found that there was little probability of significant correlation between the positivity of pupils and whether or not their parents had scientific occupations.

6.3.2.8 Scientific Literature in the Home

Another background factor that may possibly have an impact on pupil attitudes to science was concerning scientific literature in the home. Pupils were asked how many science books they had at home and this was analysed against the variable of the pupil's positivity to science. The results of this analysis are highly significant, Pearson Product-Moment Correlation Coefficient ($r = 0.311$, $p= 0.003$, 2 tailed test) and Spearman's Rho Rank Correlation test (Rho = 0.273, $p = 0.009$, two tailed test) indicating that more positive pupils have more science books at home. However, whilst this is an interesting finding the direction of the relationship i.e. whether the number of books influences positivity or whether positivity influences the number of books, cannot be determined from this.

6.3.2.9 Self Esteem

It may be expected that a pupil's positivity towards any subject in school would be influenced by how they rank themselves against their classmates in that subject. This perception of rank is related to the self esteem of the pupil. Pupils in the survey were asked to rank themselves against the rest of the group in their perception of how 'good' they were at science and this data was analysed for correlation with the pupil's science positivity scores. The results of this analysis showed, somewhat surprisingly, that there was no relationship between the pupil's self esteem and their positivity to the subject, Pearson Product-Moment Correlation Coefficient ($r = -0.032$, $p = 0.763$, 2 tailed test) and Spearman's Rho Rank Correlation test ($Rho = -0.053$, $p = 0.624$, two tailed test).

6.3.2.10 Science for Gifted Pupils

Since this result was unexpected it was decided to analyse the subset of pupils identified as gifted in science, and thus acknowledged as being at the top of the rank order, for whether this identification had resulted in higher positivity towards school science. An ANOVA test was run and again it was found that the results ($F(2,32) = 0.097$, $p = 0.907$) indicated that being identified as gifted in science did not necessarily mean that pupils were more positive about science in school. This does not necessarily mean that these pupils were not more positive about science per se but that they did not seem to rate school science highly. Is this an indication that the delivery of science education in school is failing to engage and motivate those very pupils that should be encouraged to pursue the study of science to higher levels?

When an analysis was run for the subset of pupils who were on the gifted register for science it was found that there was a good correlation ($Rho = 0.393$, $p < 0.001$) between appearance on this register and having high aspirations for continuation with science beyond 16. This would seem to indicate that the aspiration to continue with science occurs despite poor positivity to school science. So why are even the highest ability pupils disenchanted by their experience of school science?

6.3.2.11 Teaching and Learning Methodologies

Perhaps a significant influential factor may be the teaching and learning methodologies used by teachers in the science classroom. Pupils were asked about their preferred teaching and learning methodologies and also about which methodologies they particularly disliked

Most pupils across all sets cited hands on activities and spectacular demonstrations as being their favourite science lessons with revision lessons and copying being least favourite activities. Some pupils mentioned lesson where they felt they had “learned something new”(School J, pupil set 2) as being the best, but should this not be happening in every lesson? Pupils also mentioned lessons in which they had to design posters or pamphlets as being enjoyable because they felt that they had created something within the lesson. Many pupils cited occasions when they had been taken outside of the classroom as their favourite lesson, “…it was helpful to apply the theory of science to things that we ignore every day in our school”(School J, pupil set 1). Pupils from lower sets cited lessons that were “easy to understand” (School T pupil set 4) as being their best, which seems to indicate that these are the exception rather than the rule.

Were the preferred teaching and learning methodologies any different for pupils identified as gifted in science as opposed to the rest of the school population? Pupils on the gifted register cited enhancement days as being favourite science activities “ doing a hands on activity for the whole lesson without being stopped and lectured by our teacher. I felt independent” (School T pupil, identified as scientifically gifted). The idea of autonomous working was quite frequently cited as a favourite lesson “It was good because we were split up into groups, given a task and left to it” (School J, pupil, identified as scientifically gifted) Work in which creative activity featured was also popular “Best lesson was a presentation to the class about solar power. I made a song. We were given free time to do the research and treated independently” (School S, pupil identified as generically able) Other favourite lessons amongst the gifted pupils were those in which they were asked to “design something and test it to see if it worked”(School T, pupil identified as scientifically gifted) again indicating that creative exercises are found to be fulfilling for pupils. Work which pupils found enjoyable was found to be more memorable to them “ I remembered the information because I enjoyed it” (School S, pupil identified as scientifically gifted). Varied contexts for work were also mentioned as being more interesting than the usual text book approach with empirical research being valued more highly than replicated practical work.

How do these pupil responses relate to the types of classroom activities cited by science teachers as being those most frequently used in lessons? A survey of teachers' perceptions of those activities they commonly used in the classroom was conducted.

	School J	School S	School T	Total
demonstrations	4	5	7	16
investigations	3	5	7	15
problem solving exercises	2	5	7	14
instructed practical work	4	4	5	13
filling in worksheets	4	5	3	12
videos	4	4	4	12
copying from board or book	3	4	3	10
quizzes/games	3	4	3	10
discussions/debates	1	5	4	10
use of CD rom or websites	1	3	4	8
internet research	2	1	4	7
tests	2	1	4	7
pupil presentations	0	2	4	6
self assessments	0	2	3	5
data logging	2	0	3	5
study skills enhancement	0	2	1	3
use of interactive whiteboards	0	1	2	3
dictation	0	1	0	1
pupil interviews	0	1	0	1
field work	0	0	1	1

Table 6.1 Frequency of utilised classroom activities cited by teachers across 3 pilot schools

Teachers cited demonstrations and investigations as being the two most frequently used classroom activities but the interpretation of 'investigation' was the type of exercise undergone for science coursework, which is often heavily prescribed and gives little room for pupil decision making. The most commonly used teaching and learning methodologies were highly didactic whereby much of the control for the classroom activity is in the hands of the teacher rather than the pupils. Less than half of the teachers surveyed used pupil presentation or pupil self assessment and very few highlighted the enhancement of pupil study skills, leading to the inference that much of the activity within the science classroom remains teacher centred and teacher controlled.

Perhaps the reason for the use of limited classroom methodologies lay in a lack of training opportunities provided by schools. The question was put to the teachers of how much training in diverse teaching and learning methodology they had received. This was then compared to the number of pupil centred or teacher centred methodologies they cited using in the classroom.

Teacher	T&L courses attended	Diversity of methodologies used in classroom	
		Teacher centred	Pupil centred
A (School T)	1	9	3
B (School T)	1	5	0
C (School T)	0	15	2
D (School T)	3+	11	3
E (School T)	0	9	2
F (School J)	1		
G (School J)	1	10	1
H (School J)	1	6	1
I (School J)	1	7	1
J (School J)	0	10	0
K (School S)	3	10	3
L (School S)	2	8	2
M (School S)	3	9	3
N (School S)	3	8	3
O (School S)	3	8	3

Table 6.2 Frequency of teacher-centred and pupil-centred classroom activities utilised as cited by teachers alongside number of in-service training courses attended.

There is a great variability in the number of training courses attended by different teachers but there is little evidence that attendance on these courses translates into a greater diversity of teaching and learning strategies in the classroom. However, how reliable the teachers' own reporting of the teaching and learning activities used is must be questioned, especially as this information could not be verified by observational analysis. Also no information was obtained regarding the frequency of use of each of the methodologies outlined and therefore a single pupil presentation in a year would register equally with 50 uses of structured worksheets. This degree of detail cannot be revealed by questionnaire analysis and a different research methodology is needed to access this type of information.

6.3.2.12 Summary

- The data set derived from the questionnaires used in the pilot study is a robust data set, which conforms to a normal distribution and can therefore be subjected to conventional statistical analysis.
    - The reliability of the data is high showing that the questionnaire had good internal consistency
    - The validity of the questionnaire has been established by comparison with previous research using the analysis of Misiti, Shrigley and Hanson, (1991) with the originating questionnaire.
- In all schools surveyed the majority of pupils held negative attitudes towards school science.
- Positivity towards school science shows a probable dependency on gender with boys being more positive than girls.

- There is a strong correlation between the positivity of pupils to school science and their aspirations to continue with the study of science beyond 16 or to work in a science related job
- Pupil positivity towards school science is influenced negatively by their perception of physics and chemistry as being difficult subjects but this is not the case for pupils identified as gifted in science. Biology is perceived as less difficult and pupils are not put off school science by biology. Gifted pupils, who find biology easy, are more positive about school science.
- At Key Stage 3 the science subject specialism of the teacher does not influence the attitude of the pupils towards school science
- The scientific background of parents was also found to have little influence on the pupil attitudes to school science.
- There was a strong correlation between pupil positivity to science and the number of science books to be found in the home.
- There was found to be no relationship between pupil positivity to science and their self esteem as judged by self ranking amongst peers.
- Being identified as scientifically gifted does not make pupils more positive about school science but it does relate to higher aspiration to continue with science post 16.
- Most pupils prefer 'hands on' activities and spectacular demonstrations in science lessons. Revision and copying were the least favoured activities.
- Gifted pupils showed a strong preference for autonomous activity, wherein they can demonstrate independence and creativity.
- There is a mismatch between the activities that teachers cite as most commonly used and those most enjoyed by pupils.

6.3.2.13 Multiple Regression

It can be seen from the summary that the factors which may be influential upon pupils' attitudes to science education in schools, are many and varied. However, the dominance of each factor upon the overall positivity of pupils is more difficult to determine and indeed there may be other factors outside the scope of this pilot study which are also influential upon pupil positivity to school science. Multiple regression analysis attempts to represent what proportion of the outcome variable is related to a variety of input variables and to what extent the model as a whole can account for the observed outcome.

SPSS analysis produces a multiple correlation coefficient R, which represents the degree of correlation between the predicted and observed values of an outcome. If R=1 the model perfectly predicts the observed data. The value of R^2 is the amount of variation in the outcome variable that is accounted for by the model. In this case the value of $R^2 = 0.397$, indicating that 40% of the variance in pupil positivity can be attributed to the factors included in the model. However, if we wish to know which individual factors appear to be most statistically dominant then a stepwise analysis of each factor in turn must be carried out. When this is done a value β (between 0 and 1) is given to each input parameter independently, which indicates its relative dominance in relation to the outcome (pupil positivity). In this analysis the most dominant factor ($\beta = 0.414$) was found to be pupil perception of the difficulty of physics, secondly pupil aspiration to continue with science ($\beta = 0.403$), thirdly ($\beta = 0.254$) was gender and fourthly ($\beta = 0.208$) was the number of science books in the home. It must be borne in mind however, that the direction of the relationship between these parameters is not indicated and whilst one might assume that difficult physics negatively affects pupil attitudes to science and pupil positivity positively influences aspiration in science, these are only assumptions which need to be tested by further research.

6.4 Implications of the pilot study for further research

The analysis of questionnaire data by the projection of mathematical models gives rise to many more questions than answers. Even if a relationship is established, the quantitative methodology used cannot provide the context rich information required for the full interpretation of what is actually underlying that relationship. If we wish to probe further into causality, we need a different kind of methodology.

Whilst the pilot phase of the project had been successful in its objectives of establishing the attitudes to science education of pupils and their teachers, investigating the experiences of teachers regarding in-service training in teaching and learning methodology and surveying the learning and teaching activities utilised in science education it had also raised many questions regarding how this status quo had come about and what could be done at school level to improve it. If all the questions raised by the pilot study were to be addressed it would require a large team of researchers and a equally large funding budget. Thus in the interests of manageability it was decided to focus on just a few of the more interesting findings. A deciding factor in choosing the direction for the second phase of the research was the growing awareness of the gap between theoretical research and classroom practice. The need was established for the second phase of the research to adopt a more qualitative methodology, involving closer observation and possible experimental research interventions.

In the interests of closing the gap between rhetoric and reality the second phase of the research was designed as an action research project carried out in a school context and designed to address three key considerations. These were:

1. How might the adoption of teaching and learning methodologies that enable able pupils to have greater autonomy in the science classroom impact upon their attitudes towards and aspirations regarding science education?
2. Could an action research methodology prove effective in achieving changes in teachers' practice regarding teaching and learning methodology in the classroom?
3. How might teachers best be supported in engaging with the processes of action research and achieving professional development through these means?

6.5 Conclusion

The findings of this research are consistent with that done by Pomerantz and Pomerantz (2002) into the reasons why able children underachieve. They identified a number of classroom activities which 'switch off' able pupils. These include excessive copying, sitting passively, a lack of relevance and variety, dull lecturing and poorly planned lessons. Their research concluded that hands-on practice, creative activity, adult orientated work, mentoring, multi-media work and a study skills emphasis improved motivation. Evidence that some classroom activities are 'switching off' pupils is further provided by the student review of the science curriculum carried out in 2002 by the London Science Museum (Murray and Reiss, 2003). Results from this review indicated that taking notes, reading text books and copying were classroom activities least enjoyed by pupils. Extra curricular science, experiments, investigations, discussions and debates were the activities most enjoyed.

Much of the science studied in schools is 'repeating what other generations have done'. Experimental work tends towards the verification of previously held knowledge rather than the inculcation of genuinely investigative approaches to learning and research in science. The view of science perceived by pupils in school is very different to the view of science as perceived by scientific researchers. This school science perspective is what Renzulli (1986) refers to as 'schoolhouse' science. Poncini and Poncini (2000) also describe 'school science' as distinguishably different from 'real science'. Geake, Cameron, Clements & Phillipson (1996) explain that school science is not like real science because they serve different agendas. Whereas real science delves into the unknown and is time consuming, school science is often contrived and must be quick. A survey carried out by Galton and Fogelman (1998) reported that in the opinion of teachers the content overload of the programmes of study of the national curriculum and need for direct teaching methods to achieve satisfactory levels of attainment in statutory tests left little time to follow children's enthusiasms for investigation and discussion.

Improving the attitudes to science education in schools requires a culture change. How such a change may be effected when teachers are already hard pressed to keep pace with the imposed accountability agenda and new government initiatives is a question which can only be answered at chalkface level. However, in the interests of motivating the best and brightest pupils to continue with science it is a question, which urgently needs an answer. Thus it was decided that the second phase of the research project should return to chalkface level by means of a participatory action research project in a single school over the course of the following academic year.

Chapter 7

Phase 2: The Action Research Study

7.1 Objectives of the action research study

In the light of the findings from the pilot study it now became necessary to re-define the focus of the research. The data accumulated from the pilot study indicated that pupil attitudes to science education in schools were poor and aspirations low. Possible causal indicators may be connected with the way that science was delivered in schools. Teacher training in teaching science to able pupils was at best patchy and not effectively disseminated. Much of the teaching was didactic in nature and the range of classroom teaching methodology was, in many instances, narrow. Able pupils had indicated a desire for more autonomous learning and teaching activities. Why were teachers not responding by providing more practical investigations and pupil based learning activities? What were the impediments to improvement in the science classroom?

In the interests of probing for greater understanding of the situation the action research project began with three objectives in mind. These were:

1. To investigate whether the adoption of teaching and learning methodologies that enable able pupils to have greater autonomy in the science classroom would impact upon their attitudes and aspirations regarding the study of science.
2. To find out whether the method of action research could be used as a means to improve the teaching and learning methodology of science teachers.
3. To gain insights into how teachers might best be supported in engaging with action research as a means to facilitate their continuing professional development

7.2 The nature of action research

Before beginning to design an action research project it is firstly necessary to define what is meant by 'action research' in this context. The origins of action research are founded in the work of the psychologist Kurt Lewin in the 1940s (Taylor in Banister et al, 1994; Berge and Ve, 2000). Lewin (1948) describes such research as involving ‘a spiral of cycles of self-reflection’. However, such reflexivity is intended to be productive in terms of action as an agent for change. Lewin was of the opinion that research producing nothing more than text was inadequate and that the primary aim of any action research project is that it should not merely understand and interpret the situation but that it should change it. Action research may be used within any context wherein a problem is identified and solutions are sought. It can be undertaken by individual teachers, groups of teachers or a collaboration of researcher and teachers working in a sustained relationship (Holly and Whitehead, 1986).

Many definitions of action research focus on specific areas within which it can be applied. Many of the contexts involve socialist, feminist or racist issues. Taylor in Bannister et al. (1994) defines action research as,

> “ A way of trying out changes and seeing what happens….motivated by the philosophy of social change such as feminism, anti-racism or socialism.” (p.108)

Hopkins (1985) and Ebbutt (1985) are both of the view that action research is a combination of ‘action’ and ‘research’ in which a personalised interpretation of a situation is made with the intention of understanding the issues and improving the situation by reforming practice. Cohen et al. (2003) define it as

> “ A small-scale intervention in the functioning of the real world and the close examination of the effects of such an intervention.” (p.186)

Carr and Kemmis (1986) make the case that action research is a form of ‘critical self-reflective enquiry’ by participants, carried out with a view to improving practice. However, perhaps the most all-encompassing definition of action research is that given by Kemmis and McTaggart, (1992),

> “ Action research is a form of *collective* self-reflective inquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices, and the situations in which these practices are carried out…. The approach is only action research when it is *collaborative*, though it is important to realize that the action research of the group is achieved through the *critically examined action* of individual group members.” (p.5)

Instances of action research have been documented in a number of areas including teaching and learning strategies, evaluation of practice, assessment of attitudes and values, continuing professional development of teachers, behaviour management strategies and effectiveness of administration procedures. Corey (1953) emphasises that the processes of action research involve practitioners in examining a situation with regard to making an evaluation and improving decision making and practice. Kemmis and McTaggart (1992) break the process down into four actions

- Planning
- Action
- Observation
- Reflection

They further suggest that

> "Action research is concerned equally with changing *individuals*, on the one hand, and, on the other the *culture* of the groups, institutions and societies to which they belong." (p.16)

Thus action research, to some extent, is designed to overcome the failure of academic research to impact on practice (Somekh, 1995). Stenhouse (1979) goes further in suggesting that action research should not only impact on practice but should also contribute to a theory of education, which is accessible to others and encourages reflexivity. The implication is that action research is both a diagnostic and a formative process and that the practitioner has the dual role of both the subject and the object of the research (Kemmis, 2001).

Noffke and Zeichner (1987) argue that one of the principle merits of action research involving teachers is the benefit that it brings to their professional development. This view is reinforced by Zuber-Skerritt (1996), who maintains that educational action research helps to make teachers critical, accountable, self-evaluating and reflective. However, this requires that participants need to be confident in their abilities, accepting of the need for improvement and willing to be self critical and critical of many widely accepted processes in education (Winter, 1996). Hargreaves (1996) describes the failure of educational research to address the needs of those working in education and suggests that teachers make little or no use of educational research to support practice. However, Hammersley (2002) explains that this implies that research can establish causal relationships generalisable to all schools and that very often this is not the case. Whilst both of these statements bear some foundation they make no distinction regarding the types of research carried out. Action research carried out within a localised setting is more likely to encourage reflection among the participants than research carried out remote to their own setting.

Weiskopf and Laske (1996) regard the epistemological basis of action research as a derivative of critical theory and found its roots in 'critical social science'. Morrison (1995) regards action research as similar to the 'reflection-in-action' model described by Schon (1987) involving a cycle of understanding and interpreting social contexts with a view to their improvement but Elliott (1991) regards this as too narrow a view, since external influences are also constantly acting to change the situation as well as the reflective process in action.

Other researchers (Grundy, 1987; Habermas, 1976; Argyris, 1990) identify a political element to action research and make the case that it can be used to emancipate, empower and challenge given value systems. This agrees with the viewpoint of Lewin (1948) that action research can lead to the furtherance of democracy. Thus critical theorists regard action research as part of a broader agenda for changing society whereas reflective practitioners regard it as an agent for the improvement of professional practice within a local setting. However, it has to be recognised that the climate for change within such a local setting is more likely to be conducive to the action research project if the local practitioners have already begun to develop a critical view about the nature and consequences of their practice (Reason and Bradbury, 2001, pp.1 - 14). In the context of the research undertaken in this project the research is operationalised within a single science department and any claims regarding its influence upon wider educational or social practice would be inappropriate.

McNiff (1992) identifies seven key criteria defining action research. Namely that

- It is practitioner generated
- It is workplace orientated

- It seeks to improve something
- It starts from a particular situation
- It adopts a flexible trial and error approach
- It accepts that there are no final answers
- It aims to validate any claims it makes by a rigorous justification process.

This viewpoint of action research as a form of problem solving is often regarded as successful when its outcomes match its aspirations (Kemmis, 2001). However, such an approach is not without its limitations. Hammersley and Atkinson (1995) emphasise one such limitation as being the lack of generalisability of the research findings to other contexts. This may not necessarily be problematic since for much ethnographic research generalisation may not be a primary concern, especially if the aim is to see to what extent attitudes may be changed. However, it should be recognised that since each situation is unique, there will always be an element of uncertainty regarding the accurate interpretation of incoming information. Also as the practitioners react to the influences of the research it will change from the original situation to a new situation and there will evolve a dynamic and fluid feedback loop, illustrating the cyclic nature of the work. It must also be borne in mind that the beliefs and value systems of the researcher or instigator of the research will inform the research and that as the research progresses these in turn will be influenced by the reflections of the research group. Thus the research involves a culture change for all participants, including the researcher, and can be regarded as a developmental process for all involved. Therefore other items may be added to the seven key criteria described by McNiff (1992) including consideration that action research

- Reflects the beliefs and value systems of all participants
- Voices the concerns and thoughts of all participants
- Involves decisions taken by the consensus of all participants
- Empowers all participants
- Considers the ethics of its actions for all participants
- Involves metacognition on the part of all practitioners, including the researcher
- May not be generalisable to other situations

The issues of lack of generalisability and contextual limitations were discussed by Altrichter et al (1993). The view put forward was that the action research paradigm of ‘reflective rationality’, wherein it is believed that the specific solutions to problems are best developed inside the context, by practitioners within that context and that such solutions may then be tested by other practitioners in other organisations, contrasts with the paradigm of ‘technical rationality’, which holds that general solutions to problems can be developed outside the context and then applied to a large number of different organisations. Since many of the recent changes in education have been those imposed by government policy it was the stance of the researcher that such a paradigm of ‘technical rationality’ may have been causal in the creation of some of the problems under examination. Therefore the adoption of the paradigm of ‘reflective rationality’ would seem to be an entirely justified alternative in the interests of pursuing the solutions to some of these problems.

If such a paradigm is to be adopted it is important that all involved arrive at a common understanding of what is meant by ‘reflective practice’. Bright (1995a) maintains that the main importance of reflective practice is that it questions the quality of the information that is used to plan professional action. This assumes that better information will then facilitate the improvement of professional competence. However, it is debatable whether the acquisition of such knowledge alone will achieve these professional objectives. If this were the case then practice would be equally influenced by the dissemination of academic research findings. The indications are that it is not just the acquisition of knowledge that is important but also the engagement of the practitioner with that knowledge and the change in perceptions, attitudes and actions that are brought about by a meaningful engagement.

The view of many teachers is that ‘we all reflect anyway’. Whilst it is certainly the case that many teachers consider their actions and the possible alternatives in terms of the benefits to their pupils, this may not fall into the category of ‘reflective practice’. Bright (1995a) makes the case that the real issue is between efficient and inefficient reflection. Efficient reflection is ‘open’ in that it involves genuine criticism and provides authentic and accurate information regarding the reasons for and consequences of action choices. Inefficient reflection is ‘closed’ and is motivated by a defensive justification of an action. It fails to critically evaluate the action and occurs only when the individual seeks to reinforce the rightness of their action (Argyris and Schon, 1974). As a consequence of inefficient reflection teachers may remain closed to the existence of alternative ways of interpreting the action and therefore the design of future action will be less effective. Teachers may be resistant to the idea of engaging in reflective practice due to the implication that it has a relationship to professional competence (Bright, 1995a). However, this defensive reaction misses the point, as the aim of reflective practice is to raise competency relative to that which already exists. It is not simply a question of transforming incompetency. Burton and Bartlett (2005) maintain that,

> "Practitioner enquiry is an extremely effective means of pursuing and supporting this professional development." (p. 11)

Raising awareness of one's own practice may become uncomfortable and for some difficult to achieve. Generating a meaningful and honest discourse on one's own actions and the actions of other participants requires sensitive handling if ill feeling is to be avoided. An awareness of the problematic nature of critical reflection can assist in meeting the challenge but the difficulties involved must not be under estimated.

Another important consideration in action research design is that of ensuring quality assurance. Errors may include ignoring or devaluing relevant information, making unjustified assumptions, illogical reasoning and forming untested hypotheses. This can lead to flaws in information analysis and ineffective planning of new practice. Thus practitioners must accept some degree of tolerance of possible ambiguities and adopt a reflective attitude to the possibility of errors in the research, whilst at the same time making every effort to achieve robustness in the epistemic dimensions of the research. In evaluating the quality of educational action research there are two further dimensions in which its contribution to practice and its usefulness to practitioners may be assessed (Furlong and Ocancea, 2005). The first of these is the 'technological dimension' and lies in the extent to which it provides instrumental evidence for improved action. The second is the 'capacity building' value for practitioners and lies in its contribution to personal growth, increased receptiveness, reflexivity and the development of tacit knowledge and the critical dimensions of practice.

These two dimensions imply that action research is a constructivist activity. The core of constructivism according to Taylor (1993), is

> " A view of human knowledge as a process of personal cognitive construction, or invention, undertaken by the individual who is trying, for whatever purpose, to make sense of her social or natural environment." (p. 268)

Lincoln (2001) makes the case that action research and constructivism share some fundamental assumptions. These include, focussing equally on tangible and socially constructed realities, focussing on the redistribution of power by information sharing and creating a climate for action on the findings of the enquiry. Further to this, Lincoln adds that both paradigms involve a political dimension designed to influence powerful infrastructures.

> "In some respects both action research and constructivist enquiry are focussed upon utilization, especially utilization of research results by those bearing the brunt of highest impact, and they are also focussed upon ideological ends." (p.126)

Thus action research and constructivism share similar properties in that they provoke action, seek social justice, develop a new participatory research relationship, present a different perspective to the academic community, develop new ethical ground rules and establish an epistemology for mutual learning (Guba and Lincoln, 1989). However, action research and constructivist enquiry are not the same thing. In action research the primary aim lies in the stimulation of a group towards the reconstruction of a reality. In constructivist enquiry the primary aim may merely be the highlighting of the different existing constructions of that social reality and any reconstructing activity may be secondary (Lincoln, 2001). Another consideration is that in action research all participants share the same values and goals but in constructivist enquiry this may not be the case. Lincoln (1999) also identifies that action research can by necessity often be unclear in its epistemological and methodological foci because of the need for these to emerge from participant reflection, whereas constructivist enquiry has far clearer epistemological and methodological foci because it is principally concerned with the creation of new knowledge rather than social change. Thus action research requires a more egalitarian stance from the researcher, who must lay aside academic status and work on an equal footing with other participants. Also action research requires engagement as a prolonged activity since any social change will take time to achieve. Thus academics involved in action research may need to mediate its demands with those of their research institution and this may be difficult to manage.

Research which adopts an interventionist strategy aimed towards both knowledge creation and individual and organisational development has been described by Argyris et al (1985) as ‘action science’. This is distinct from ‘positivist science’, which requires completeness, precision, control, objectivity and a search for causality. Action science is described as having four key features (Friedman, 2001).

- It seeks to create communities of inquiry within communities of practice. It helps practitioners discover the tacit choices that they make regarding their perceptions of reality. By publicly reflecting upon these choices they are made explicit and more open to change.
- It seeks to build theories in practice. Theories of reality are continually constructed and tested through action.
- It combines interpretation with rigorous testing. In this respect criticisms that action research may have less validity than positivist scientific research are addressed. When both practitioners and researchers make explicit their interpretations of processes then the research is opened up to intersubjective testing. Espoused theories may be observed to be different to theories in use (Reason and Bradbury, 2001) and by critical observation the espoused theories may be disconfirmed. This is consistent with Popper’s (1968) concept of ‘falsifiability’. Theories in practice cannot be proven but the argument can be maintained as long as actions do not disconfirm it. This can often go against the natural desire to ‘prove oneself right’ as it is perhaps more important to examine where one is wrong.
- It creates an alternative to the status quo. It is aimed at enabling practitioners to achieve change through knowledge production.

Thus action research enables teachers to reflect on their practice by creating a dialogue with fellow professionals, question their implicit assumptions about how they perceive their roles in the classroom, test out new theories emerging from such reflection and dialogue in action and develop their professional skills. This model of using action research as a tool for continuing professional development is acknowledged by Taber (2007d) as an effective one.

> "Indeed, there may even be a case for suggesting that we can do more to change teachers' classroom practice through a co-ordinated programme of small-scale action research." (p.214)

The empowerment of teachers brought about by action research projects, which help them to adopt and apply new methodologies, can do much to develop their professional practice and in this thesis an action research approach is being used as a basis for such professional development activity.

7.3 Methodology for the action research project

Whilst many researchers would maintain that the objectives for an action research project should emerge from the reflections of the participants as the research develops, the evidence from the pilot served to establish a starting point. Firstly it was necessary to find a research site, which would allow access to the science classroom for the purpose of observing those classroom activities, commonly used with the higher ability sets. Secondly it would also be essential to establish an ethos of participant collaboration between the researcher and the school science department. To this end, there would be a need for regular meetings to discuss the research in progress and make decisions about next steps. A genuine desire on the part of the science staff for reflective practice and professional development was important, as without this the research could easily lose momentum. Thirdly the research should fit within the paradigm of participant action research, with the intention of producing change for the better. This would at some point mean using interventionist strategies. In addition decisions would need to be taken regarding how the outcome of any interventionist strategies would be assessed. As with any small scale research study, a consideration of how generalisable the findings would be to a larger field would also need to be considered.

During the year in which the pilot study had been carried out, a number of informal conversations had taken place with Heads of Science Departments, as to the underlying reasons behind some of the findings. The choice of the field of research for the action research project arose from one such conversation. The school selected was an age 11 to 16, suburban comprehensive, which had no special provision for able children, within the school curriculum. The school did run an out of hours 'Discovery Club' for the more able but this was not specifically in science. The Head of Science described the department as 'good but coasting' and was enthusiastic about instigating an action research project to promote improved practice.

The first obstacle to be overcome was that of access. Permission was sought from the Head of School and the Governors for the research to take place within the school. There were natural concerns over the burden that the research would impose upon the staff and the pupils and reassurances were sought and given, that all reasonable precautions would be taken to limit this to a minimum. There were also other ethical concerns over the role played by the school in the reporting of the research and assurances were, again, given that the identity of the school would be kept confidential, unless the permission of the Head was given for the school to be named and, indeed, acknowledged in future publication. (BERA, 2004)

The second question to be considered was one posed by Mason (1996), of how to go about developing relationships in the setting? The problem of acceptance is an extremely important consideration. It is a problem, which is succinctly described by Cohen et al (2003),

> "Since the researcher's potential for intrusion and perhaps disruption is considerable, amicable relations with the class teacher in particular should be fostered as expeditiously as possible." (p.235)

It was decided, in the interests of fostering good working relationships that science departmental meetings would form the basis of a 'dialogue group' for the research. The topics for the dialogue group may be supplied by the researcher or by the teachers themselves. It is through both the interaction with the researcher and the interactions between each other that elements of research data begin to emerge (Cohen et al, 2003). One of the main advantages of the dialogue group is that by open discussion of the issues under examination any bias on the part of the researcher may be exposed and it's effects minimised. Another feature of the dialogue group is that the researcher cannot anticipate the outcome. Teacher responses to the observations and actions of the researcher are unpredictable and thus the direction of the research would need to remain flexible and reactive to the views expressed within the dialogue groups.

Over the course of the research period the science staff meetings did evolve into a reflective dialogue group, within which the teachers interacted with each other, rather than with the researcher. This was a useful development in that it was the views of the participants which began to predominate. Indeed the ‘ownership’ of the research task belonged to all concerned rather than just the researcher and the pattern of the research methodology became more closely aligned with that of participant action research. One disadvantage of dialogue groups is that the discourse taking place within them may be dominated by one or more individuals with strongly held views and some participants might not feel able to voice their own contrary views, especially if they are in conflict with those in senior positions. One way of getting around this was to again employ the research method of survey.

Since the research would involve classroom intervention it was decided to survey pupils both pre and post intervention using the same questionnaire as had been used in the pilot study. In this way a judgement could be made as to what extent the views of the pupils in this school mirrored those of the pupils in the pilot study, prior to any intervention taking place and also if those views had changed after the intervention had taken place. It was also decided that if the views of the teachers were to be represented, as honestly as possible a survey would be one means by which those views may be elucidated. Although the data analysis of questionnaires would involve quantitative methods, as in the pilot study, it was felt that in the interests of both objectivity and consistency such analysis would form part of the overall analysis of the action research data. However, as already discussed in the pilot study a questionnaire cannot access the mindset behind the response given and, in an attempt to access this, interviews were held with both teachers and pupils at appropriate points throughout the research period.

Interviewing is a means by which a researcher can find out what the situation looks like from other points of view (Elliott, 1991). One to one interviews give the opportunity to probe more deeply, verify meaning and volunteer further perspectives on a question. However, one to one interviews have the disadvantage that the researcher's body language, intonation and question phrasing may influence the respondent. Complex lengthy questions and leading questions are to be avoided and the researcher must be aware of respondent sensitivities regarding questions, which may hold a personal threat or be uncomfortable for them to discuss. In this regard the ordering of questions is just as important in an interview as it is in a questionnaire. Respondents need to be put at their ease at the beginning of the interview process by the use of simple impersonal questions until the rapport has built between the interviewer and the respondent.

Interviewing children on a one to one basis can hold its own dangers as the researcher may leave himself open to litigation if the interview is improperly carried out. The ethical considerations of informed consent and respondent anonymity must also be addressed. All pupils were informed of the reasons for all of the research instruments used and their consent sought. Additionally the consent of the Head teacher was sought and granted 'in loco parentis'. It was decided that any interviews carried out with pupils should therefore be group interviews with structured questions, whereas interviews with teachers could be more informal and open-ended.

Cohen et al (2003) describe four categories of interview as informal conversational, guided approach, standardised open ended and closed quantitative. Within this framework the interviews carried out with groups of pupils would fall into the standardised open-ended category where the exact wording and sequence of questions was decided in advance and interviews with teachers would be informal and conversational. Independent observers recorded interviews with pupils, whereas interviews with teachers were recorded by contemporaneous note taking by the researcher. The notes from the interviews were then analysed and field coded into category responses. This method may introduce field-coding error, where the researcher wrongly interprets a response but when the data is triangulated against data collected by other research methods the effect of this error is reduced. Miles and Huberman (1994) regard the coding of interview responses as an important method of data reduction and a way of enabling the researcher to detect patterns and themes. However, there is a danger in doing this that the 'sense of the whole' (Hycner,1985) may be lost and they recommend that a 'composite summary' of the interview be related back to the context from which any particular theme emerged.

Group interviews with pupils have the advantages that they allow discussion to develop and are less intimidating than individual interviews but they do have a number of disadvantages. Pupils can divert questions and make irrelevant interjections, they can be destructive of each other's views and some may feel uncomfortable giving opinions in front of their friends (Lewis, 1992). Elliott (1991) describes the elicitation of authentic accounts from pupils as 'not easy', given a teacher's authority position. However, since the researcher may not be regarded as holding the same 'authority' as the regular classroom teacher, this effect may be mitigated.

A second way of gaining insight into the mindset of pupils is by direct observation of their behaviour during lessons. During the initial phase and at intervals throughout the study observations were carried out of pupils' lessons. Field notes were kept of the format of lessons, the interplay between teacher and pupils and any incidental conversations between the researcher and the pupils or teachers. The mechanism of observation used mirrored that described by Hopkins (1993) as 'open observation'.

> "In this approach the observer literally uses a blank sheet of paper to record the lesson. The observer either notes down key points about the lesson or uses a personal form of shorthand for making verbatim recording of classroom transactions. The aim is usually to enable subsequent reconstruction of the lesson." (Hopkins, 1993, p. 92)

The criticism that this method can be unfocussed and lead to premature judgements may be countered by the argument that from an ontological perspective the holistic approach to observation is unlikely to eliminate data that may later prove to be valuable to the study. The triangulation of the viewpoints of the researcher, the teacher and the pupils was also used to help to eliminate observer bias. Also the analysis of documentary evidence from pupils' work helped to confirm or refute observations of how the pupils responded to various classroom methodologies.

The pupils were informed about the purposes of the observation and their willingness to participate was sought. It was accepted by the researcher that an introductory period of observation was necessary, not just to establish the baseline picture but also to minimise any Hawthorne Effect, due to the presence of the researcher in the class. Cohen et al (2003) describe this type of observation as ‘participant observation’.

> “In participant observational studies the researcher stays with the participants for a substantial period of time to reduce reactivity effects, recording what is happening, whilst taking a role in that situation”. (p.311)

A single observer may unwittingly introduce a high level of observer bias into a study. Nisbet and Watt (1980) point out that no observer records what actually happens, only what they perceive to happen and this may be influenced by a personal agenda. Mason (1996) emphasises the possible effect of observer bias on the record of observations,

> “Although the purpose of observation is to witness what is going on in a particular setting or set of interactions, the intellectual problem for the researcher is what to observe and what to be interested in. If you reject the view – as I do- that it is possible to produce a full and neutral account of a setting or set of interactions based on observation, then you must work out how to tackle the questions of selectivity and perspective in observation. The key to this is to understand *how* you are using selectivity and perspective, rather than to assume – or to hope –that you are not.”(p.132)

One way of reducing observer bias was to interchange observers and although the researcher observed the class with the classroom teacher in the early and later phases of the action research, during the intermediate intervention phase the teachers observed the class with the researcher. Reports on observations, in both cases, were reported back to dialogue group meetings. By using more than one observer the validity of the observational data was strengthened. By using additional supporting documentary evidence from pupils’ work to reinforce the observational data on teaching and learning activities the reliability of the conclusions drawn regarding the outcomes of the teaching and learning methodologies could be strengthened.

The documentary evidence gathered during the research involved accessing pupils’ written work and their scores on attainment tasks set within school. Again pupil and Head teacher permission was sought and granted for this. Relevant pupil work was photocopied and used to further illustrate how effective learning had been in the classroom for some pupils. The school database was accessed for pupils’ previous and current test scores. Whilst lists of test scores may, for a number of reasons, tell us little about a pupil's understanding of their lessons or their ability to engage in higher order thinking, they do serve to give some partial knowledge of what a pupil may be capable of.

Care must be taken in using pupil work as an indicator of understanding and higher order thinking. Whilst certain examples of pupil work may illustrate that that particular child was thinking in a certain way during a lesson, the absence of such work amongst other children does not necessarily mean that they were not understanding or using higher order thinking skills within the lesson, it only means that they did not provide documentary evidence of this. Conclusions drawn from such evidence alone would not be valid for a whole class and can only be empirically applied to individual pupils. However the use of documentary evidence can provide another piece of the jigsaw and by triangulating this against the other research methods discussed enough jigsaw pieces may fall into place for the interpreter to understand the picture presented.

7.4 Introduction to the research context

The period of action research began in late September of 2004. The school within which the project took place was an 11 – 16 suburban comprehensive school with a small science department of six teachers, two biologists, two chemists and two physicists. The school had been selected because it was one of the University's partnership schools used for teacher training and the Head of Science had shown interest in the findings of the pilot study carried out in other similar schools during the previous year. It was thought a good idea to use a completely different school for the action research phase of the study since the teachers and pupils would come fresh to the project with no pre-conceived ideas.

An interview was held with the Head teacher who was very willing for the school to participate in the research. However, the Head teacher naturally expected to receive a report on the findings at the end of the study and this introduced an ethical complication right at the start of the enterprise. If staff and pupils thought that everything that they told me would be relayed to the Head teacher then that would naturally inhibit what they were prepared to say. The perspective of the researcher as a political agent can be an impediment to the research (Punch, 1998b) as it can lead to an inherent mistrust between the researcher and the participants. It was necessary to explain from the outset that while I would be very happy to report the broad findings that I would not be able to divulge precise information about any member of staff and that their identities and that of the school would be anonymised in any report. The Head was willing for the research to go ahead and to provide a letter of support to the University for this purpose.

This meeting was then followed by a meeting with the school's Gifted and Talented co-ordinator, who explained that the school operated a system whereby the top 5% of pupils were selected for the gifted and talented register by a combination of Key Stage 2 and 3 SAT's scores (Standard Attainment Tasks) and cognitive attainment tests. These were used to identify pupils who were able across the board but in addition to this, teachers were also encouraged to nominate pupils as being gifted in particular subjects, on the basis of their classroom performance in that subject. The pupils thus identified as specifically gifted in the domain of science are the 'gifted pupils' referred to in this study.

The first step in deciding how to begin the research was to attend the first science department meeting of the academic year in order to outline the purpose of the project and to discuss possible procedures and groups of children for the research sample. The science department meetings were to provide the 'dialogue group' for discussion of the progress of the action research throughout the following academic year. It was explained to the science department that the purpose of the project was to look at the kind of teaching and learning methodologies that they used with able pupils, particularly those gifted in science and to try to find out whether by allowing these pupils to having more autonomy in the classroom, enabling them to structure their own learning and make decisions about how they wished to tackle topics on the work scheme, their attitudes and aspirations towards science education may be improved. The outcome of this first meeting was the cautious support of the science department. There was some hesitancy about this mainly for two reasons. Firstly there was at the outset a suspicion on the part of the staff that the purpose of the exercise was some kind of appraisal or inspection designed to feedback to the Head teacher. Secondly there was a concern voiced by one of the biology teachers that time spent on pupil centred investigative approaches would mean that the science work scheme did not get covered and that would be detrimental to both the pupils and to the department's performance figures. The issue of performance figures was important to the staff because not only was the department held professionally accountable for these but it also reflected on personal promotion and pay structures within the school.

It was decided, after some discussion, to use the two parallel top year 7 groups for an experimental research design, with one group as 'control' and one group as 'experimental' and also to use a top year 10 group in order to see how the intervention would work at different key stages. It was felt by the department that, in the case of year 7, if the intervention did adversely affect attainment the impact would not be too serious as there would be plenty of time before SATs examinations to 'put things right'. In the case of the top year 10 group it was felt that they were sufficiently able to survive any adverse effects and to regain any lost ground before GCSE examinations in year 11. Whilst this was hardly a vote of confidence it did at least allow the research to go ahead.

7.5 Pre-intervention surveys

7.5.1 Year 7

Classes 7A and B were two parallel top sets, taught by the same science teacher, who were evenly matched on key stage 2 SAT scores and drawn equally from the same feeder primary schools. It was anticipated that these two groups would follow the same scheme of work at the same pace. Before any observation or intervention with these groups a pre-study survey was given to them, in early October, which was identical to that used in the pilot study. This survey was then analysed in order to identify to what extent these two sample groups were indeed similar. It was then intended that one group would act as a control group and continue with their regular teacher in following the work scheme whilst the other group would become an experimental group, working with the researcher, and be exposed to a series of more autonomous teaching and learning strategies, based on the same topics, in order to see how this influenced their learning and attitude to science.

The preliminary analysis of the survey data revealed that although the two groups were regarded as similar there were some differences prior to any intervention being undertaken. 7A contained 14 boys, of whom 9 were regarded as gifted in science and 19 girls, of whom 6 were regarded as gifted in science. 7B contained 14 boys, of whom 5 were regarded as gifted in science and 18 girls, of whom 5 were regarded as gifted in science.

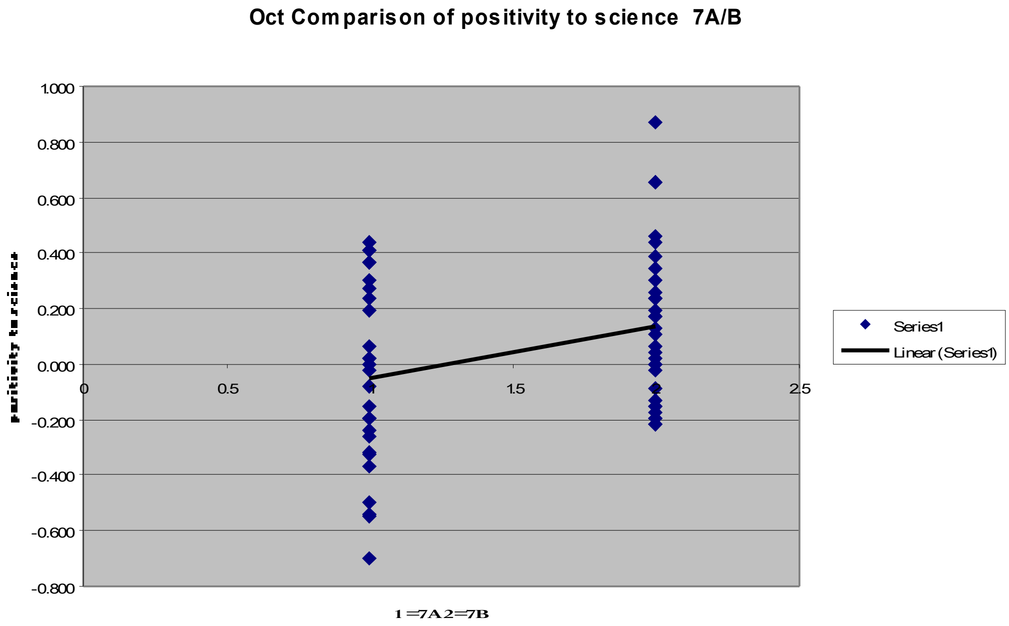


Figure 7.1 *Comparison of pre-test attitude scores for 7A and 7B before intervention activities*

7B were much more positive towards science education than 7A although there was no significant correlation of positivity to science with gender in either class. An analysis of positivity to science for those on the gifted register showed that there was no significant correlation in increased positivity to science for those in either group who had been identified as gifted in science. The same teacher taught both groups during their early weeks in secondary school so differences in teacher did not account for differences in positivity to science. When an analysis was carried out to see if having parents who were involved in scientific occupations had an influence upon pupil positivity to science, it was found that there was a strong correlation (Pearson Product-Moment Correlation Coefficient $r = 0.452$, $p= 0.016$ 2 tailed, Spearman Rho $= 0.375$, $p= 0.049$). This was true of both groups. However, since 7A and 7B had similar numbers of pupils with parents in scientific occupations (11 and 12 respectively) this does not explain the difference in positivity to science between the groups.

There was also a strong correlation between the positivity to science of these pupils and their aspiration to continue with science beyond school (r= 0.674, p< 0.001 2 tailed, Rho = 0.673, p< 0.001) and again this was true of both groups.

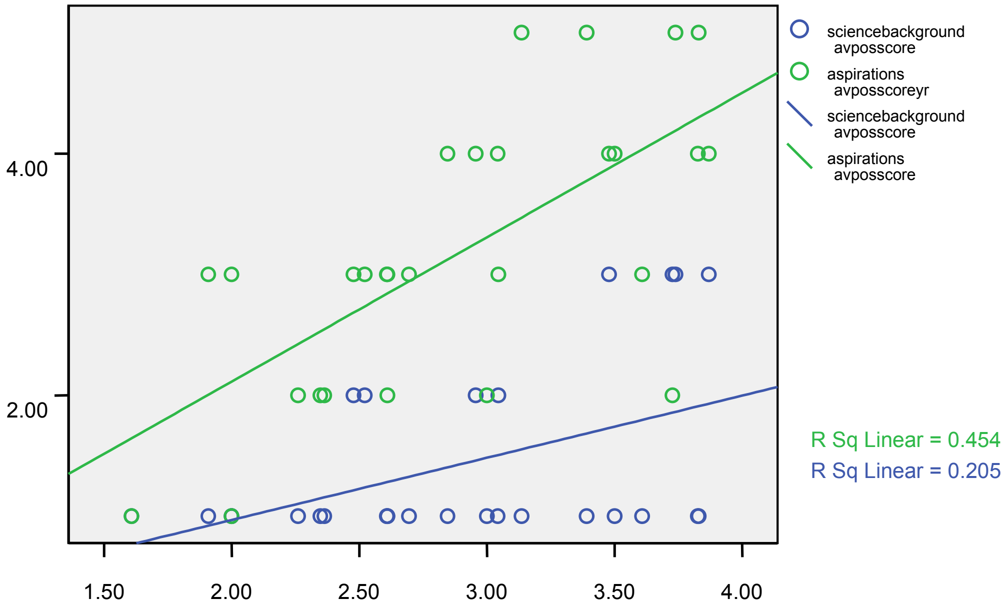


Figure 7.2 *Plot of correlations between parental background in science and pupils' positivity to school science (blue) and aspiration to continue with science beyond school and pupils' positivity to school science (green) before intervention*

When the pupils were asked about whether they had previously been taken to places of scientific interest or done scientific activities out of school, 12 pupils from 7A had been on such visits compared with 23 from 7B. In order to try to ascertain whether this accounted for the difference in positivity to science between the two groups the pupils were asked to rate their enjoyment of the activity and this was plotted against their positivity to school science.

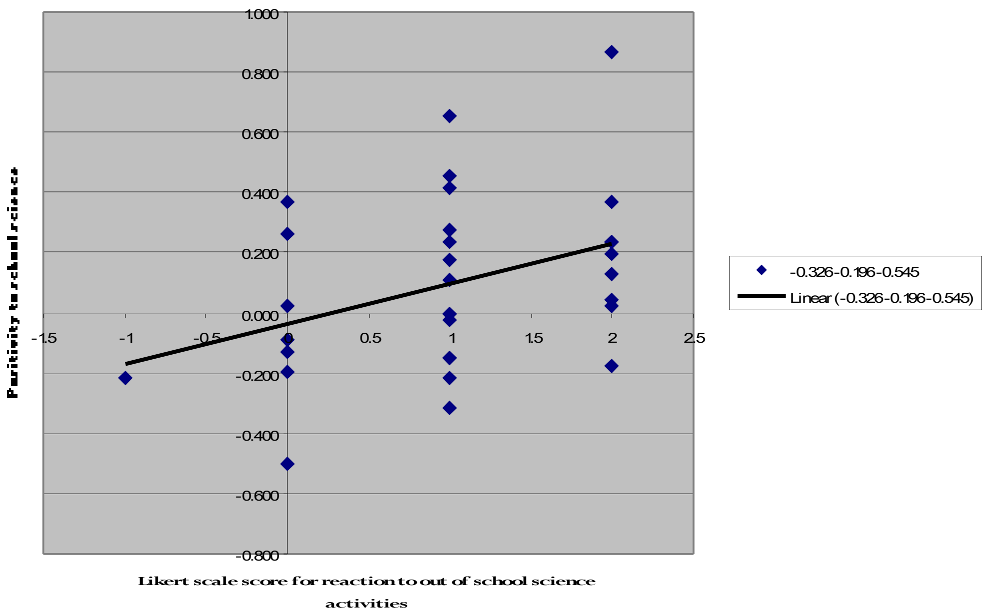


Figure 7.3 Plot of pupil positivity to school science against pupil enjoyment of out of school science activities before intervention

It may be unsurprising that those pupils who had most enjoyed the out of school activities also had more positive attitudes to science in school but the direction of this relationship cannot be determined from the quantitative data presented. The fact that so many more of 7B had experienced science in an out of school context may have resulted in their improved positivity to science compared to 7A. Also when asked about the number of science books in the home the positivity of pupils in 7B was found to correlate with the number of science books at home ($r = 0.547$, $p=0.001$) whereas no such correlation was evident for 7A.

Questions about their favourite science lessons prompted pupils to cite practicals as those lessons they most enjoyed and tests as those they least enjoyed. This finding echoed that of the pilot study and may be indicative that the high frequency of testing and low frequency of experimental work found in the pilot study acted as disincentives to pupils studying science.

> "My best lesson was testing the pH of acids, alkalis and neutral liquids because it was practical and you could be indipendent instead of just writing" (girl on gifted register, 7A)

> "My best leson was testing solutions in test tubes using copper, zinc and magnesium. It was a practical leson where you got to try what you were writeing about. Not just take the teachers word for it" (girl on gifted register, 7B)

The feature of preferred lessons that many pupils commented on was 'being able to do it for yourself' rather than being directed by the teacher. Again this reflected the findings from the pilot study and indicated a preference amongst these able pupils for 'ownership of tasks' in lessons.

7.5.2 Year 10

Class 10 A were a top set year 10 class containing 13 boys, 5 of whom were on the gifted register and 16 girls, 3 of whom were on the gifted register. At the beginning of the academic year, in October, the class were given the same questionnaire that had been given to the year 9 pupils in other schools during the pilot study the previous year.

When the correlation between positivity and being on the gifted register was analysed for this group, it was found that there was a statistically significant negative correlation ($r = -0.395$, $p=0.046$) with those on the gifted register have significantly poorer attitudes to science education than those not on the gifted register. This would appear to indicate that the gifted pupils particularly were 'switched off' regarding the science education that they were receiving. One possible reason for this, cited by pupils was the didactic nature of most of their lessons and their own lack of involvement.

> " My best lesson was dissecting a pig's heart. It was really interesting to find out what they are really like. Also I prefer to actually 'do' things rather than listen to a teacher talk for a long time." (gifted girl, 10A1)

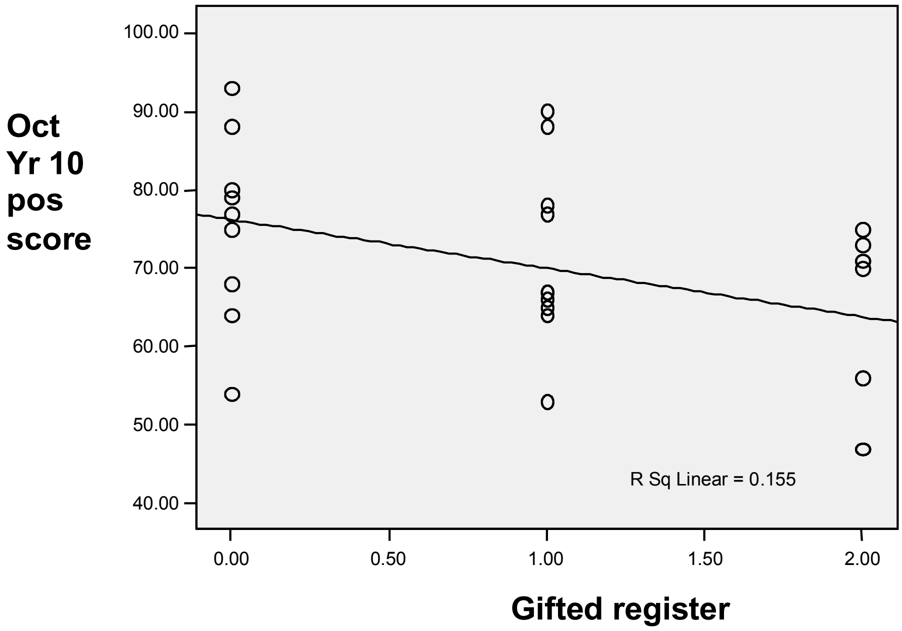


Figure 7.4 Plot of correlation between positivity to school science and being on the gifted register for pupils in 10A before intervention

As previously shown with year 7 there was also a positive correlation (rho = 0.371 p= 0.062) between pupil positivity and aspiration to continue with science beyond the age of 16. This link between attitudes and aspirations is potentially important. If we wish to motivate more pupils to advanced level study in science then improving attitudes to science through what happens within the classroom may prove key to this.

When pupils were asked about their perception of the difficulty of physics, chemistry and biology it was found that there was no influence of any subject discipline upon pupil positivity to science, indicating that this group were not ‘switched off’ by any perception of subject difficulty. This may be indicative that this top set was under-challenged by their science lessons. The dichotomy between providing ‘challenge’ in science lessons and the need to avoid ‘switching pupils off’ by presenting work with a level of difficulty beyond a pupil’s ZPD (zone of proximal development) presents dilemmas for teachers. Each individual pupil will have a different ZPD and thus teachers need to be able to differentiate for ability in their teaching, to provide sufficient challenge for each pupil in order to develop their understanding without taking them so far out of their comfort zone that they give up. To achieve this for each pupil in a class is a tall order for even the best teachers!

When questions regarding home background were analysed it was found that, for this age group, there was no correlation between positivity to science and the science background of parents. This contrasts with the finding for year 7 pupils. This may indicate a reduction in the influence of parents as pupils move from childhood towards adolescence.

Questions about their best and worst science lessons led to responses which indicated that those lessons involving ‘hands on’ activities were preferred over filling in worksheets.

> “The best lesson was dissecting a pig’s heart. It made it more real to learn about, more interesting. I do have some boring lessons when we just listen to the teacher talking or just filling in sheets I don’t have a clue about.” (girl, 10A1)

In order to ascertain to what extent the teachers took account of these preferred activities it was decided to begin with a period of observation of all three classes so that the current teaching and learning methodologies and interactions of pupils and teachers could be explored.

7.6 Initial Observation

7.6.1 Year 7 October

The observation of the two year 7 classes began in early October. The first lesson observed with 7B was a lesson on the chemical reactions of metals. A group of 4 pupils was brought to the front of the laboratory to perform the experiments under the direct supervision of the teacher while the rest of the class were instructed to fill in a grid on what they observed taking place. When pupils were asked to describe what they saw some of their descriptions were ‘corrected’ by the teacher, who then told the class what she wanted to be filled in on their work sheets. The dialogue within this lesson was mainly teacher talk and the only pupil talk observed was pupils responding to questions or asking for confirmation of ‘doing it right’. The only opportunity for unstructured writing on the part of the pupils was when they were asked to write their own description of the test for hydrogen gas that they had seen. When pupils were allowed to write freely it led to some inaccurate information being recorded in pupils’ books and underlined the first dilemma involved in getting pupils to decide for themselves what to write, namely that of accuracy. This teacher was very concerned that the information that pupils had written in their books should be accurate. In order to ensure that it was, the pupils were given very little leeway for error and told exactly what to write. However the fears of the teacher did seem to be justified as when given the opportunity to decide for themselves what to write error was observed. The question arising was how effective was the learning gained from the teacher directed notes compared to the notes written by the pupils themselves. Science education was portrayed as a series of 'right answers' to be learned for a test, possibly at the expense of real understanding of what they were writing notes about. When the teacher was asked why she felt it was so important that what the pupils write was completely accurate she explained that inaccurate work would be picked up by parents and could result in critical feedback to the school. Thus parental pressures were impacting upon teaching and learning methodology.

The first lesson observed with 7A began with a scientific word search designed to raise scientific vocabulary skills. The flaw in this is that the pupils needed to know the word already in order to find it in the word search and thus may not have expanded their scientific vocabulary at all. Following this the teacher dictated a conclusion for some previous experimental work. The pupils were then asked to verbally evaluate the experiment carried out and their responses demonstrated that they were capable of evaluating the experimental procedures but when it came to writing the information in their notebooks the teacher again told them what to write. Following this a sequence of structured worksheets was given to the pupils in rapid succession. The rapid pace at which pupils were expected to complete the sheets resulted in many leaving sheets only partially completed. The pace of working was forced by the teacher in an attempt to get everyone through the 'requisite subject material', as described in the work scheme and pupils were not allowed to work at their personal pace. This caused some frustration amongst those pupils who could not keep up and these demonstrated no real learning as they had insufficient thinking time to assimilate concepts. The pupils in this lesson had little ownership of their tasks and rather than being engaged by the lesson they were frustrated and confused.

After these two lessons had been observed a discussion was held with the class teacher on why they had been structured in such a way. The teacher emphasised the need to ‘cover the work scheme’ and that the lessons were timed according to the number of worksheets that had to be covered. This system had been adopted so that every class could cover exactly the same work, even though they may not have a teacher with expertise in that particular science specialism. For this reason there was little time to diversify or adopt autonomous approaches to learning.

The next lesson observed with 7B was a practical lesson on testing the strengths of acids and alkalis. The pupils were brought into the room and instructed to copy out a blank results table from the board. Pupils then began to carry out the tests as they had been instructed. Whilst they were doing this, the researcher asked groups of pupils questions about their practical work. Feedback from pupils indicated that they preferred this kind of activity to that used in the previous lesson.

> “We remember it better when we do it ourselves” (Boy, 7B)

> “If you’re just watching the teacher do it you tend to ‘drift off’” (Gifted boy, 7B)

After they had completed the experiments pupils were then asked to write down the method used for themselves. Whilst they were doing this, the researcher again circulated the groups asking whether pupils preferred to have notes given to them or write them themselves. The responses of the pupils indicated that they preferred the autonomous activity as they thought it aided their learning.

> “We would rather write our own method ‘cos if the teacher writes it we have to do it exactly as she said” (Girl, 7B)

> “If we write a method we can do it our way” (Boy, 7B)

This illustrated that these pupils liked to have ownership of what they were doing in class. Many were capable of expressing themselves well orally but were given little opportunity for extended writing, resulting in their writing fluency being weaker than their oral fluency. It would seem that the teacher’s pursuit of ‘knowledge’ for these pupils was at the expense of ‘skills’. Perhaps a greater emphasis on the acquisition of such ‘skills’ would equip these pupils to be able to pursue ‘knowledge’ for themselves.

During the next lesson with this class a work sheet was given out with instructions on how to make an indicator from red cabbage. The immediate response of many children was that they had done this already at primary school. Despite this the pupils were instructed to follow the instructions on the worksheet. The instructions were very prescriptive, giving no allowance for personal investigation on how to make the ‘best’ solution. Yet once the pupils had completed the task, they were then told to write their ‘own plan’ from the instructions on the sheet. This was entirely retrospective and therefore was not a ‘planning’ activity in so far as it led to no future action. This corruption of the principles of scientific enquiry did little to enable the pupils to appreciate the ethos of ‘science’.

In the final lesson observed the pupils were given a worksheet and asked to copy out the notes from this into their books. The pupils completed this task at different rates. Before some pupils had finished, the next worksheet was given out with instructions on how to do a practical on neutralising an acid with an alkali. As the pupils completed this task the researcher moved around the groups asking pupils to make quantitative predictions about what volumes of each reactant needed to be added to their solutions. This involved the pupils in using some higher order thinking, involving analysis and synthesis of information. Many demonstrated an ability to do this and indicated that they were capable of working at much higher levels than those demanded by the worksheet.

> “ If the acid and alkali are the same strength you will need equal volumes but if one is weaker you will need more of it” (Gifted girl, 7A)

When pupils were asked about the difficulty of the work almost all said that it was quite easy. A homework sheet of questions was then given out containing structured closed questions. Despite the pupils displaying their ability to think using higher order thinking skills and to express themselves with fluency in class the homework task did not make this demand upon them, as most questions required only single word or short phrase answers. The indications from both the lesson and the homework task was that the teacher’s level of expectation of these pupils was much lower than that of which they were capable.

Summary

During the observation period the main teaching and learning activities, which had been observed with year 7, were

- Question and answer sessions
- Dictation
- Free writing
- Instructed practicals
- Copying from the board
- Following instructions
- Demonstrations
- Tests
- Word searches
- Evaluation of methods
- Reading aloud

It was also observed that teacher talk made up the vast majority of the lesson time and pupil talk featured for only a very small proportion of most lessons, usually when answering a direct question. In many cases the need of the teacher to move on with the subject matter of the lesson led to pupil discourse being quickly closed down and pupils encouraged to 'get on' with the task.

Worksheets were very prescriptive, giving little ownership of task to the pupils. The lessons were very teacher directed and pupils made hardly any decisions about how to investigate, extend or broaden topics. Despite some pupils displaying the ability to use higher order thinking skills, there was no differentiation by task and all pupils were expected to complete the same work at exactly the same pace. Although many pupils displayed verbal fluency, homework was closed and structured and did not use the scope of the extended time available for this.

Little use was made of pupil hypothesis or task design, although pupils' observation skills and evaluation skills were utilised. Pupils were not exposed to the ideas of ‘scientific enquiry’ and most of the science was merely repeating work for which the outcomes were already known, hence the ‘right answer’ philosophy permeated most of the work carried out by the pupils.

7.6.2 Year 10 October / November

In order to compare the teaching and learning methodology for year 7 with that of older pupils class 10A1 was also observed, for an introductory period from early October to late November. This also served the purpose of introducing the researcher to the pupils as if she was an additional member of staff. It was hoped that the pupils would become familiar with the presence of the researcher and their behaviour would not be unduly altered by the presence of a new person arriving in the classroom. The lessons of three different teachers were observed during this period.

The first lesson observed took place in early October and was a physics lesson on energy resources. It began with a sheet of short structured GCSE examination questions. This revealed the diversity in confidence, ability and work rates amongst the pupils. Following this pupils were asked to perform internet searches to find information about energy sources. Pupils were given some freedom to explore a number of websites and were mostly engaged by the activity and interested in the information that they were finding out. Again there was a diversity of computer skills displayed by pupils but there was no differentiation for this by the teacher. At the end of the lesson a question and answer session revealed that most pupils could recall factual knowledge but few had engaged in any higher order thinking skills, involving analysis or evaluation of information obtained from the websites. The following day, at the start of the next lesson, the pupils were asked to recall what they had learned the day before. Only 3 pupils managed to recall any of the facts that they had read about the day before, indicating that the learning had been very short term. Was this because the pupils were not required to think about the topic but merely to repeat what they had read? This raises the question of how necessary higher order thinking skills are to the retention of factual information.

Following the question and answer session the teacher talked at length about hydrogen as a renewable source of energy and pupils were given more examination past papers to work through. The nature of the examination questions was again structured short answers with no scope for extended writing. It was noticed that a group of girls was actually answering the questions in their books in pencil rather than pen. When asked why, by the researcher, one of the girls responded,

> "It's so that I can rub it out and put the right answer in when the teacher goes through it" (Gifted girl, 10A1)

Again pupils have a 'right answer' view of the science that they are studying. This is perhaps hardly surprising since the pupils are drilled in how to answer the questions in order to maximise their examination score. Is this true 'science education'? There was very little scope for the pupils to display any depth of understanding during the work that they were doing as most of the questions required factual recall with little demand for analysis, synthesis or evaluation. For the most able set in the year group this was a surprising finding. When pupils were asked how difficult they thought the questions were most responded that they were 'pretty easy' and only two pupils said that they were just 'okay'. No one thought that the questions that they had been given were 'hard'. This indicates that the pupils met with little challenge and teacher expectation was probably lower than their capability.

The next lesson observed was a biology lesson with a different teacher, which began with pupils creating a 'mind map' about the circulatory system on the interactive white board. Pupils engaged well with this visual learning medium. The pupils were then asked to make notes in their books using the mind map to prompt their thinking. This required the pupils to understand the map, assimilate the concepts it represented and then synthesise the essence of the knowledge into coherent sentences. These are all quite demanding higher order thinking skills and yet the pupils engaged with the process without any difficulty. The level of demand of this lesson was much greater than that of the previous lesson and yet the pupils took this in their stride. This indicated that there were very different expectations of the pupils demonstrated by the two teachers and the pupils seemed to comply with whatever level of demand the teacher made of them.

The lesson then proceeded with the teacher displaying an image of the circulatory system. He then began to teach the pupils a memorisation technique for remembering the details of the system and brought pupils out to the front to role-play the heart and lungs and oxygen passing through the bloodstream. These kinaesthetic techniques and study skills helped the pupils to remember not just the facts but to also understand the processes involved and utilised a mixture of visual, kinaesthetic and verbal learning styles. How long term this learning was would be an interesting focus for future lessons.

The next lesson observed was again a physics lesson and the pupils began immediately with a worksheet which told them exactly how to prepare the results grid and graph axes for recording practical work which was to follow. Homework, on past examination questions, was then returned and pupils given instructions on how they may maximise their scores. The method for the experiment was then explained by the teacher in precise detail. Up to this point there had been no pupil talk at all in the lesson. The pupils were then told to start the experiment.

At this point the researcher decided to probe the understanding of the pupils by asking some groups to draw a prediction of the graph that they might expect to get at the end of the experiment. The experiment involved a beaker of hot water and a beaker of refrigerated water being left in the room and their temperatures taken every few minutes. The first group drew the temperature of the cold water getting higher and the temperature of the hot water getting lower. The second group drew a similar graph but had labelled the y-axis of the graph 'heat' and when asked said that he did not know what the difference was between heat and temperature. The third group were unable to draw any predicted graph. At this point the first group then suggested that they would like another go and re-drew the graph showing the temperature in both beakers levelling off as the temperature approached room temperature. This hypothesising on the part of the pupils had involved a degree of abstract thought in order to come up with a mental model of what they thought would happen. The fact that some pupils were prepared to modify their model as they experienced the dissonance between what they had previously thought and what they began to observe, illustrated that the pupils were capable of scientific thinking and model adaptation in the light of new evidence i.e. they were thinking like *scientists*. However, for the remaining groups who had not been asked to do this, the lesson proceeded to be completely instructional. Pupils were not even expected to make a decision on the page layout of what they put into their books but followed the instructions on the worksheet almost slavishly, resorting to using pencil in their books when they were unsure if they were 'doing it right'. The ownership of the work carried out within this lesson belonged to the teacher and pupils had made no decisions at all regarding how to investigate the ideas of thermal equilibrium.

In the following lesson pupils watched a demonstration of heat convection but were slow to respond in a question and answer session on what they had observed. In an effort to get the pupils to respond the teacher asked them to write about what they had seen. This was the first opportunity for any extended writing that had been observed. The researcher moved around the room reading the accounts written by the pupils. The writing of four pupils was examined in detail. The first pupil had found it difficult to place the stages of the experiment in the correct sequence and by muddling the ordering of events displayed that she did not understand the concepts of cause and effect that had been demonstrated. The second pupil did not use sentences but instead drew an annotated diagram of what had happened. The third pupil described the activity in fluent sentences but used the word heat in the context of temperature and clearly could not differentiate the meaning of the two words. The last piece of work was correctly sequenced but consisted of short phrases and incomplete sentences. Some pupils in the room were at a complete loss as to what to write and the teacher ended the lesson by dictating the experiment description to the class. The inability of the pupils to cope with the extended writing task was at odds with their skills in spoken verbal fluency. The question of whether their inability to complete the task was due to a lack of understanding of the science or a lack of experience and skill in extended writing in science remained unresolved.

A second biology lesson, following on from the circulatory system lesson, began with the teacher asking the class to recall what they could remember about the transport of oxygen around the bloodstream. The pupils competed to respond to the teacher and showed good recall despite the lesson having taken place some days before, indicating that their engagement with interactive technology and use of higher order thinking in the previous lesson had indeed resulted in good retention. An interactive animation of cell activity was then displayed on the interactive white board. The pupils were interested and attentive and asked questions about the images displayed. The lesson consisted of a high percentage of pupil talk. This contrasted with the final observation of a chemistry lesson in which the teacher displayed images and talked about models of the atom on the interactive white board, using this simply as a display board. This failed to engage and many of the class were inattentive or even disruptive. Many of the criticisms voiced by the pupils in this lesson were justified but were dismissed. Again the ‘ownership’ of the classroom tasks belonged to the teacher and the pupils were not allowed to adopt any ownership of the interactive technology. Although much has been made of the acquisition of interactive white boards in schools this observation served to underline that merely possessing the technology is not enough, learning outcomes are dependent upon how it is used. Meaningful learning was only observed to happen when pupils were fully engaged and allowed some say in the direction of the lesson.

Summary

During the observation period the main teaching and learning activities, which had been observed with year 10, were

- Question and answer sessions
- Dictation
- Completing structured worksheets
- Completing past examination questions
- Instructed practical work
- Mind mapping
- Role play
- Animations
- Internet searches
- Free writing
- Copying from the board
- Demonstrations
- Story telling
- Slide shows

Again teacher talk made up the majority of the lessons but pupils were allowed more pupil talk than had been the case with year 7. However, very little decision-making had been afforded to the pupils and the direction of the lessons was almost entirely teacher led. A greater variety of teaching and learning activities had been used with these older pupils but only a few of these had supported the use of higher order thinking skills. Teaching to the test was prevalent and pupils were drilled in how to answer examination questions in almost every lesson. Is this a strategy genuinely in the best interest of the pupils or a consequence of the accountability agenda imposed upon school staff by performance management structures? To probe this further the issue would need to be raised at the next science department meeting.

Pupils had also little opportunity to express themselves by extended writing and some lacked the skills to do this. Again the question arises as to whether this is a case of the assessment tail wagging the educational dog. Principles of scientific enquiry seem to be neglected in favour of the pursuit of 'right answers' and high examination scores. Expectations from different teachers involved different levels of pupil demand but pupils seem to adapt to 'satisfy' the teacher's expectations, providing higher level work when it was required but not when it was not.

When pupils were vocally critical of lessons and activities used this was interpreted as poor behaviour and admonished. No consideration was given to the justification of the pupil view and no autonomy given to the pupils to choose what or how they wished to learn. Despite teachers holding the view that they did not have time to use pupil directed learning, it appeared that some of the classroom time involved the pupils in repetition of work that they already knew. Perhaps this time could be used more effectively?

7.7 Discussions with the science department - October

At a meeting of the science department in October the salient points from the observational period were discussed. Science staff were presented with checklists of the types of activity observed in the classroom for both the year 7 and year10 pupils and asked to comment on how well it matched their own perception of the activities utilised in lessons.

7 **Class 10A1**	**<u>Classes 7A/B</u>**
Class activities observed • Q/A • Completing past paper questions • Internet searches • Following instructions • Demonstrations • Listening to teacher • Extended writing • Use of Interactive White Board • Mind maps • Memorising technique • Worksheets • Feedback on homework • Graph plotting and interpretation • Looking at data projector images • Dictation • Practical experiments	**Class activities observed** • Q/A • Dictation • Free writing • Practicals • Copying • Following instructions • Demonstrations • Tests • Word search • Evaluation of work • Reading aloud • Diagram drawing

Table 7.1 Comparison of classroom activities observed in year 7 science lessons with those observed in year 10 before intervention

The science teachers were then asked to consider which activities had been pupil directed and which had been teacher directed. This was a useful activity for raising the awareness of the teachers regarding the lack of opportunity afforded to pupils to make decisions about what they wanted to learn and how they wanted to learn it. The consensus of opinion was that with year 10 the only activities which had involved some direct pupil input into their design were mind mapping, internet searching and extended writing. With year 7 the range was even less with only the free writing and evaluation activities giving some autonomy to the pupils regarding how they organised and went about the task. The science staff agreed that the remaining activities observed had been largely teacher directed but they hotly defended the necessity of this, stating that there was no other way that they could cover the work scheme in the time allowed and produce the high test scores required.

The issue of the pupils always being directed to the belief that there was a ‘right answer’ and being given little opportunity to consider alternative possible answers and weigh up the probability of evidence was regarded by most staff as time wasting. The view that ‘learning by discovery’ was time consuming and fraught with the danger that pupils would come to ‘wrong’ conclusions, leading to erroneous examination answers dominated the discourse. This was also offered as an explanation as to why pupil enquiries were often quickly closed down and re-directed back to the teacher-planned activity.

The issue of prescriptive worksheets was also discussed and the Head of Department explained that since staff had to teach out of their subject specialism at key stage 3 it was necessary to teach to the worksheet. This was in order that all pupils had equal opportunity to cover all the work required for SATs examinations to the same degree of detail no matter what the specialism of the teacher teaching them. However, this did not explain why the worksheets continued to be prescriptive at key stage 4 when the teachers were working within their own specialism. In explanation of this, the Head of Department explained that it was felt to be very important that the pupils have clear and correct notes in their books for revision purposes when tests came around.

The fact that few worksheets allowed for differentiation by task for pupils of different abilities was also raised and the counter view given was that those pupils who finished early could have extension tasks and those who did not finish in the lesson time could complete tasks at home. This seems rather punitive at both ends of the spectrum with the likely outcome that gifted pupils would take their time to avoid being given extra work and slower pupils who had struggled when the teacher was there would be likely to give up when that support was unavailable at home. One teacher explained that if she felt that some pupils had not ‘got the idea’ in one lesson she would repeat the work to consolidate this in a later lesson. This may have explained why in the case of both year 7 and year 10 there were some lessons observed in which the work appeared to be repetitive for some of the pupils. Another member of staff put forward the view that it was a classroom management issue, since it was easier to manage everyone doing the same thing rather than a number of different activities all going on at once. The idea of different pupils having different starting points in lessons was rejected unanimously as being too difficult to manage.

The sensitivities of the staff to inferences that they could do a better job led to some heated debate and strong views expressed over contentious issues of workload and time management. The rather defensive stance of the science department in response to the issues arising from the observational period of the research highlighted one of the difficulties involved in action research. If the research was to involve reflective practice on the part of the staff then it required that a culture of openness and mutual trust be established. This was not going to be achieved over night! In the interests of cultivating this culture the researcher proposed that the next period of the research project should 'turn the tables' and give the science staff an opportunity to observe the practice of the researcher and feedback their opinions of some possible alternative teaching and learning methodologies, involving the pupils having greater decision making powers and more autonomy over their learning processes in the classroom.

It was decided that in year 7 the researcher would take over class 7A for the next module of work on 'Environment and Feeding Relationships', whilst the original classroom teacher continued in the established way with class 7 B. The original classroom teacher would observe the 7A lessons and feedback observations at the next dialogue group. At the end of this period a comparison would be made of attainment for each class.

Similarly for class 10A1 the researcher would conduct a science investigation project involving autonomous decisions made by pupils on how this was conducted. The levels of attainment and the attitudes of the pupils to the lessons could then be established at the end of the intervention period. These lessons would be observed by the classroom teacher and observations again fed back to the next science department meeting.

7.8 Intervention 1

7.8.1 Year 7 November

The intervention exercise with 7A began in early November. The module was to be delivered within a time frame of seven lessons. The first of these was on habitats. The lesson delivered to 7B involved them completing 4 structured worksheets using observations of slides of animals in different habitats. By contrast the lesson with 7A began by introducing the class to a container full of woodlice and asking the class to design an investigation to find out where the woodlice liked to live best. Groups consisting of 3 pupils in each were asked to discuss a design for their investigation. When they had decided what they wanted to do they had to write or draw a plan and submit it to the researcher for permission to continue. This step was felt to be necessary in order to ensure the welfare of the organisms being used. Around the room were various materials that could be used e.g. soil, gravel, sand, tree bark, moss, grass, leaf litter. The pupils exhibited some excitement at being asked to work with 'creepy crawlies' but once they had settled they began to discuss and even argue with each other about what they were going to do. Questions like, how many wood lice to use, how fair it would be if some places were wetter or darker than others and how long to wait before the woodlice would choose where they wanted to go were all heard from different groups.

Almost all the groups eventually decided to arrange different little habitats on their tables for the woodlice and then release them and watch where they went. Some of the groups who were less sure what to do just waited until others had started the task and then copied them. Letting the pupils go ahead with their own investigation designs was not without its hazards as some of the woodlice ran completely off tables and were chased around the room. This was such a contrast to the usual worksheet driven lessons that excitement levels were high and only a few pupils actually got around to recording the populations of each habitat in their books. This reinforced what teaching staff had said about fears that pupil directed tasks would take much longer. At the end of the lesson 7A had not recorded very much at all whereas 7B had four worksheets of writing about habitats completed. Would this mean that the learning outcomes for 7A would compare unfavourably with those for 7B?

During the second lesson 7B were instructed to make lists of the conditions within a habitat and identifying the things that habitats provide, again by observing slides. The pupils were then asked to complete the missing words from five structured sentences about how organisms are adapted to their habitat. The words that they could choose from were listed under the sentences. At the start of the second lesson with 7A a sample of groups of pupils were brought out to the front to describe to the rest of the class how they had done their woodlice investigation. Despite this being two days earlier and little having been recorded, the recall of the pupils was good. The class were then asked to complete their recording of the outcomes of the investigation using four prompting questions about the purpose, the variables decided upon, whether their tests were fair and their choice of sample size. The standard of response was high and pupils demonstrated that they had understood the principles of fair testing.

> “ We were trying to find out what habitat do woodlice prefer and we had to decide which habitats to use. We decided
> - Compost
> - Leaves
> - Damp sand
>
> We left the middle free from any of the habitats and put the woodlice in the middle, so that they could make their own choice on which habitat to go in. We used 10 woodlice. If you had more than 10 you may not be able to count all of them. This would then not be a fair test because you might count the same woodlouse twice.” (Girl 7A)

> “ I wanted to use 1000 woodlice. This is better because if you have some woodlice not like typical woodlice it does not matter because you will have loads of other normal ones” (Gifted boy 7A)

> “I used just 10 because you could do the experiment and only have 10 to count, counting 100 or 1000 would take you ages and then you could do a ratio e.g. leaves: 4/10 = 40/100 = 400/1000 and if you had only one it wouldn’t be fair because all woodlice would be different.” (Gifted girl, 7A)

As each pupil finished recording their investigation they were allowed to get up and go to a display of plants and preserved animals that had been set up around the periphery of the room. The pupils were asked to choose one organism to study and to try to decide what evidence they could see which would tell them what the habitat of the organism might be like. They were asked to draw their chosen organism and label the features which had made the organism successfully adapted to its habitat. For homework pupils were then given a picture of a dark and swampy alien planet and asked to invent the features of the creature that might live there. Pupils were told that the most imaginative drawings would be displayed on the classroom wall. Although the researcher had made the choice of these tasks, the way in which the pupils approached each task was their own. Some pupils sought reassurance that they were ‘doing it right’. When they were reassured that what they were doing was satisfactory, they were happy to take on the responsibility of making further choices about the way that they did the tasks. With a little reassurance these pupils seemed to be adapting well to the autonomous learning methodology.

The third lesson with 7B used more slides to show the adaptations of plants and animals for survival. Pupils were asked to list as many adaptations as possible and give reasons. The pupils then had to paste a picture of an animal into their book and identify which of the habitats shown in the slides, it came from. The third lesson with 7A began with the display of the pupils' alien creatures. These drawings of these imaginary creatures, with labelled adaptations had taken some pupils much longer than their allotted homework time to draw and indicated that pupil motivation to complete this task was high. The pupils whose drawing were displayed manned the display stands and told the story of their creature, where it lived, what it ate and how it survived its predators to the rest of the class. Pupil demonstrated confidence in talking about their work and raised self-esteem through being regarded as 'authorities' on their subject.

Pupils were then asked to imagine what the difference between summer and winter might be like on the alien planet and how it would affect their creature. This led on to a discussion of what the differences were between summer and winter on our own planet, how they affect our plants and animals and how these differences could be monitored. The researcher then introduced the pupils to sensors and data logging equipment, which could be used to record temperature, sound levels, humidity and light levels over long periods. Pupils were then asked to use the sensors to investigate the changes in the school environment over the next 24 hours. Pupils had to decide which sensor to use and where it should be placed to record data. Sensors were left on radiators, hanging out of windows, in the fish tank, in the corridors and in the soil around plants.

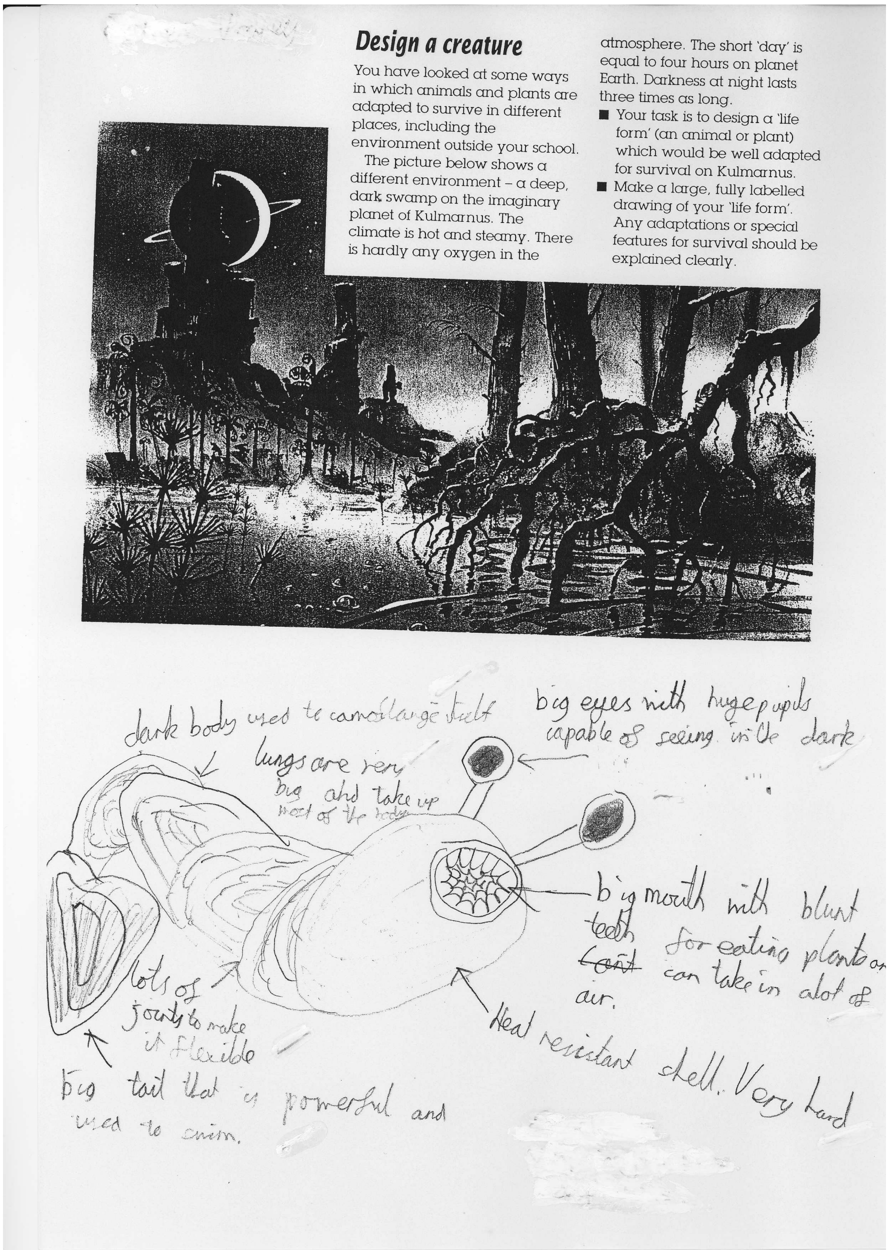


Figure 7.5 Example of creative work in year 7 on adaptations for survival during intervention 1

At the start of the next lesson the pupils were asked to draw predicted graphs of how they expected their chosen variable condition to have changed over the last 24 hours. They were then presented with the computer-generated graphs and asked to compare them with their predictions. The pupils' graphs showed a good degree of comparability with the computer generated graphs and where there were differences, discussion over the reasons for the differences was prompted. The class was then asked to choose an organism that they could see around the school and to try to explain how that might have been affected by the changes. The pupils showed a good understanding of the effects of changing conditions on wildlife. Meanwhile 7B had again been using slides showing daily and annual adaptations of organisms and had copied out a 'language bank' of technical terms associated with the topic. There appeared to be a great emphasis on the encouragement of scientific literacy through 'learning' words rather than through using them in the context of discussion. A group work exercise was then done where pupils had to cut out creatures and paste them into photographs taken at different times of day and different seasons of the year. Whilst this did constitute an assessment of pupils' understanding, it did not assess their scientific literacy.

The penultimate lesson in the module was concerned with predator / prey relationships. 7B worked through worksheets on food chains and food webs. The lesson with 7A began with the class being given a grid with letters along the top and numbers down the side and asked to invent a board game for predators vs. prey. Some pupils used a kind of 'snakes and ladders' scenario for when prey was eaten by predator. Others used a kind of 'battleships' game where the roll of a dice dictated whether you were eaten. The rules of the games were entirely up to the children and some of the gifted pupils made up game rules that were very complex and intricate. Most of the games ended when one species was wiped out. Some games included 'wildcard' natural disasters like drought, floods or fires. The level of sophistication of the games was surprising. Pupils did not want to stop playing and many asked that they be allowed to take their game boards home to play. This was again an indication that the 'ownership' of this task was producing a high level of motivation. When games were over and pupils were asked to describe what had happened in the game, they showed a high level of verbal fluency and understanding of the fluctuations in species' populations as a result of the features that they had built into their board games, although indirect relationships were less well appreciated e.g. when a predator had two lots of prey, how the population of one type of prey would affect the population of the other.

Once the pupils were finally induced to put away their board games they were then introduced to a piece of interactive whiteboard software which allowed pupils to choose the scenario for the predator prey relationships within a food web and to control a chosen population in order to see how that influenced other populations. The pupils were very engaged with the program and showed understanding of the way in which the populations were interdependent. Pupils were competitive and eager to make decisions over the control of populations. Although the pupils had not used the interactive whiteboard themselves before they very quickly understood it's operation and even the more reticent were keen to become involved. Pupils did not show the same fear of failure in 'losing' their population games as they had done previously in writing 'wrong' information into their books. This made the pupils more willing to adopt a 'trial and error' approach and enabled them to learn through their mistakes, in a way that they had not been allowed to do in their exercise books.

The final lesson in the module, in late November, was intended to be a revision lesson for both 7A and 7B before the inevitable module test. Whilst 7B practised past SATs questions, 7A constructed their own concept maps for the topics covered in the module. This was their first experience of concept mapping and yet none of the pupils failed to produce a 'map' of their ideas regarding the topics covered. Many of the pupils displayed additional knowledge to that accessed in their lessons, which can only have come from their previous school or their work at home. This may have been an indication that some pupils had pursued the topic further in their own time. However, to what extent pupils had been motivated to do additional work could not be ascertained from the concept maps alone.

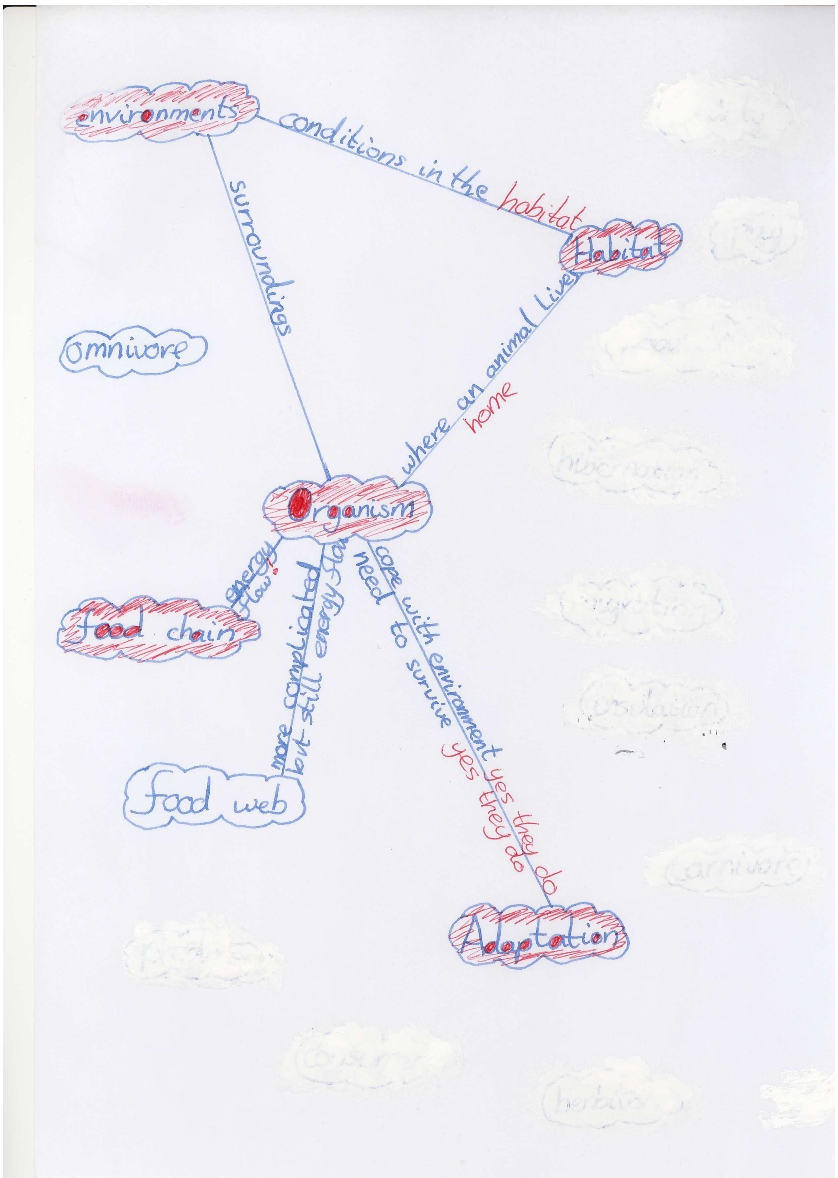


Figure 7.6 Example of Year 7 concept map on ecosystems after intervention 1

7.8.2 Discussion with science department - November

At the end of the module the classroom teacher who had been observing the lessons with 7A gave a report on her observations to the rest of the science department at a departmental meeting.

> " HH (researcher) delivered the information to the group in pretty much the same way that we do, using the format suggested in the departmental teaching folder. The style of teaching used was very similar to ours and she incorporated pupil discussion, group work, structured and free writing just as we do"

This response was somewhat unanticipated by the researcher. At best it minimised the pupil directed activities and at worst it negated them. The flavour of the report given was ‘we do all this anyway’. If the perception of the teacher was that there was no difference between the previous teaching and learning practice and that used in the intervention then logically the intervention should not have made any difference to the pupils. The report then continued to say

> “ Design a creature living on a strange planet activity was similar to ‘Boardworks’ slides 13&14 but in reverse. A graph grid for pupils to add their predictions, of changes in light, humidity, noise and temperature over 24 hours, that was completed in lesson 3, was used again in lesson 4 to add actual data. We could get data off the internet or from a local weather station to develop this idea.
>
> A practical using woodlice during lesson 1 which allowed the pupils to plan a simple experiment to test what habitat woodlice prefer, then to carry out the experiment and then write their conclusions allowed pupils to understand the concepts of fair testing, reliable data and anomalous results. A fun activity enjoyed by most of the pupils but finding time to capture the woodlice and collect the variety of habitat materials needed could be difficult.
>
> An adaptations circus during lesson 2 where pupils had to look at different organisms and write the adaptations, describe the environments and decide on the habitat of each organism was used. Although this was similar to the way that we approach this the ‘real’ specimens added an extra ‘oooohhh’ factor to the proceedings that projected photographs do not always achieve.
>
> Equipment to monitor the environment was used during lesson 3. This is equipment we would love to have if only our budget allowed. HH did not make use of the ‘Boardworks’ software that we use but she did use the interactive whiteboard for a food web populations program. Pupils decided what they would change and were prompted to make predictions about what would happen. After a few goes the pupils started to get the idea and there were lots of enthusiastic noises when the results were shown. This program would be a useful addition to the current resources that we have on this topic.
>
> Overall HH did not really teach this topic any differently than the way that we as a department teach it. However HH did incorporate a few fresh ideas that we could develop and include in the department teacher file.”

The inferences of the report were that essentially the work of the researcher had not differed significantly from that of the teaching department. This was both surprising and frustrating. The report focussed on the *content* of the lessons rather than on the processes of the teaching and learning methodology. Whilst the subject content for both 7A and 7B had been essentially the same, the researcher felt that the processes involved in the teaching and learning methodology had been very different. Had the report recognised the difference and then argued against it, at least some impact would have been demonstrated but to fail to recognise any difference was perhaps the most depressing outcome since before change can occur the need for change must be accepted.

Another alternative interpretation of the report could have been that of reluctance on the part of the teacher concerned to countenance that there was any need for improvement. By making the report indicate that there was no difference in practice then no reason for change would be acknowledged and thus the comfort zone of the status quo may be preserved. In order to find out if there had indeed been any difference in teaching and learning methodology it became necessary to ask the only others involved, the pupils.

7.8.3 Discussions with 7A pupils - December

At the start of December the pupils in 7A were asked to come to a meeting in the lunch hour and two science PGCE students who were on placement at the school were asked to record the responses of the pupils to a series of questions put to them regarding the module of work that they had just completed. These independent recorders were used in order to minimise bias in selecting responses either on the part of the researcher or on the part of the classroom teacher.

The first question put to the pupils was how they felt that the science that they had studied in the last module had compared to the previous module. Responses included

> " It was more like what we did at primary school. We did BAYS (British Association of Young Scientists) at primary school. We had trips and had to do different experiments to get awards. We did challenges like making rafts and structures. We brought work from outside back into school. It was better because it was more practical and had more challenges." (Gifted girl, 7A)

> "Teachers here are liars! They say that we can choose our own experiments and then they just steer us into doing what *they* want. We have only once done choosing our own experiment, with the woodlice." (Gifted girl, 7A)

> "Yeh! It's important to make your own ideas 'cos you learn from the mistakes" (Boy, 7A)

This unfavourable comparison between science as studied in year 6 and science as studied in year 7 served to reinforce the theory that pupils may indeed have less autonomy in secondary school than they did in primary school. The pupils were then asked which science activities they liked the best. The Bunsen burner experiments still remained favourites with many pupils but the woodlouse experiment also featured as a popular choice.

> "The woodlice experiment was my favourite because we got to choose and it was something real" (Girl, 7A)

The pupils were then asked which teaching activities they like the least. The vehemence of their responses took both the researcher and the recorders by surprise. Almost every pupil cited tests as being their least favourite lesson.

> " I am always embarrassed when I answer wrong" (Girl, 7A)

> " I always under perform in tests. They don't show all the other things that you *can* do" (Gifted girl, 7A)

This was the strongest evidence yet of the demotivating effect of the testing schedule. Finally the pupils were asked what else they would like to see in their science lessons. Again their replies were surprising, pertaining more to classroom management than to teaching and learning processes.

> "I like an orderly classroom" (Gifted girl, 7A)

> " Yeh! If people are shouting all you do is focus on the person shouting and not pay attention to the teacher" (Boy, 7A)

> "Yeh! There should be no shouting. It's better for learning 'cos you can concentrate on what's said." (Girl, 7A)

The conclusions drawn from the conversation with the pupils were that they definitely wanted more ownership of experiments and less testing in the classroom. They had appreciated the decision-making opportunities that they had experienced in the woodlice experiment and wanted more work done in this way. They had also appreciated being introduced to study skill techniques in concept mapping and they recognised that this had helped them to move themselves forward in their learning. They liked experiments that were relevant to real life and they enjoyed being given challenges. These opinions were equally well voiced from those who were on the gifted register as well as those who were not. It was clear from the conversations that the pupils were well aware of the pecking order in the class in terms of ability and they wanted to have more individualised learning so that everybody could work at their own pace and not be made to go too fast or have to wait for others. Pupils wanted orderly classrooms with good behaviour management from teachers and recognised that learning was more effective in such an environment.

7.8.4 Attainment outcomes 'Environment and Feeding Relationships' module, end of November

At the end of the module the pupils in both 7A and 7B sat a module test made up from past SATs questions. The mean score for each class was compared with their performance on previous modules.

Topic	**Introductions %**	**Acids %**	**Cells %**	**Environment %**
7B	81	66	74	83
7A	81	65	73	82

Table 7.2 Comparison of attainment scores for 7A and 7B on end of module SATs questions both pre and post intervention 1

There was no significant difference between 7A and 7B in terms of performance on SATs questions. This demonstrated that 7A had not been disadvantaged by the intervention in terms of attainment outcomes. It also demonstrated that the same knowledge outcomes had been achieved in the same lesson time using the alternative teaching and learning methodology. Thus the initial view of the staff that they could not cover the work scheme in the time available using pupil centred methods was, in the view of the researcher, undermined. However, this comparison of results was interpreted by the teaching staff to be evidence that the treatment of the 'experimental group' and the 'control group' had been essentially the same because the measured outcomes were the same. The question that remained unanswered was whether there were differences in unmeasured outcomes such as positivity of attitude to science and aspirations to be 'scientists'. Encouraged by the conversation with the pupils the researcher decided to continue with the intervention in order to see if any more long-term differences would become apparent between the two groups.

Another event which further encouraged the researcher to continue, occurred the following week when a lesson taken by the teacher who had written the feedback report was observed with 7B. The lesson was on animal classification. On entering the room it was found that the walls of the classroom were filled with display work from 7B. On asking the pupils how they felt about the teacher selecting their work for display the class told me that they had been allowed to select the best posters themselves and that they had done the display. Although it was originally thought that the focus of the intervention study would be its effects on the pupils, it now began to emerge that it would useful to also focus on the effect of the intervention study on the teachers. Although the teachers had maintained that the researcher had 'done nothing different', over the next few weeks in the run up to Christmas more display work became noticeable around the classrooms and the Head of Science also purchased sensors, data loggers and interactive software for the staff to use on the interactive white board. These small changes may have been unconsciously undertaken but they were nevertheless leading to a subtle change in practice.

7.9 Intervention 2

7.9.1 Year 10 December

At the start of December an intervention exercise with a group of top set year 10 pupils began. Since the most favourable response from year 7 had been in respect of being given the autonomy to conduct their own investigations, it was decided to see how a similar exercise would be received by the older pupils. At the start of the first lesson a scenario was put to pupils regarding the environmental effects of climate change and the need to ensure that all energy using devices operated as efficiently as possible in the interests of minimising energy wastage. The class was asked to consider how many devices containing electric motors they used in their home and what would be the benefits to the economy and the environment of ensuring that all of these motors ran as efficiently as possible. Following this they were asked to design their own investigations into how they may be able to improve the efficiency of an electric motor. Each pair of pupils was provided with an electric motor and a power supply and told that they could ask for any other equipment that they felt that they needed.

Many of the pupils were insecure in the face of such lack of direction. Some of the initial questions such as,

> “Are we *allowed* to look at the text book?” (Girl, 10A1)

suggested that some of the pupils thought the exercise was some kind of test. Some pupils felt at loss as to how to begin and questions like,

> “What’s the title?” and “What do we have to write down” (Boy, 10A1)

showed that some pupils felt uncomfortable with having to make their own decisions because it was such an unfamiliar experience. One boy who refused to start actually admitted that he was at a loss because he had not been told what to do and he just waited and watched what other groups started to do before he did anything. This paralysing effect of being given autonomy was interesting as it was in stark contrast to the eager way that the year 7 pupils had embraced their challenges. Perhaps this was due to the self-consciousness of adolescence and the risk of failure being a higher stakes issue with this age group. As the pupils started to familiarise themselves with the motors they became more absorbed and started to observe how the motors operated. Ways of proceeding began to be discussed. Some pupils consulted text books, some began to write out a ‘method’ whilst others tested out the equipment. Pupils had not encountered the idea of an experimental project which was to extend over several lessons before and were unused to having to exercise time management skills. At the end of the lesson the pupils were asked to list any equipment that they thought they would need to continue with the task in the next lesson, in order that the school technician could supply them with it. For many it was the first time they had considered the need to work in harness with ancillary staff.

The next lesson was two days later. At the start of the lesson there was an array of equipment supplied that was much more than had been asked for in the previous lesson. When the school technician was asked about this she said that the previous day a number of the pupils had been to see her to request additional equipment. Whether this had occurred to them by themselves or whether they had been in discussion with each other and possibly parents was impossible to say but at the start of the lesson all the pupils embarked on the experiments with a greater air of confidence. One of the boys who seemed to be getting on well was asked if he preferred to work in this way. He replied,

> " Doing it this way does mean that you have to think. It is easier if you are just told what to do" (Gifted boy, 10A1)

There were still a number of pupils who were constantly seeking reassurance that they were 'doing it right' and were somewhat uncomfortable about the response from the researcher that there was no right or wrong only the way that they wanted to do it. This was definitely an alien concept!

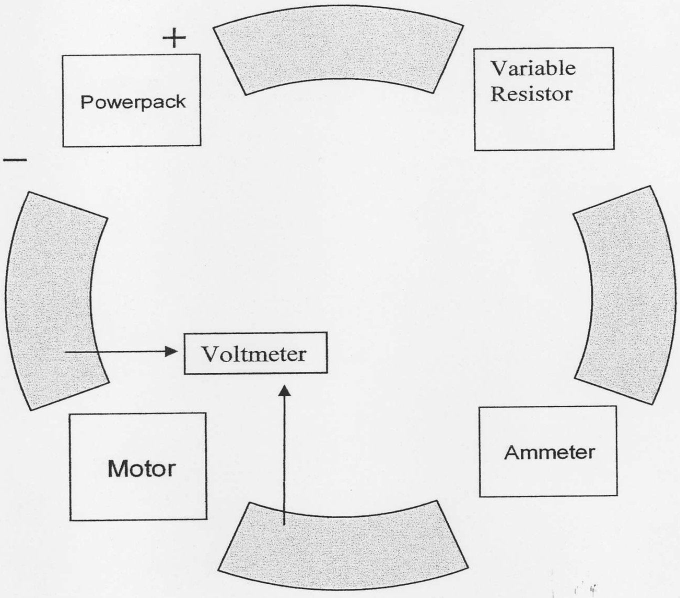
Many of the pupils had decided to test the motors by lifting weights. One of the gifted boys refused to accept that the weights supplied were actually of the value that they had stamped upon them and insisted that each one should be checked by a balance. Another boy was seen to be taking each measurement a number of times and averaging the values. One of the girls became very concerned at the flickering of the needle when she was trying to take ammeter readings and asked questions about how she could be sure to get the best reading. The degree of care that was being taken to get precise values was much greater than in any practical that had been observed with this class before. The lesson proceeded with hardly any intervention by the researcher and no 'teacher talk' at all, except to answer pupil's questions. It was noticed that when the bell went signifying the end of the lesson most pupils were still working and were reluctant to have what they were doing cut short. Some pupils wanted to know if they could return in the lunch hour to continue with work that had been cut short. Despite initial misgivings and insecurities the willingness of some pupils to use their own free time indicated that this autonomous exercise was proving to be motivational.

As the pupils entered the room for their last lesson on the project they collected their equipment and began work without a word from the researcher. A number had arrived during the middle of break time because they wanted to get started. By this time pupils were at different stages of work, with some engaged in calculating and analysing results and others still taking readings. The pupils simply resumed work from wherever they had left off the previous lesson. The final reports produced by the pupils demonstrated that through this exercise they had encountered both new knowledge concerning the operation of motors and new skills in 'project management'.

Electric Motor Efficiency Experiment

I have performed an experiment to work out the efficiency of an electric motor when pulling different loads. From these calculations I will find the optimum load for the motor.

Method



- The current flows clockwise around the circuit.
- The voltmeter is set up in parallel across the motor.
- The motor is held in a clamp stand.
- The motor had weights (load) attached using string as the pulley.
- The string is kept from slipping with blue tack.

We needed to find the current, voltage, time, mass of weight and the length of string the motor pulled. The mass was easy to find as we loaded the weights, we used a stopwatch for the time, the voltage and currents were read off the meters and the string length was measured with a metre stick.

Results

Electric Motor Efficiency Experiment

	Current (A)	*Voltage (v)*	*Mass (kg)*	*Time (secs)*	*Length of string (cm)*
Result 1	0.59	3.63	0.105	1.33	65
Result 2	1.26	5.96	0.155	1.59	65
Result 3	1.34	8.75	0.205	1.55	65
Result 4	3.46	6.78	0.255	1.66	61

To find the efficiency of the motor which is the objective we use the formulae

- efficiency=useful energy output/total energy input then *100 for a percentage.

For the useful energy we do: current*voltage*time.
The energy input is found using: (mass*gravity field constant) *height because the useful energy is gravitational potential energy.

Result 1
Useful energy=0.59*3.63*1.33=2.848461 joules

Energy input= (0.105*9.81)*65=66.95325 joules

2.848461/66.95325=0.042544 *100=4.25%

Result 2
Useful=1.26*5.96*1.59=11.940264

Input= (0.155*9.81)*65=98.83575

11.940264/98.83575=0.120809*100=12.08%

Result 3
Useful=1.34*8.75*1.55=18.17375

Input= (0.205*9.81)*65=130.71825

18.17375/130.71825=0.1390299…*100=13.90%

Michael Bradbury 10A1

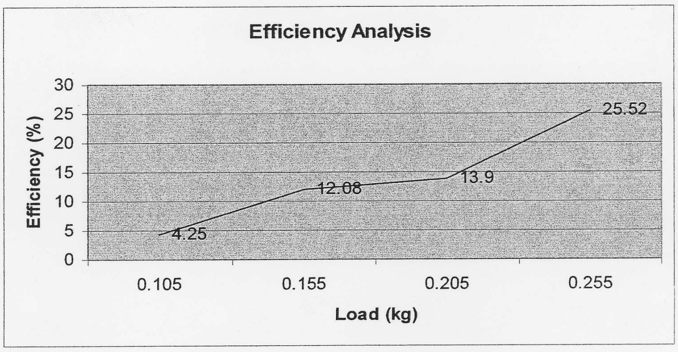
Result 4
Useful=3.46*6.78*1.66=38.941608

Input= (0.255*9.81)*61=152.59455

38.941608/152.59455=0.255196…*100=25.52%

Analysis

Load (kg)	Efficiency (%)
0.105	4.25
0.155	12.08
0.205	13.90
0.255	25.52



This graph shows me that as the load increases we approach the optimum load for the efficiency of the motor.

If I could start this investigation I would collect more results with a wider span, hopefully to find the optimum load exactly. I would, however, definitely still keep the set-up of the equipment the same because I thought this worked well

From this experiment I have learned that just providing the motor with the lightest load possible is not the most energy-efficient method as I previously thought

If I were the craft engineer in a space factory I would now perform a similar experiment on my machines to examine the weight of craft that optimises the efficiency of the motors to lift them onto the platform.

Figure 7.7 Example of scientific enquiry work in year 10 during intervention 2

However, the major difference between this work and the work seen previously was in the pupils' ability to evaluate what they had done.

> "After looking at my results table, I noticed that the figures didn't seem realistic! (e.g. the efficiency). After a lot of thought, I realised that I had written the mass in the wrong units (it should have been in kg not g) Therefore my graph is actually wrong but the shape of it is probably correct. So I can still see

> from the graph the weight at which the electric motor was most efficient" (Girl, 10A1)

> " I found that by the time we had set everything half the lesson had gone. There were also hurdles to overcome during the experiment such as the string breaking and because there was little friction between the string and the motor, the motor just spun around and didn't pull up the string. I think next time I would use thicker string and tie it tighter to the motor." (Girl,10A1)

> "While doing this experiment my problems included the string snapping, weights swinging, crocodile clips detaching and I had problems trying to adjust the variable resistor to run the motor at the desired speed. If I repeated the experiment I would use stronger string, but it would still need to be thin to coil around the motor. I would try to attach the crocodile clips from the voltmeter at other places apart from immediately beside the motor, as these cause the motor clips to detach easily and I had more risk of short-circuiting. If I could get a more accurate variable resistor, I would use that, because when you can set a slow steady speed you can time the experiment much easier, the slower it runs, the less your reaction time matters. Finally I would use a wider range of weights, maybe increasing by 20g each time as the better efficiencies would show up clearer. To save money we must have a higher efficiency when operating the motor. Heat causes more resistance in the motor, which in turn decreases its efficiency. Therefore we should look to get rid of the heat in the motor. One possible way would be to attach a metal pieces with a large surface area to distribute this heat." (Gifted boy, 10A1)

The fluency of the extended writing had not been seen in any of the previous lessons and showed that the pupils were capable of much more than the short structured responses that they had been drilled to produce in practising past SATs questions. The level of thought given to the experiment also was much more detailed than any work seen previously. When asked to conclude what they had learned in their project the replies showed that the pupils had considered not just the results that they had obtained but also the processes by which they had obtained them.

> "I conclude that the whole experiment seemed to go well except for the mistakes in my results. It was good to be left to our own devices. There were some problems but we managed to overcome most of them. I have found changes that I could make to the experiment which would make it run more smoothly next time. I have also learned how to use an ammeter and a voltmeter." (Girl, 10A1)

> I have learned a lot from this experiment. My original thoughts were that perhaps a smaller load would be more efficient as it would be lighter and therefore lifted at a quicker pace. I have also learned that even the slightest change in efficiency would have such a dramatic impact on energy losses. It is unbelievable that something we class as so irrelevant can make such a

> difference. Overall despite various difficulties, the experiment was quite successful and I thoroughly enjoyed the freedom and independence given throughout the task." (Gifted girl,10A1)

Despite the intervention period having been only 3 lessons there appears to have been a number of outcomes worthy of comment. Many pupils, who were initially intimidated by being given responsibility for planning their work, did eventually cope well and achieve good results. Some even commented that they had enjoyed being given this autonomy. A few of the less confident and less able pupils had felt most out of their depth but by imitating the work of their peers they too had completed the task. The degree of verbal fluency, commitment to the task and personal organisation had also improved. Pupils had engaged with higher order thinking skills and had continued to work on the task in their time at home. Many had conducted internet searches or obtained books from the library to help them and all the pupils had consulted the school textbook for guidance on how to calculate efficiencies. Most pupils thought they had worked harder in these lessons than in previous ones.

7.9.2 Discussion with year 10 pupils - December

During part of the next lesson a discussion group was held, with pupils being able to comment upon how they thought the last three lessons had been different from their usual ones and which they preferred. As with the year 7 discussion PGCE students were used as independent recorders to note pupil responses. When asked how they had felt about being given ownership of the investigation the responses varied from those who had appreciated this autonomy to those who had felt intimidated by it.

> " I found it quite scary to have to make the decisions" (Girl, 10A1)

> "It was daunting at first but once you got into it, it was okay" (Gifted boy, 10A1)

When asked, if they were to be given another investigation to design themselves how many would feel more confident about it now 90% of the pupils (by hand count) indicated that they would feel more confident. When asked what exactly had been good about the exercise pupils responded,

> " We could make mistakes and learn from it" (Girl, 10A1)

> "It makes you think for yourself" (Gifted girl, 10A1)

This freedom to be allowed to make mistakes was seen by the pupils as a distinct advantage of autonomous learning. The sense of being in control had enabled pupils to adopt trial and error approaches and removed the pressure of not always having to get 'the right answer'. However the preference for autonomous learning amongst year 10 pupils was less than had been the case for year 7. About one third of the class said that they preferred the autonomous approach and the remainder did not have any strong preference one way or the other. Perhaps autonomous approaches need to be embedded into teaching and learning methodology at an earlier stage than key stage 4 in order for them to be willingly embraced.

7.9.3 Discussions with science department - January

At the first science staff meeting of the Spring Term (end of January) the intervention with year 10 was discussed. The classroom teacher who had observed the intervention lessons (The Head of Science) produced a report on the intervention and subsequent work that he had done with the class stating

> "The class are now much better at evaluating their own work than has historically been the case before the 'autonomous learning' approach. They are able to think and answer the question, 'What would you do to extend your investigation?' They are exhibiting better skills of transfer of knowledge from one topic into another. They have a raised self-esteem. As a result of this it may be a good idea to change the year 10 work scheme to include opportunities for autonomous investigations with the intention of better provision for more able groups."

This response was much more encouraging than had been the case in the November meeting. If the work scheme were changed then it would have a significant impact upon departmental practice. There did seem to be a small but detectable shift in the way that the department was thinking about the pupils as individuals with different individual needs rather than the 'whole class' approach that had been seen previously.

It was decided to invite both the science staff and the most scientifically gifted year 10 pupils to a 'Saturday School' at the University, in the next term, in order to allow staff to see at first hand what the pupils may be capable of when given the freedom to direct their own learning.

7.9.4 Post intervention observation Year 10 February

During the next month four further lessons were observed with 10A1. It was observed that pupil – teacher interaction increased with pupils asking more questions than they had previously. Pupils were also asked to *predict* more regarding what they thought was going to happen prior to demonstrations being carried out. Although pupils sometimes found this difficult the gifted pupils in the class responded well and were prepared to give it a go, further encouraging the others to take part. There were also more independent research tasks given to the pupils for homework, requiring higher order thinking skills. The teacher also introduced a set of laminated wipe on / wipe off sheets which the pupils were to use to write down their answers to questions. Since the writing was erasable the pupils lost some of their fear of ‘giving the wrong answer’ and became more willing to take risks in hypothesising and describing their thought processes. The level of work had also been raised and some of the work covered was outside the GCSE examination specification and was leading directly into Advanced Level work. Pupils were also encouraged to use analogy to describe concepts and to describe experimental behaviour from the interpretation of graphical representations. The expectations of these pupils were now notably higher than had been the case before the intervention.

The unanticipated outcome of the action research to date was proving to be its impact on the practice of the teachers and consequent indirect impact on pupils, rather than a direct impact on pupils as had been thought originally. This was beneficial because through the changes in practice of the teachers the impact on pupils was wider than had originally been anticipated. The insight gained from this observation was that action research *in itself* was proving to be not just a means by which research data may be gathered but also an effective agent for change.

7.10 Intervention 3

7.10.1 Observation - Year 7 February

Staffing changes due to a maternity leave at the end of the autumn term meant that a new teacher was now teaching both 7A and B so one purpose for the period of observation was to develop the working relationship between the new classroom teacher and the researcher. During the first lesson observed it became apparent that this new teacher had a very different style to the previous teacher as he was much more authoritarian in approach. However, the teaching and learning activities observed during this introductory phase were similar to those observed with the previous teacher in September

- Question and answer sessions
- Demonstrations
- Dictation
- Extended writing
- Instructed practicals
- Answering structured worksheets
- Tests

The topic of work being studied was molecular theory which contains some abstract concepts requiring visualisation skills and many pupils asked questions indicating that they had difficulty in visualising the concepts discussed. Again the 'right answer' philosophy permeated the classroom and pupil discussion and diversification was quickly closed down in pursuit of getting the 'right answers' into the pupils' books. During the first lesson observed it became apparent that some pupils held misconceptions regarding this topic e.g. that particles in a solid expand as they are heated but no molecular modelling was used to try to correct this.

During the second lesson, pupils were asked to consider whether particles in the air were squashed when the teacher clapped his hands. This led to some argument between pupils and some deeper thinking about the topic. However, dictated notes were given at the end of this rather than pupils expressing their own thoughts. The third lesson observed was on the subject of 'mixtures'. This was a practical lesson but culminated in dictation at the end of the experiment. Pupils were not allowed to decide for themselves how to describe what they had done. The final lesson was the end of topic test, which was greeted with little enthusiasm by the pupils. Over the four lessons pupils were given no opportunity to make any decisions about their classroom activities and, despite the change of teacher, little seemed to have changed for this class since the previous September.

7.10.2 Intervention 7A March

The intervention topic which followed was on circuit electricity. During the first lesson pupils were given an introduction to symbols used for circuit components and then asked to find out how many different ways they could find to connect a cell to three bulbs. Overall, the lesson was not successful because it had tried too great a leap from introductory basics to an expectation of autonomous learning without the scaffolding of some intervening structure to circuit building. Translation between 2-dimensional circuit drawings and 3-dimensional constructions was an essential skill to be mastered before the pupils could be expected to design and build their own experiments. A scaffolded structure, provided at the start of the next lesson resulted in the pupils being much more engaged. By the end of the lesson all pupils, even the more reluctant, were able to construct circuits from drawings. Pupils seemed to enjoy the circuit building challenges that they were given now that their confidence level had increased.

In order for the researcher to ascertain what mental models the pupils held regarding the nature of electric current, the pupils were asked to design and draw a 'storyboard' for homework which modelled what the behaviour of charged particles in circuits was like. This was to involve a mixture of diagrammatic representations and words explaining a 'story' that modelled the flow of an electric current. A number of stories were drawn and presented to the class by pupils.

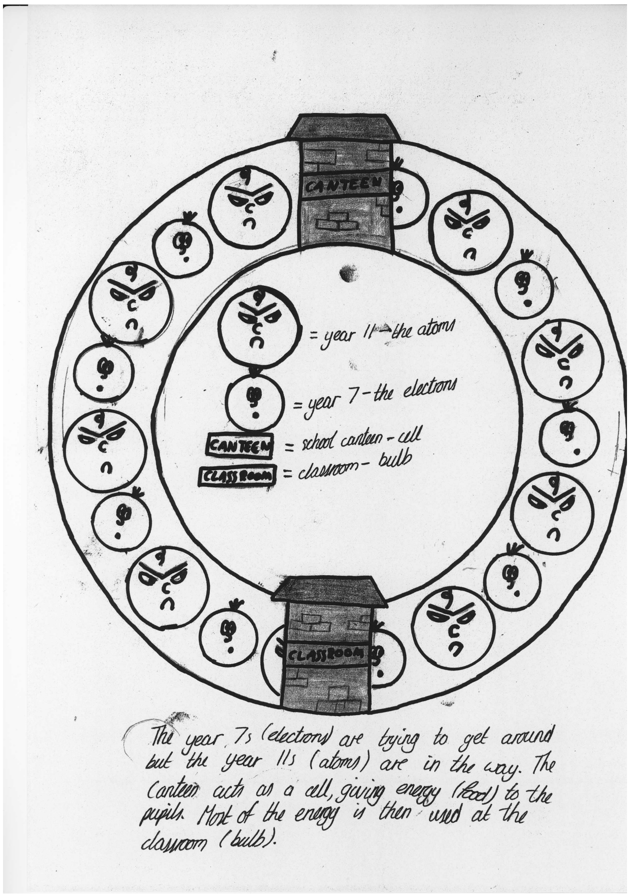


Figure 7.8 Example 1 of modelling by year 7during intervention 3

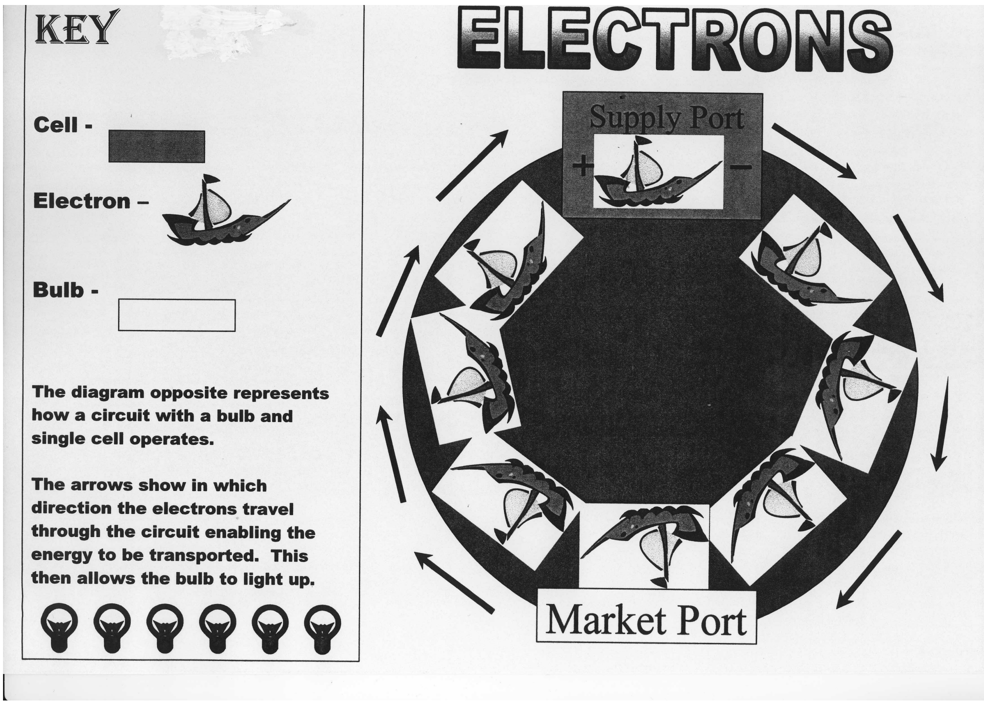


Figure 7.9 Example 2 of modelling by year 7 during intervention 3

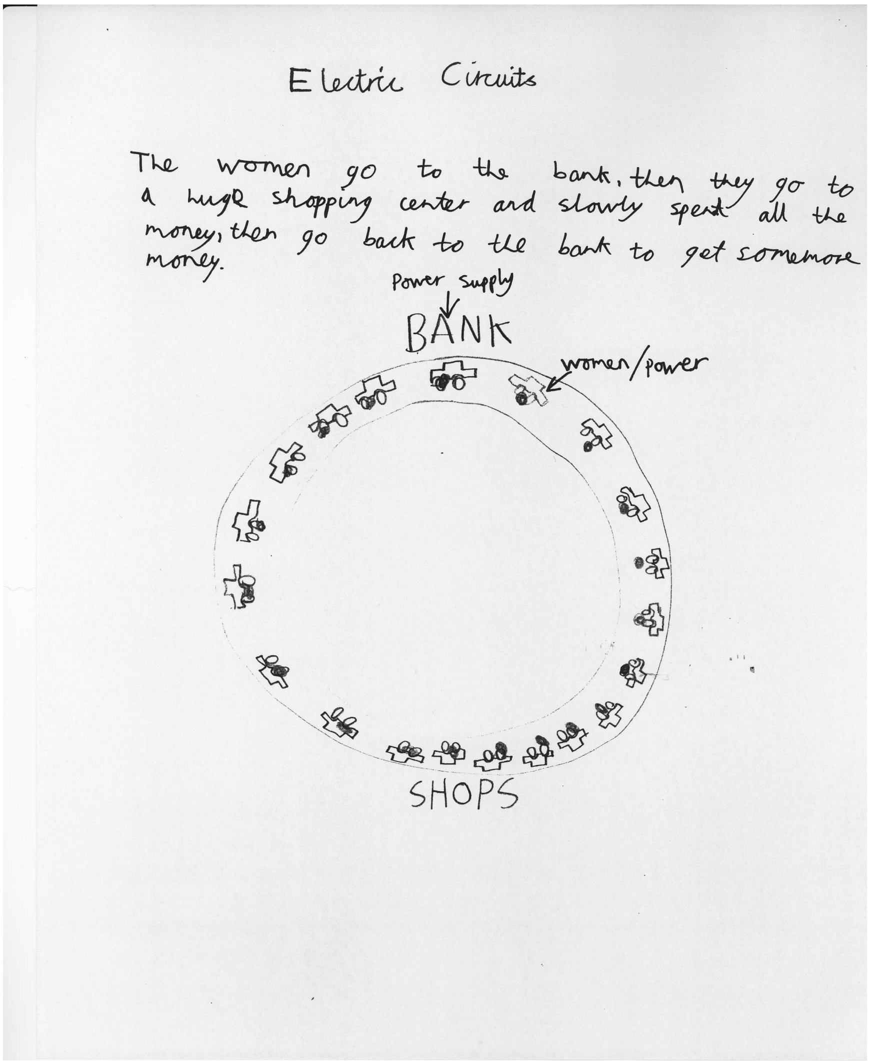


Figure 7.10 Example 3 of modelling by year 7during intervention 3

The modelling exercise revealed that most of the pupils now had good ideas about resistances in circuits and the energy transformed into heat as the charged particles passed through the resistance. The researcher decided that a sufficient knowledge base now existed for the pupils to be able to attempt some autonomous investigations. However, because there were different levels of confidence and different paces of working, the pupils were offered a choice between a 'green' task for the more confident and an 'amber' task for the less confident.

At the start of the next lesson all the pupils were given the 'green' task, investigation into how a fuse works and 'amber' task, investigation into how a dimmer switch works. The 'amber' task had a more scaffolded set of instructions and the green task had no scaffolded instructions at all. The pupils were told that they had a free choice of which task to do. Only one group chose to do the ‘amber’ task and when they observed that they were the only group doing that task they quickly changed their minds to do the other task. It was interesting to observe the subtle effect of the peer pressure at play. Although the group involved would have felt more comfortable with the amber task they said that they had changed their minds because the task was ‘too easy’. This may have been the case or it may have been more likely that this group did not want to be thought inferior to the others.

For the fuse wire task pupils were given a range of different fuse wires and asked to investigate what affected how much current a wire could carry before it melted. They were given no further instructions. Appropriate warnings were given over potential burns and pupils were supplied with heatproof mats upon which to place the wire. For the first half of the lesson most pupils just took different pieces of wire and applied larger and larger voltages to them until they melted, without necessarily thinking about controlling variables such as length and thickness of wire. This caused a great deal of excitement and it wasn’t until the initial flurry of excitement died down that pupils actually addressed the point of the activity.

The groups took a great deal of time to decide on a plan for the investigation and argued between each other on what was the best way to go about it. However the pupils were totally engaged with the task and did seem to be enjoying the freedom of being able to decide on their own plan. Since the class had spent a great deal of time in preparatory ‘playing’ they were told that they could think about the task for homework and come up with a plan in their books for the next lesson. When pupils’ books were examined the morning before the next lesson it was clear that a great deal of work had been done. Pupils had written plans with diagrams explaining what they intended to do. Most pupils intended to change the thickness of a fixed length of wire and see how much current it took to melt it. Some pupils had more complex designs where they intended to take the temperature of the wire for different values of current passing through it or to use the wire to warm up a beaker of water and take the temperature of that. Most of the pupils had the idea of fair testing and controlling other variables e.g. length, and others said that you could do length tests as an additional experiment. One pupil wanted to find out what difference it made if the wire was coiled as opposed to uncoiled. There were only two out of 32 pupils who had not managed to formulate a plan. However since this task had been given for homework there was no way of knowing how much input parents or siblings may have had.

At the start of the next lesson pupils were told to carry out the plans that they had prepared. Most managed to do this without too many problems and recorded the values of current for which fuse wires of different thicknesses melted. Two of the boys on the science gifted register argued over how to find the thickness of the wire and devised a folding technique for measuring the thickness of several strands and then dividing by the number of wires. Most pupils just called the wires thin, normal and fat and did not apply a great deal of quantitative analysis to their work other than recording on an ammeter the value of the maximum current before melting. One pupil observed that the current dropped just before the wire melted and speculated on why,

> "I think when it starts to melt one bit goes thinner and that makes the resistance bigger so the current can't get through so easily" (Gifted girl, 7A)

Eventually all the pupils had managed to conduct a basic investigation and some had managed to achieve quite complex experimental designs, manipulating both changes in thickness, length and shape of fuse wire. Pupil comments recorded during the experiment indicated that they had considered the relevance of what they were learning to the home and some had discussed the task with parents.

> "My Dad showed me how the cooker fuse wire is thicker than the lights' fuse wire so I think that the thicker the wire the more current it needs to melt it" (Girl, 7A)

> " Do you get different thicknesses of wire in different light bulbs? " (Gifted girl 7A)

It was observed that the pupil centred activity meant that the learning outcomes had varied for different pupils since some investigations had taken alternative directions to others. Did this matter? It was also observed that the presentation of pupils' bookwork had improved considerably compared to previous dictated work. This may have been because the pupils could write at a pace that suited them rather than having to keep up with the dictation of the teacher or it may have been that the ‘ownership’ of the task had led to greater pride in how the work was presented in their books.

7.10.3 Discussion with science department - March

At the end of this intervention the two teachers, who had been observing the intervention lessons, gave a brief report at the next science department meeting.

> “ Pupils in 7A were taught without recourse to any of the ‘in house’ worksheets and without using the circuit boards that are normally recommended for this unit of work. It was interesting to note that when using devices connected by standard wires pupils could not recognise when two circuits were actually the same but their circuit drawings had been configured differently. Pupils had the misconception that moving the position of the bulb in a series circuit actually changed the circuit. It was also surprising how many pupils had difficulty in drawing circuits from the 3D reality. Our worksheets do not ask them to do this.”

A discussion then ensued of the pros and cons of the use of circuit boards versus ordinary circuit components and wires. This was the first time that the observer had encountered an open discussion of practice and this provided evidence that science staff were actually reflecting on their own practice and were prepared to consider alternative models for teaching and learning. The report continued,

> “ It was interesting to observe pupils expressing their understanding in different ways – through a poem or story. This did reveal pupil misconceptions in a way that the use of worksheets may not have.”

The science staff then discussed how the use of different methodologies actually provided them with information such as degrees of pupils’ spatial awareness and erroneous concepts in a way that the structured worksheets may not have done. There was some agreement that whilst the worksheets revealed what the pupils did not understand, they did not reveal why they did not understand it and that additional teaching and learning methodologies may be necessary to give teachers a fuller picture of the nature of pupil difficulties. The final point made in the report was,

> “Pupils who were given ‘investigation’ exercises before they had sufficient prior knowledge and conceptual understanding struggled to succeed with the investigation task but once they had a reasonable grounding in the topic pupils were able to proceed to worthwhile outcomes. However, the exercise was time

> consuming and some pupils went off at a tangent to the topic, making their learning not relevant to the end of topic test."

The issue of time taken and learning outcomes achieved was still of overriding importance for many of the science staff. A discussion ensued of how much time could be 'sacrificed' for 'investigational' teaching. However, the Head of Department said that he felt that the benefits of the exercise made the methodology worth adopting 'occasionally' when time and the nature of the topic permitted and he felt that there were opportunities for including more investigative work within the work scheme. An agreement was reached that when such exercises were undertaken the intervention of the teacher should be "just enough for pupils to be helped to overcome difficulties but not enough to do it for them".

After seven months of working with this department a sense of changing culture was beginning to emerge. Science staff were much more comfortable about having their own practice and that of their colleagues questioned. They had accepted that no appraisal was being carried out that would reflect upon them professionally and that the spirit of the work was collaborative, in the interests of improving practice and outcomes for both themselves and their pupils. More 'reflective practice' was emerging with the result that teaching was becoming less formulaic and more intuitive. It was also noticed that the atmosphere of the staff meetings had also changed. There were fewer 'grievances' being expressed about work pressure, new government initiatives and the agenda of accountability and there was a more energised approach to new resources and to the adoption of methodologies that the teachers themselves might enjoy. A perception that changing teaching and learning methodology might actually stimulate greater fulfilment *for teachers* was emerging.

In order to keep this momentum going the science staff were invited to come to the University to observe a selection of year 10 pupils carrying out science activities at the forthcoming Saturday School and to give feedback on what they observed.

7.10.4 Discussion with 7A pupils - March

An invitation to pupils to come back to the science laboratory during a break time resulted in only 9 pupils turning up. This may have been a biased sample since these were obviously more motivated than others, as their presence evidenced. Pupils were asked how they felt their electricity lessons had differed from the previous module. Again the main response was that they had done more practical work. However other replies indicated that they had done more work overall.

> " We had to work harder because we weren't told what to do." (Gifted boy, 7A)

> "It was good that we could go as far as we wanted and work at our own pace" (Gifted girl, 7A)

> "I did more writing than in other lessons but it was okay because it was what I wanted to write." (Boy, 7A)

The pupils were then asked whether they thought that designing the investigation had been a hard thing to do. Their responses indicated that they had found starting the task difficult but once they had an idea of what to do they enjoyed the empowerment of making their own decisions.

> " It was easier to write about when you had done it and it was good that you could do what you wanted, like doubling the wire or coiling it and seeing what happened. We should have more practicals where we can do that sort of thing" (Girl, 7A)

It would have been easy to interpret the exercise as a very positive experience for the pupils but since the group was not representative of the class as a whole it would have been unreliable to claim this. In order to get a better idea of whether the pupils had improved in their understanding, it was felt necessary to look again at the attainment scores for the module compared to those of 7B who had followed the normal methodology as laid out in the scheme of work.

7.10.5 Attainment outcomes 'Electricity' module - March

The end of topic test carried out with both 7A and 7B was again made up from SATs questions. Some of the higher level questions tested both knowledge and understanding of electrical circuits but again there were many other possible learning outcomes that could not be accessed by this test.

Topic	Introductions %	Acids %	Cells %	Environment %	Classification %	Electricity %
7B	81	66	74	83	83	82
7A	81	65	73	82	82	79

Table 7.3 Comparison of attainment scores for 7A and 7B on end of module SATs questions both pre and post intervention 3

The mean mark for 7A was 3% lower than that for 7B but this was not statistically significant and the only valid conclusion was that the attainment scores for 7A had not been significantly influenced by the intervention. Thus the pupil centred approaches to teaching and learning did not appear to have been detrimental to the mean attainment score for 7A. The original argument put forward by the science staff that by spending time on autonomous learning methodology pupil attainment scores would suffer appeared to be groundless.

7.10.6 Post intervention observation 7A - April

After the completion of the intervention exercise class 7A were observed for a further three lessons, with two different staff. At the start of the first lesson pupils were asked to write a story about the creation of fossil fuels. Pupils found this free writing exercise difficult to do since they had little knowledge and had to keep referring to the textbook. Since the pupils were not writing from their own experience they found the sequencing of events difficult. The teacher reacted by allowing the pupils to draw the story in cartoons. This resulted in more engagement with the task and some pupils were selected to draw their cartoons on the board and explain them to the rest of the class. Once the drawings had helped to sequence the order of events the pupils were then enabled to return to the writing task and proceed more effectively. This scaffolding of the writing task was a definite change in teaching methodology and resulted in pupils being able to write accurate and well-structured accounts about the topic.

The second lesson with a different teacher began with a question and answer session on alternative energy sources. Pupils were slow to respond and the teacher asked them to write some bullet points in their notebooks on what they knew about alternative energy sources to fossil fuels. Pupils were still not responding well and so a debate was organised about whether or not to build more nuclear reactors. Through this debate the pupils showed that their knowledge was actually quite extensive and were enabled to write the bullet points. The extended writing task was then given as a homework exercise. This constructivist approach was a change from previously observed didactic practice and the researcher began to feel that a classroom culture change was indeed underway. However, in the final lesson observed the opening question and answer session went on for 25 minutes by which time the pupils were tiring of the topic. The class was becoming disorderly and the teacher gave a copying task to restore order. The observed behaviour of the teacher was very much of someone anxious to maintain control above all else. The observation illustrated how difficult it can be for teachers to 'let go' of teacher directed methods. The responsibility for behaviour management is viewed to belong to the teacher and allowing pupils to have autonomy within lessons can feel like a 'loss of control' on the part of the teacher. Before autonomous learning practices can be adopted teachers must feel confident within their classroom and unintimidated by issues of behaviour management.

The conclusions drawn from this last observational phase were that practice was changing within the school albeit gradually but that in order for change to occur teachers need to recognise the need for change, be enabled to implement change free from the constraints of a rigid work scheme or the pressure to achieve externally imposed performance figures, become open and reflective about their own practice and that of others and feel confident in their role as behaviour managers.

7.11 Enhancement activities - April

7.11.1 Autonomous investigations as enrichment activities

In April a group of twenty of the most scientifically gifted Year 10 pupils was invited, along with their science teachers to a Saturday School held at the University of Keele. The purpose of the day was for pupils to be able to spend some extended time working on autonomous investigations and for their teachers to observe their progress. The pupils had not been specifically prepared, in any way, for what they would encounter during the day. The theme for the day was 'The Physics of Music' and the pupils experienced five workshops, each addressing the physics behind a different musical instrument.

- Why does it matter where you put the holes in a recorder?
- Why do different sized drums produce different sounds?
- How do electric guitars work?
- How can you make a set of tubular bells that sound harmonious?
- How can we make electronic music?

Groups of pupils were assigned to tasks in turn and were allowed to design their investigations autonomously, with physics PGCE students and a laboratory technician to assist them. All of the equipment used was similar to that readily available in school and where additional equipment had been needed it was sourced locally e.g. the recorders were made from plastic plumbing pipe, the tubular bells from copper pipe, the drums from rubber sheet stretched over plastic bins and electric guitar pick-ups had been bought from a local music shop. Student facilitators had been instructed only to engage in 'Socratic' questioning so that pupils were not *told* how to do anything but their thinking was prompted and possible lines of enquiry emerged from discussion. Facilitators ensured that safe practice was followed and that pupils were supplied with all the equipment that they requested.

Quite quickly the pupils responded to the opportunity to do 'off the wall' activities and they were soon drilling holes in plastic pipe in different places to investigate how it changed the sound in their 'recorder', sprinkling sand onto drum skins to see how they vibrated, cutting copper pipe to different lengths and testing the note that it produced when struck and changing the length, tension and thickness of guitar strings. The pupils were not required to write anything down but they did have to discuss with the others in their group the design of their investigation and this often involved them in drawing out their ideas on paper. The pupils had prior knowledge of sound and wave theory from school lessons and some were proficient in playing musical instruments so had a good knowledge base from which to operate. However, they did need to transfer what they knew from school to the new situation and most showed an ability to do this. There was also a source of textbooks and Internet access in the laboratory for those who wanted to look up information. The pupils were engaged with the activities and debate between them became quite heated when they conflicted in their design ideas. All pupils were involved and if any pupils were reticent student facilitators actively encouraged them to take a role in the activities. Frequently pupils would refer to the observing teachers, telling them what they had found or drawing similarities between what they were doing and what they had done previously at school. When refreshment breaks were announced pupils were reluctant to stop what they were doing indicating that pupils were motivated to complete their tasks.

The observing teachers watched the pupil activities closely and sometimes expressed surprise at the abilities seen that had not previously been seen in the classroom. The sophistication of some of the experimental design was also commented upon but most expressed doubt that the same could be achieved within a science lesson in school because of the level of organisation involved and the extended time frame offered.

At the end of the day the pupils were assembled in one room and the teachers in another and two separate group interviews were conducted.

7.11.2 Pupil feedback on the enhancement day

The first question put to the pupils was how they felt the activities done that day compared to those done in school. There were a number of positive comments made as pupils compared the workshops to lessons in school.

> "They were more practical and they made you have to think more. They weren't boring or monotonous" (Year 10 boy)

> "We have used instruments that we have never seen before and we have had a clear visual on the outcomes of different actions. We have seen the use of waves in real life situations. It was a lot more hands on" (Year 10 girl)

> "It gives a better variety to see how physics principles can be used in real life. It also gave you views from many people" (Year 10 girl)

The pupils were then asked if they felt more confident as a result of the work they had done. Most pupils admitted that they had been apprehensive at the start but ended up feeling pleased by what they had achieved.

> “Yes. I know more than I thought I did. It’s just a case of having a go” (Year 10 girl)

> “Yes, because when I tried to explain things other people told me what was right or wrong about what I said. It also refreshed my memory about physics topics that I have covered before.” (Year 10 girl)

When questioned about how they felt about having to make their own decisions most indicated that they had not felt intimidated but there were still some who expressed some hesitancy.

> “I really enjoyed taking the initiative” (Year 10 boy)

> “I put forward my view of what would happen in the experiment and helped to set it up, which made me feel more confident” (Year 10 girl)

> “I answered some questions but other people took over a bit. I didn’t really mind because I wasn’t very confident.” (Year 10 boy)

The pupils were then asked whether they preferred to do science activities where they made the decisions or ones where they were told what to do. There was some variation in how pupils felt about this, mostly connected with being given challenges that were too hard or having too much expected of them and feeling pressurised.

> “I prefer it when I make the decisions because I think more and learn better” (Year 10 girl)

> “I prefer to come to my own decisions but have the knowledge behind it told to me” (Year 10 girl)

> “ I like making decisions with people there to guide me along in the right answer rather than being instructed because it is a better way to learn as it gives you more freedom.” (Year 10 girl)

> “I prefer to be instructed so I know what I’m doing” (Year 10 boy)

The final question posed to the pupils was whether the Saturday School had changed their attitude to science education. However since the pupils invited had been those who were identified as gifted in science, most of them already had positive attitudes and were thinking of studying science further beyond GCSE.

> "It has not changed my attitude as I enjoy science anyway but it has improved my understanding and refreshed my memory of what I already know" (Year 10 girl)

> "Yes. It's made me more confident and I'm going to try harder in lessons and suggest we do more practicals." (Year 10 girl)

Overall the pupil feedback was favourable. However caution is needed before concluding that this methodology could be applied to all pupils because the sample was not representative of the full ability range in school. However, it would appear that for the scientifically gifted pupils who attended, the experience had been positive and may have given them a different perspective on the continuing study of science.

7.11.3 Teacher feedback on the enhancement day

A group interview held with the observing teachers at the end of the day enabled those observing to voice their opinions regarding what they had seen. When asked whether what they had observed had given them any new thoughts about their own teaching back in school almost all the teachers indicated that the day had provided food for thought.

> " I appreciated how much science could be taught through the use of household or recycled materials" (Chemistry teacher)

> "The different contexts for teaching physics principles were very useful and I will certainly use some of them in the classroom" (Physics teacher)

> "The learning activities were beyond the curriculum and encouraged me to teach 'outside the box'" (Physics teacher)

Teachers were then asked to consider the advantages and disadvantages for pupils of participating in enhancement days. All the teachers perceived that there were far more advantages for the pupils than disadvantages.

Advantages	Disadvantages
Fun and light hearted	Giving up their own time
No assessment	May be intimidating
Very practical	
Increases confidence	
Application of basic skills	
Uses new skills	
A good reinforcement exercise	
Applies existing knowledge to new situations	
Gives a chance for pupils to progress their thinking skills	
Encourages pupils to take a deeper interest	
A positive learning environment	
Getting first hand high level explanations for what they observe	
More personalised learning	
More opportunities for discussion	
Getting their questions answered	

Table 7.4 Teachers' perceptions of the advantages and disadvantages of enhancement activities for pupils

Teachers were then asked what they thought the advantages / disadvantages had been for themselves in attending the enhancement day

Advantages	**Disadvantages**
Fun and light hearted	Giving up my own time
No marking	
Very practical	
Increases confidence	
Uses new skills	
Gave an opportunity to talk to other teachers about teaching and share strategies	
Interact with pupils in a different environment	
You see different ways to introduce concepts	
Working with positive pupils	
Learning about how to engage pupils	
Deepened my subject knowledge	
Gave me ideas for the classroom	
Insight into ways to get difficult ideas across	

Table 7.5 Teachers' perceptions of the advantages and disadvantages of enhancement activities for themselves

These responses from the teachers were enlightening and served to emphasise the contrast between the kind of activities experienced and their usual classroom experience. This was reassuring in that it helped to strengthen the argument that the autonomous learning activities were indeed different to what took place in many classrooms despite initial views of the teachers in the early days of the action research that ‘they do this sort of thing anyway’. Teachers were then asked if what they had seen on the enhancement day had served to make them revise their opinions of what the pupils were capable of.

> “Yes. Pupils can be more engaged when thinking outside the curriculum box. It challenges their learning” (Physics teacher)

> “The pupils were much more open and forthcoming in a positive environment” (Chemistry teacher)

It appeared that most of the teachers knew what the pupils were capable of but not how to get them to perform to this maximum capability in the classroom. The difficulties discussed seemed to lie more in school culture and pupil attitudes to learning than in a lack of willingness by teachers to be innovative. The final question put to the teachers was whether what they had observed would have an impact upon their classroom practice.

> “Yes. I will try to include more open ended challenging activities in the classroom to see if it produces a more positive learning environment.” (Chemistry teacher)

> “I would use this as a ‘science day’ to promote the take up of A level physics.” (Physics teacher)

> “It would depend on class behaviour. It might be better to use this approach for an after school science club.” (Biology teacher)

> “ Not sure! It would be exciting but one teacher with 30 children could possibly not have the same atmosphere. Also evidence of learning would probably need to be produced.” (2nd Chemistry teacher)

7.11.4 Conclusions and reflections

The activities experienced by the able and gifted pupils and their science teachers on the enhancement day had a positive effect on the day but how well that would translate back into the classroom was yet to be determined. It was interesting that the teachers' comments indicated that the day had been a positive experience for them as much as for the pupils and highlighted the issue of the role of staff morale in schools and it's effect on the classroom. Many of the teachers had felt that the enhancement day had dealt with smaller numbers in a more positive learning environment than regular school science lessons. Many cited constraints in school that they felt did not apply to the enhancement day.

The question arising was why the teachers felt that this positive learning environment could not be achieved in school, especially amongst the best and the brightest pupils, who should be encouraged to continue with the study of science beyond GCSE. The science teachers were now beginning to question their slavish adherence to the 'work scheme' and perhaps were beginning to see that by 'teaching outside the box' and giving greater ownership of their learning process to the pupils, a more facilitative learning environment may be achieved and interestingly not just for the pupils but also for themselves.

One outcome of the observational exercise for the researcher was to underline the role of research in providing a medium for the professional development of teachers. Although this observation had only been a small exercise it had served to increase the awareness of the teachers regarding the efficacy of autonomous learning methodology. Whilst the impact on the classroom of such a small exercise could not immediately be analysed the overall impact of the action research could be more readily evaluated.

7.12 Post intervention evaluation

As the end of the academic year approached and pupils and teachers began to focus on end of year examinations the action research project drew to a close. In order to try to evaluate the impact of the exercise on both pupils and teachers four final data gathering actions were put into place. These were a pupil survey, 'pupil voice' feedback, a science teacher survey and a science department meeting for final reflections.

7.12.1 Post-intervention pupil survey

In late April and early May, at the conclusion of the intervention exercise the classes were again surveyed in order to try to ascertain what measurable effect, if any, the intervention had had on the pupils in the sample population.

7.12.1.1 Year 7

A comparison of positivity scores between 7A and 7B shows much the same pattern as before the intervention exercise except that in both cases the mean positivity has dropped by a similar amount. Evidence from early pupil interviews suggests that pupils come into secondary school with high expectations of science lessons but their experience does not seem to match up to this expectation. The race to 'get through the work scheme' and the high regimen of testing may go some way towards an explanation for this.

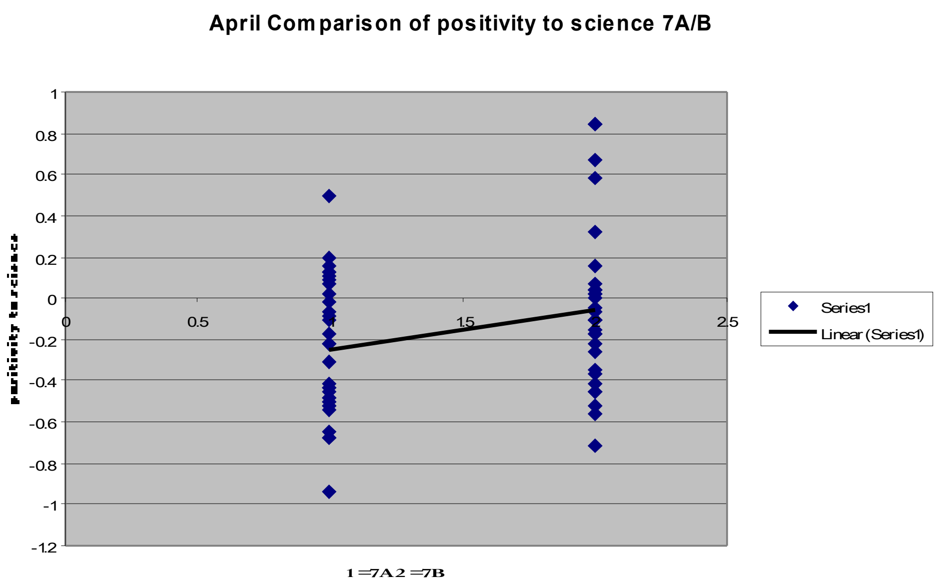


Figure 7.11 Comparison of post-test attitude scores for 7A and 7B after intervention activities

There was still a strong correlation between the pupils' positivity to science and their aspirations to continue with science beyond school for both 7A and 7B (Pearson Product-Moment Correlation Coefficient $r = 0.743$, $p < 0.001$).

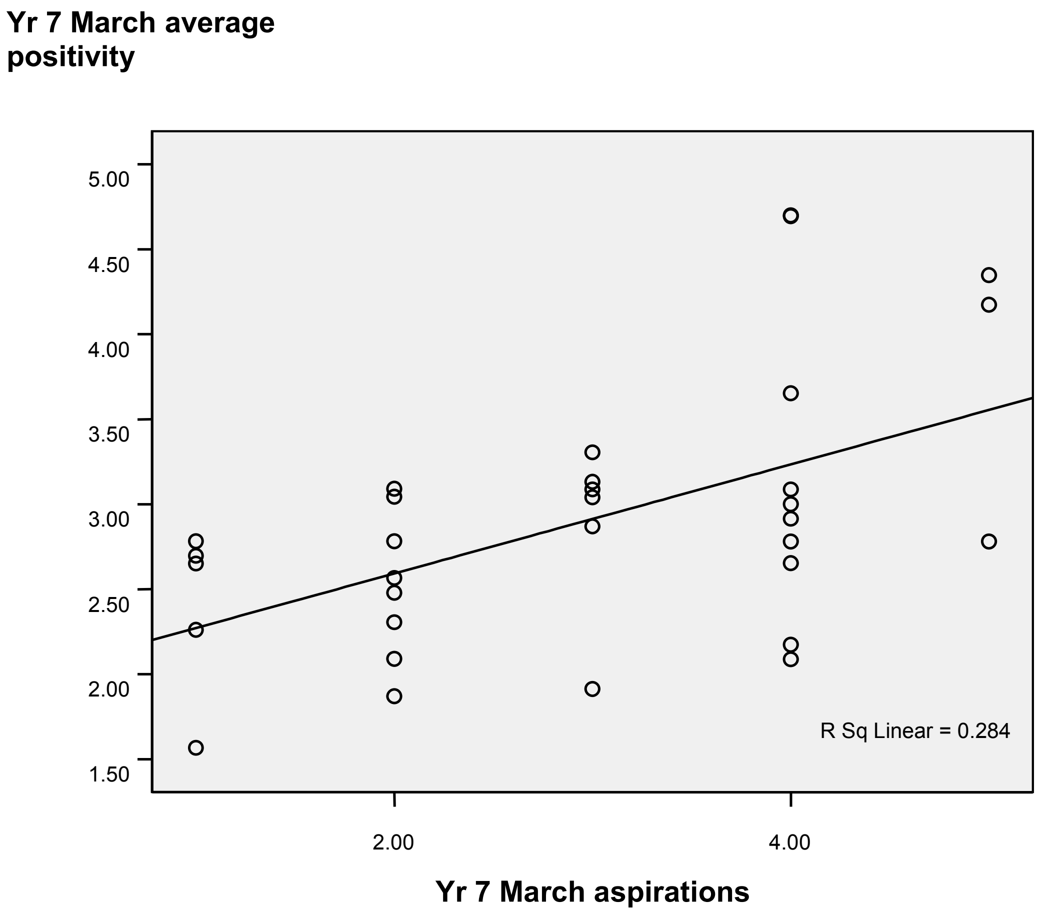


Figure 7.12 Plot of correlation between pupils' positivity to science and aspirations to continue with the study of science post 16 for Year 7 after the intervention activities

In the case of 7A there was also a strong correlation between the number of science books that they now had in their home and their positivity to science ($r = 0.486$, $p = 0.006$) indicating a change from the situation in October when no such correlation had been evident. Was this an indication that some of the research based learning that 7A had been exposed to had resulted in increased access to books at home. This may be an indication that autonomous learning methodology had impacted upon pupils' study skills.

Another difference observed between 7A and 7B was that although the mean positivity to science scores fell by a similar amount for both groups, when the scores for the gifted pupils in each class were analysed separately it was found that the mean positivity scores for gifted pupils in 7B had dropped by a value of 0.614, whereas the mean positivity scores for gifted pupils in 7A had fallen by only half as much 0.297.

Although this is rather tenuous evidence it may suggest that the pupil centred teaching and learning methodologies used during the intervention with 7A had had a relatively beneficial effect for the gifted pupils in 7A when compared with the more teacher centred methodologies used with those in 7B.

Summary

- There is a strong correlation between positivity to science and the aspiration to continue with science beyond age 16 for both groups both before and after the intervention
- Positivity to science education for both experimental and control groups had fallen by similar amounts between Oct and March
- The positivity of gifted pupils in the control group had fallen significantly more than the positivity of the gifted pupils in the experimental group.

7.12.1.2 Year 10

At the end of the intervention exercise the positivity of all pupils in 10A1 had fallen significantly (boys Z = -2.223, p= 0.026; girls Z = -2.040, p= 0.041).

Positivity
mean +- 2 SD

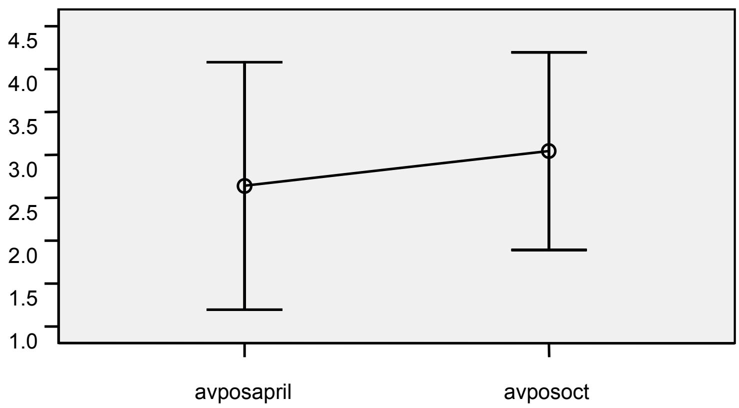
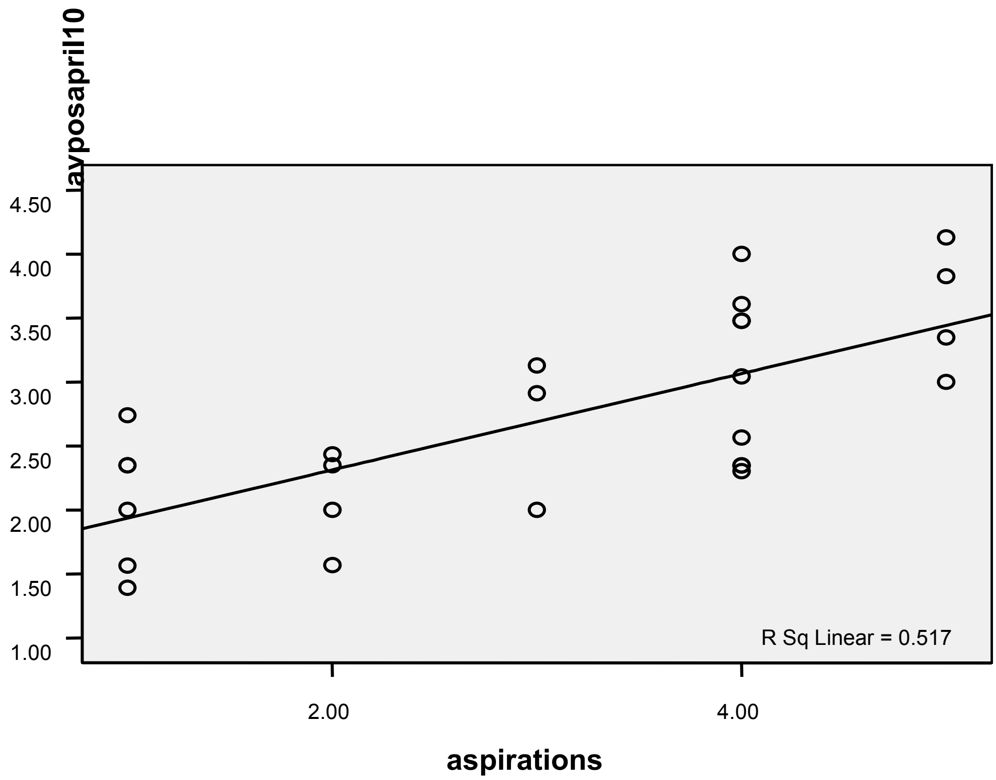


Figure 7.13 Comparison of average pupil positivity to school science for pupils in 10A after intervention to that before intervention

In common with the October findings there was still found to be a strong correlation between positivity and aspiration (r = 0.719, p < 0.001, rho = 0.685, p< 0.001)



aspirations to continue study beyond 16 after intervention

The aspirations of both genders towards continuing with science education beyond the age of 16 had risen during the period of the intervention, with the boys' aspirations having risen more significantly than those of the girls.

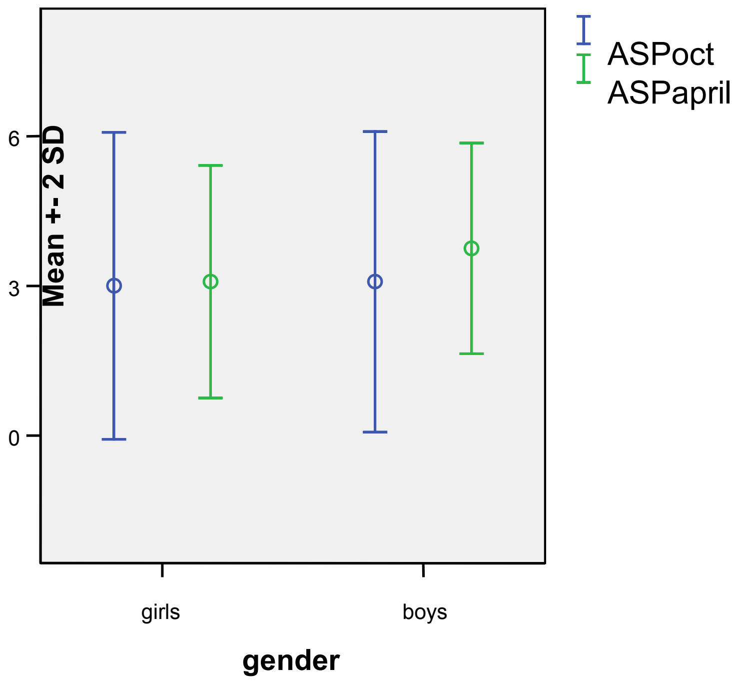


Figure 7.15 Comparison of aspirations of girls and boys to continue with science education before (blue) and after (green) the intervention

This finding is intriguing and is open to a number of different possible interpretations. It may be that the autonomous teaching and learning methods used during the intervention had given the pupils and especially the boys a taste for autonomous learning leading them to aspire to continuing with this more adult form of study. Whatever the explanation the fact that aspiration towards further study of science had risen may provide encouraging evidence that pupils had found the exposure to autonomous teaching and learning methodology motivational. It would be also possible to ascribe the renewed interest in continuing with the study of science to the University visit, which had been experienced by the gifted cohort in year 10 during this time but if this were the case why did the effect appear across the whole ability set and not just for the subset of gifted pupils? It may also be a possible explanation that the presence in the school of a University researcher had heightened the profile of the study of science at University and made it seem a more accessible option to many pupils.

However, one last finding from the questionnaire analysis throws a little more light upon these possible interpretations and that is that the experimental group in year 10, like the experimental group in year 7 showed at the end of the intervention a significant correlation between the positivity of attitude to science education and the number of science books that they had at home.

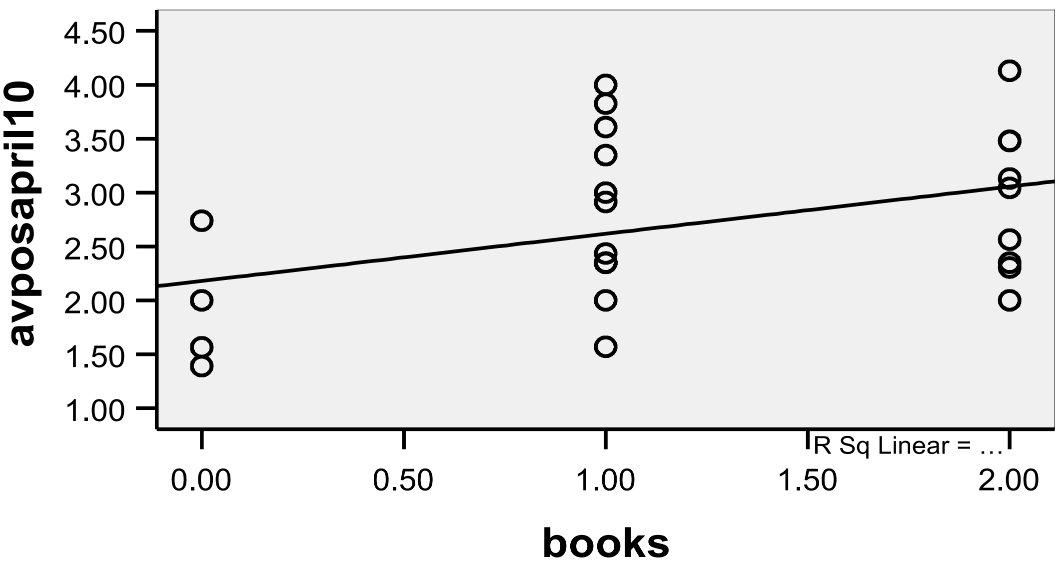


Figure 7.16 Plot of correlation between positivity to science and number of science books in the home for year 10 after the intervention

This correlation had not been present in October for either group and may be indicative that the study skills of pupils subjected to autonomous learning techniques had undergone a change during this period, with more independent study resourced from books at home being utilised.

Summary

- The positivity of both genders to school science education had fallen during the period from October to April
- The aspirations of both genders and more significantly boys had risen during the intervention period
- There was a correlation between the pupils' positivity to science and the number of science books in the home evidenced in April that had not been in evidence in October for the experimental groups undergoing the intervention.

7.12.1.3 Conclusions from the surveys

Year 7

Pupils in both Year 7 classes are less positive towards science education by the end of the Spring Term compared to the start of the Autumn Term. Evidence from 'pupil voice' suggests that part of the reason for this may be to do with negative feelings regarding the rigorous frequency of testing at the end of every module.

However there is a consistently strong link between positivity of attitude to science and the aspiration to continue with science beyond the age of 16. This indicates that if pupils can be made more positive about the science education that they receive in school then this should impact upon the desire to continue with it's study post 16.

There may be some evidence to suggest that research based learning had resulted in some cases in pupils acquiring more scientific books in the home and that the practical intervention strategies may have gone some way towards mitigating the effect of pupil 'turn off' for gifted pupils and loss of aspiration towards science careers for girls. However the small sample size used in the study makes the reliability of the quantitative analysis poor and in order to obtain a deeper understanding of the dynamics at play the additional information gleaned from observation, interview and dialogue groups must be taken into account.

Year 10

Whilst the positivity of the sample towards science education fell during the intervention period, the causes of this cannot necessarily be ascribed to the intervention, as there were many other factors at play during this time, including some intensive preparation for modular examinations. Despite this, in the period from October to April there was a rise in aspiration to continue with the study of science beyond the age of 16 and perhaps this is indicative that the experience that the pupils had gained in autonomous learning had given them the perception that this more 'adult' form of study may hold interest for them beyond GCSE.

The correlation between positivity to science and the number of science books in the home may also be indicative that autonomous and independent study became more of a modus operandi for many pupils during the intervention period. This would be consistent with the evidence gained from 'pupil voice' that pupils enjoy guided but independent learning and feel empowered by being allowed to make decisions for themselves about how they learn best.

7.12.2 Post-intervention 'Pupil Voice'

7.12.2.1 Year 7

The two module topics in which the intervention exercise had taken place were ecology and electricity. At the end of the study the pupils were again asked which lessons that year had been their best and worst lessons.

In 7A 9 out of 33 (27%) pupils had changed their previous 'best lesson' to one of the lessons in which the pupil centred learning had taken place. Four of the 9 pupils were girls and 5 were boys. Three of these 9 pupils were on the gifted register. But only 2 of the 9 had improved positivity to science between October and April. Reasons for choosing their best lesson centred on their enjoyment of what they were doing and the 'hands on' approach.

> “ The best lesson was when we made a habitat for an animal. I enjoyed making it” (girl, 7A)

> “ The best lesson was testing fuses as wires in circuits because the wire melted and it was fun to see how much each wire could take.” (gifted boy, 7A)

For 11 of the 33 pupils the worst lesson was cited as doing tests. Another 6 cited lessons in which they only do writing as the worst. It was obvious from what pupils were saying that the frequent testing at the end of each module was the biggest ‘switch off’ for them in science lessons and this may account for the overall drop in positivity to science education in school during this time.

> “The worst lesson is tests and tests. Tests make you very nervess. It’s bad because it’s boring and you panick a lot” (gifted girl, 7A)

> “ The worst lesson is any lesson doing tests. They are boring because there is no practical in a test. There should be practicals in tests.” (gifted boy, 7A)

In 7B 6 out of 32 (19%) pupils had changed their previous ‘best lesson’ to one in the electricity topic and no one cited a lesson in the ecology module. Only 2 of the 6 were on the gifted register and only 2 of the 6 were girls. None of these pupils had improved their positivity to science between October and April. Reasons given for their best lesson being on electricity was again largely the ‘hands on’ approach.The worst lessons were cited as ‘just writing’ by 10 pupils and tests by another 5 pupils. Showing again that almost half the class were switched off by these activities. It appeared that the incidence of the ‘just writing’ lessons was higher with 7B than with 7A.

The views of the pupils in 7A at the end of the exercise indicate that they enjoyed the ‘hands on’ teaching and learning activities that they had experienced but that this had had little impact on their overall attitude to science education. A bigger influential factor may have been the frequent testing, at the end of each science module, which was customary practice with both groups and led to pupil disaffection with science. It was noticeable that pupils in 7B also cited ‘just writing’ as a switch off, whereas no pupil in 7A had found this to be a discouraging feature of their lessons. Perhaps this was because the writing exercises undertaken by 7A had been pupil generated and not teacher generated. Pupils were writing because they felt that they had something to say rather than to fulfil the wishes of their teacher.

7.12.2.2 Year 10

The intervention module topic undertaken with Year 10 had been electromagnetism, based on the working of the electric motor. At the end of the exercise pupils commented on their appreciation of the 'hands on' nature of the lessons. This contrasts with work that they had been doing in a concurrent chemistry module, where 15 out of 29 pupils commented on the boring nature of watching power point presentations and writing.

> "The worst lessons are when you are writing all lesson. You get bored easily and not interested in what you are writing and you don't learn as well." (gifted boy, 10A1)

The responses of year 10 confirm to a large extent the views expressed by year 7, with most pupils agreeing that 'hands on' activities are their preferred learning activities and teacher directed writing being the biggest 'switch off'. In year 10 pupils do not seem to be so greatly disaffected by frequent testing. This may be because by this stage of their school experience they have accepted the test culture as a way of life and ceased to question it's necessity.

7.12.3 Post intervention staff survey – May

At the end of the action research period the six teaching staff at the school were asked to complete a survey prior to the final science department meeting. It was felt that the survey was more likely to access thoughts and opinions from individuals that they may not have wished to voice openly in the staff meeting. The first question posed was what teaching and learning methodologies had they used with able pupils in the classroom since the intervention exercise.

Worksheets	6
Copying from board or book	6
Internet research	6
Quizzes / games	6
Pupil presentations	6
Videos	6
Tests	6
Use of CD Rom or websites	6
Instructed practical work	6
Investigational practical work	6
Dictation	6
Demonstrations	6
Concept mapping	5
Discussion / debate	4
Using pupil display work	4
Problem solving exercises	3
Use of interactive white board	3
Study skills enhancement	3
Pupil self assessment	3
Concept modelling	3
Pupil challenges	3
Data logging	3
Pupil choice of task	2
Field work	1
Concept challenges	1
Role play	1
Pupils take the lesson	1

Table 7.6 Teachers most frequently used classroom activities with able pupils post-intervention

The range used was much more diverse than had been the case at the start of the academic year and all of the teachers were now making the distinction between ‘instructed’ practical work and ‘investigational’ practical work. One of the teachers had even gone beyond the stage of allowing pupils to have decision-making powers over parts of the lesson and had given them control of whole lessons. The use of worksheets, dictation, copying, demonstration and tests still featured but these were now a smaller part of a larger repertoire of teaching and learning strategies with a bigger emphasis on pupil centred learning.

When the staff were asked which of these new strategies had been tried as a direct result of the action research project they included greater use of internet searches, new websites, visual displays, role play, modelling, pupil investigations, games, quizzes, model building, pupil presentations and the use of interactive software. The evidence that the intervention in the school had brought about changes in teaching and learning methodology was well established. When asked what had motivated them to try new teaching and learning strategies there were some thoughtful responses.

> " I now try to equate the method of teaching to the ability and interests of the group or pupil concerned" (Chemistry teacher)
>
> " I have been made aware of new resources, which enable me to be more interactive than before" (Biology teacher)
>
> "Teachers have shared ideas that have worked for them and I wanted to liven up the delivery of some topics" (2nd Chemistry teacher)
>
> "I needed a change and talking to others about what could be done helped me" (2nd Biology teacher)
>
> "I wanted to expand and enhance real understanding" (Physics teacher)

The degree of reflectivity amongst the science teachers was now much greater than at the beginning of the year. The main difference was that the teachers were now willing to question their own practice, they wanted to work towards an improvement paradigm and they accepted that self evaluation and critical analysis was not meant to be judgemental but to bring about improvements in working practice for both their pupils and *themselves*. It would appear that the action research in itself was proving an effective means for professional development.

Staff were then asked what they perceived to be the principal constraints on their choice of teaching and learning strategies. Universally the top response was time. One science teacher also identified class size as a constraint. However another teacher voiced a concern over being intimidated by the thought of change.

> "Change is difficult to do at times and worrying because if you know something works why change it?" (Chemistry teacher)

The fact that this thought was voiced at all served to illustrate how far the staff had come on the journey of critical reflection. At the beginning of the year the attitude of the science department had been quite dismissive towards the philosophy of the action research but at the end of the exercise the reflections of the science teachers indicated that it had carried some benefit. However the benefit observed on reflective practice and impact on teaching and learning strategy had been unanticipated by all, including the researcher, at the start of the exercise.

The question of whether the science staff now thought differently about the teaching and learning needs of those pupils identified as gifted in the domain of science was asked. Most of the staff agreed that whilst ‘differentiation by outcome’ was their principle strategy they now had a better appreciation of what that meant and were able to design practical investigational tasks for pupils that allowed them to access higher order thinking skills. Some staff were now offering different homework tasks for the more able pupils and some were giving a choice of homework task so that pupils could decide for themselves the degree of challenge that they wanted to tackle. One teacher described a greater use of mind mapping with able pupils in order that she could appreciate how much they knew already and tailor her teaching to the correct starting point or allow them to skip stages that the rest of the class needed to do.

The final question put to staff was how well they thought the gifted pupils learned when in the company of other pupils of lesser ability. Unanimously the staff thought that the gifted pupils would be better taught in a separate group, especially after their observations of the University enhancement day. Many of their concerns centred around being able to create a better facilitative environment for able pupils when they were separated out since there would be fewer behaviour management issues.

> “ At GCSE level gifted pupils should definitely be in different groups. Mixed ability groups are good to some extent as pupils can learn from one another. However the ends of the spectrum are too great to differentiate for. Also with behaviour often being linked with ability, you wouldn’t want naughty pupils in with the higher ability as a lot of your focus would be on the disruptive individuals” (Chemistry teacher)

Staff had seen the benefits for gifted pupils of the interaction with other like-minded individuals on the University enhancement day and this had made an impression. It was felt that the pupils would achieve more, be better motivated and more likely to want to continue with science beyond GCSE if they had the stimulation of working with and ‘sparking off’ other equally gifted pupils. The Head of Department had introduced some extra curricular activities for scientifically gifted pupils in years 8 and 9 of the school, involving challenging science investigations and the pupils were responding enthusiastically. Overall the degree of innovation revealed by the survey was extensive and it pervaded not just the classes for which the intervention had taken place but also other teaching groups within the school.

7.12.4 Discussion with science department post intervention - May

At the final science department meeting, held at the end of the action research period, the question of the needs of the scientifically gifted pupils was discussed. It was now recognised that these pupils did finish work well before the allocated time and then ended up spending time going over old ground, which was thought to be de-motivating. The science staff asked for the work scheme to be revised in order that higher ability pupils were given *different* work to do than the rest of the class rather than more of the same.

A long discussion ensued as to how the teacher would then decide which children should be given the higher level work and what the backlash may be from parents and senior management if it was thought that some pupils were getting a lesser deal than others within the lessons. It was decided that such problems could be largely avoided if pupils were offered the choice and could self-select the tasks that they wanted to pursue. It was recognised that this approach could carry the risk of bright but lazy pupils always going for the easier tasks but teachers felt that they would recognise those who were performing too well within their comfort zone and challenge them individually. There was also the risk of the less able losing self esteem if they were continually given lower level work but some of the staff felt that this was less of a risk to their self esteem than if they were continually given overly challenging work which resulted in failure. The Head of Department felt that it was important that the degree of challenge should be appropriate to the abilities of the pupils in order to encourage them to progress their skills and that comments made by teachers on the work of the pupils should emphasise how the pupil was progressing rather than how they were performing compared to the rest of the class. Another science teacher described how some of the less able pupils in the class had felt about having their work displayed alongside that of the more able pupils and she stated that it was important to celebrate the achievement of all of the pupils, no matter at what level.

The results of the post intervention pupil surveys were outlined to the science staff and the drop in positivity of the pupils to science over the year was discussed. Some of the possible explanations, other than teaching and learning strategies, as to why this may be the case were then discussed. For year 7 these included

- The able pupils no longer being the ‘top dogs’ as they had been in year 6
- Science being confined to 1 hour slots rather than the extended periods experienced in primary school
- Pupils had been exposed to many other subjects which vied for popularity
- Exposure to the secondary school culture of ‘it’s not cool to be keen’
- Exposure to the regular ‘end of module’ testing and the pressure this may have produced.

For year 10 the last three of these points were felt to also hold true but there were felt to be other factors involved.

- The media image of science and scientists as being ‘geeky’
- The reputation of science, particularly physical science, ‘A’ levels being harder to get top grades in than other subjects
- Science not being perceived as relevant to everyday life or financially well rewarded in the way that media studies, ICT or business studies were perceived to be.

The finding from the pupil post intervention survey, that the trend identified of pupil aspirations rising towards careers in science over the course of the intervention period, was felt by the teaching staff to be an interesting outcome. Whilst the intervention cannot be deemed to have been causal in this, the indication that the adoption of more autonomous learning practices had resulted in raised aspiration to continue with science was felt to be sufficiently well evidenced to justify changes in practice. Whilst it was recognised that there was no evidence to justify that this would necessarily improve pupil attainment, it was accepted by the science department that the approach did not produce lower attainment levels but it may impact upon future choices of ‘A’ level study and that this may be beneficial, especially for girls who were under-represented at science ‘A’ level.

A second unanticipated finding from the post intervention pupil survey was that pupils had more science books at home than at the beginning. Again caution must be taken in interpreting this in terms of the inculcation of greater study skills in the pupils but the finding is intriguing. The science staff felt that the 'research' nature of the science investigation tasks might well be linked to this finding. If this were the case then the 'ownership' of task given to the pupils during the investigation may have resulted in them taking more responsibility for their own learning and needing to consult books and websites to access information needed. This more 'adult' approach to learning was also felt by the staff to prepare the pupils better for the type of work that they would have to undertake an 'A' level and could serve to prepare these pupils better for the transition to sixth form study.

Whatever the impact on the pupils, the impact on the science staff was clear. The role of educational action research was now seen to have value and relevance to actual practice. The action research experience was providing a force for change and only time would tell what the impact of that change would be.

7.13 Epilogue

7.13.1 Pupil uptake of 'A' level sciences

In the August of 2005 the Head of Science at the school, in which the action research had taken place, contacted the researcher to report, that the Principal of the local Sixth Form College had telephoned the Head teacher of the school to ask why larger than average numbers of pupils from the school were opting to take 'A' level science courses. Of the thirty pupils in the top set of year 11 nineteen were choosing at least one 'A' level science subject, eleven were taking two science subjects at 'A' level and three were taking all three sciences. Twelve of these nineteen pupils were girls. Thirteen pupils were taking biology, nine were taking chemistry, ten were taking physics and one was taking electronics. Amongst these pupils, five had attended the Enhancement Day at the University in the April of that year. The number of pupils opting to take science 'A' level was unprecedented for the school.

Although it would have been gratifying for the teachers and the researcher to make the assumption that the changes in teaching and learning methodology in science had caused this outcome, that could not be assumed and so in the February of 2006, after one term of studying ‘A’ level, these nineteen ex-pupils were asked back to the school for a reunion evening. During the course of the evening the ex-pupils were asked to complete a questionnaire.

One of the free response questions put to the ex-pupils was ‘what motivated you to choose to do science ‘A’ levels’. The responses of the ex-pupils were analysed and categorised into five response categories.

Enjoyed the subjects at GCSE	16
Best choices for my intended career	13
Felt they were my stronger subjects	7
These were the subjects that most interested me	6
Because we had good teachers at GCSE	4

Table 7.7 Most frequent responses from sixth formers of reasons for making advanced level science subject choices

Almost every pupil had cited enjoyment or interest as his or her main motivating factor in choosing ‘A’ level sciences. The recognition of ‘good teaching’, whilst only commented upon by a few, nevertheless was evidence that the teaching and learning methodology employed by the department had been appreciated and effective in provoking interest, enjoyment and aspiration to study further. The pupils were asked how their ‘A’ level courses were comparing with their prior expectations. Fifteen of the ex-pupils said that the subjects were harder than expected and eight commented that they were expected to be independent learners at ‘A’ level.

> “I always knew it would be more difficult than GCSE, however the actual workload was surprising. There are a lot more independent research tasks” (Female ex-pupil taking biology, psychology, art and media studies)
>
> “Far harder than I expected but quite enjoyable all the same. I wasn’t expecting to do so much self-teaching but as it happens it isn’t too bad. I really enjoy the practical aspect to the lessons. It’s great fun.” (female ex-pupil taking biology, chemistry, history and English)
>
> “The chemistry is a bit harder than I expected. We need to give more detailed answers and we cover a wider topic range. We have more to think about for ourselves rather than the teacher telling us. We also work in smaller groups and

can discuss our ideas openly.” (female ex-pupil taking physics, biology, chemistry and English language)

> “ I find ‘A’ levels much more difficult than previous work, not only because they are more in depth and complex, but also because you are more dependent on your own studies. The teachers do not really explain everything you need to know to pass your exam but expect you to make notes on what you think is necessary.” (female ex-pupil taking biology, chemistry, history and English)

> “They are harder but are a lot better as you are given more freedom with the experiments. The way I am taught is very similar, however it is more in depth.” (female ex-pupil taking biology, psychology, geography and English literature)

Mostly the ex-pupils felt that the autonomous teaching and learning strategies that they had been exposed to at GCSE had helped when they encountered the expectation that they would operate more self-sufficiently at ‘A’ level. When asked if they still aspired to study science related courses or work in a science related job after ‘A’ levels only two of the nineteen replied that this was not their intention. Of the others health related courses were the most popular choice (9), with engineering (2), flying (2), scientific research (2), teaching (1) and forensics (1) also being mentioned.

The increase of interest in science related careers evidenced by the choices and comments made by these pupils supports the conclusion that the teaching and learning methodologies that they had been exposed to had resulted in pupils becoming more confident and aspirational regarding science education. Whether this conclusion may be generalised to other contexts cannot be determined from this research but the question does provide scope for the extension of the research to other school contexts and possibly to other arenas of professional development training for teachers.

7.13.2 Teacher development – post script

Another unanticipated outcome of the action research intervention occurred in the April of 2006, when the work of the researcher within the University was expanded, requiring the necessity for additional staffing. Such was the interest in the value of the educational research that had been aroused in the Head of the Science Department at the action research school that when the vacancy at the University arose, he applied and succeeded in obtaining a post within the science education team. It was felt by the researcher to be somewhat ironic that an intervention that had originally been designed to find out whether the aspirations of the most able pupils towards the furtherance of their science education could be improved also resulted in an impact upon the aspiration of the most able teacher!

Chapter 8
Conclusion and Recommendations

In discussing what has been learned from this research considerations fall into three areas. These are:

1. What has been learned about the role of pupil autonomy in effective teaching and learning methodology for able pupils in science?
2. What has been learned about the efficacy of action research as a means of enabling the engagement of teachers with such teaching and learning methodology?
3. What has been learned about the research process as a whole and the means by which teachers may be supported in using action research for continued professional development?

From these considerations theoretical issues regarding classroom provision for able pupils in science and the continuing professional development of their teachers are synthesised. The study concludes by making recommendations for action within these two areas and identifies foci for further research.

8.1 What has been learned about the role of pupil autonomy in effective teaching and learning methodology for able pupils in science?

The starkest finding from both the pilot study and the action research phase of this research was that pupils surveyed in both phases of the research have predominantly negative attitudes towards school science lessons. This is consistent with the findings of previous research (Miller and Osborne, 1998; Schreiner and Sjoberg, 2004; Hyam, 2006). The pilot study revealed that this negativity did not just apply to able pupils but to pupils across all ability levels and across all schools sampled and particularly to girls; although this is in conflict with the work of Galton (2002) who found the greatest 'switch off' occurred for high attaining boys. There was also an indication that the disaffection for school science was more evident in the context of the study of physical sciences than for biological sciences. The pre and post testing carried out in the action research phase of the project also revealed that pupil negativity to science is higher towards the end of the academic year than at the beginning. This is consistent with previous research (Galton, 2002; Osborne et al. 2003), which found that on average, pupils' attitudes towards school science lessons became more negative from age 11 to age 16. If one of the purposes of science lessons is to promote enthusiasm for and interest in the further study of science then the majority of science lessons are proving ineffective with regard to this. Whilst didactic teaching may be effective in generating high test scores by using a 'teaching to the test' methodology, other research has shown (Gilbert, 2006) that one impact of frequent testing is a reduction in motivation for learning. Such methods may be detrimental to pupils' attitudes to school science.

There are suggestions from the action research phase of the study that the frequent testing of pupils and the quantity of teacher directed writing, driven by the performance accountability agenda and content density of the curriculum, might be contributing to pupil 'switch off' to science and particularly physical science. The observed mismatch between the teaching and learning methodologies most commonly used by teachers and those most enjoyed by pupils may also be a contributing factor to the lack of positive attitude towards school science lessons. Previous research has shown that one of the main factors determining the attitudes of pupils is the quality of the educational experience provided by the teacher (Osborne et al. 2003; Ponchaud, 2006). Taber (2007b) describes how didactic teaching and learning methodology fails to allow able pupils to experience the 'flow' (Csikszentmihalyi, 1988) that comes with total absorption in a task.

> "Clearly as educators we have a responsibility to develop the affective response to science and we do a disservice when we bore the most able learners." (Taber, 2007b, p.9)

Both the pilot study questionnaires and the action research pre-testing revealed that the majority of teachers were using didactic teaching and learning methodologies for the majority of the time. The responses of the pupils in both phases of the study would appear to indicate that they do not engage well with this methodology and that they prefer more interactive methodologies, which devolve some responsibility for their learning to the pupils themselves. This was especially the case for the more able pupils. Gilbert (2006) reports that,

> "For teaching to be effective in promoting learning, it must involve interaction between teachers and students. One-way delivery from a teacher does not work for the vast majority of pupils." (p. 8)

Ofsted have reported that pupils' attitudes to science are positively affected by how actively involved they are through scientific enquiry, making decisions and expressing views (DfES, 2006b). In this study pupils were not observed to be actively involved in these pursuits in their lessons prior to the intervention exercise. In order for teaching and learning to become more 'personalised' (DfES, 2004b), a major shift in the teachers' conceptions of their role needs to take place. Campbell et al (2004a) are in agreement and explain that rather than deliverers of information, teachers need to have the perception that they are learning facilitators and demonstrate a stronger commitment to giving pupils choices in the content, source, pace and direction of their learning. By this means pupils are enabled to become less reliant on the teachers and more reliant upon themselves.

Just because pupils are negative about 'school science' does not mean that they are negative about science in other contexts and some pupils may aspire to further scientific study despite negative feelings about 'school science'; but the evidence from this research indicates that there is a general correlation between positivity to 'school science' and aspiration to continue with its study beyond age 16. Therefore the implication is that the adoption of teaching and learning methodologies which result in promoting a positive attitude to school science lessons should ultimately also result in improved uptake of sixth form science. This finding agrees with that of Ponchaud (2006) who reports that,

> "Large numbers opt for science in the sixth form because they have had a positive experience in the lower school." (p. 29)

Thus the emphasis of provision for able pupils in science being concentrated mainly in out of classroom contexts may be misplaced. Whilst these enhancement activities certainly have a role and should play a part in the overall provision for able pupils in science it is what happens in the regular science classroom that has the most dominant effect and the energies of both researchers and teachers need to focus upon this area. Betts and Kercher (2005) report that the 'autonomous learner model' has been successfully incorporated into the framework of secondary schools in Colorado but that it requires intensive staff development. These researchers identify one disadvantage of the model as a lack of research on the effectiveness of its approach. One possible area of focus for further research may be in assessing how great a part, including classroom teachers in out of school enhancement activities, plays in producing a resulting impact on subsequent classroom practice, both in the short and long term. It may well be that such a strategy could be used to raise the expectations of the teachers regarding the standard of work that able pupils are capable of engaging in. This action research study clearly indicated that many teachers have expectations of their pupils that are far too low and that differentiation skills in lesson planning for the more able pupils were not well advanced. These findings would appear to be supported by Eyre (2007b) who stated, in an address to the World Conference on Gifted and Talented Education,

> "The basic curriculum at school and classroom level must be specifically designed to anticipate excellence if the needs of the G&T are to be properly catered for. Rather than the school or class teacher offering a core curriculum aimed at the middle ability point and then extending it for those pupils who exceed the base requirements, this model requires the school/teacher to design in expectation that some pupils will achieve the more demanding requirements without knowing precisely who will achieve them." (pp. 7 – 8)

This research provides some evidence that able pupils in science prefer learning using autonomous methods in the classroom since indications were that less disaffection was evident for those pupils who were allowed to adopt autonomous learning practices for some of their lesson time. Pupils who were recognised to be gifted in science particularly felt frustrated when they were not allowed the scope to follow their own ideas and pursue learning by methods that they felt to be most personally empowering and this seemed to be true for more girls than boys. This finding echoes that of Campbell et al (2006b) who reported that girls were also found to be more positive about enhancement activities for gifted pupils than boys.

The evidence of the rise in the number of science related books possessed by pupils in their homes over the course of the study might be indicative of the outcome that autonomous methodologies result in greater independent study skills. If this is the case then the implication is that the promotion of autonomous learning has an impact on both present and future learning since the acquisition of independent study skills is key to 'adult' learning both within higher education and within the workplace. Two of the aims of the 'Science Annual Plan 2007/8' (DCFS, 2007a) are to improve the quality of learning and teaching in science and to increase the number of young people taking 'A' level sciences. It would appear that the promotion of autonomous teaching and learning methodologies might prove to be key to achieving these aims.

Despite teachers' initial fears that autonomous teaching and learning methods would detract from high performance in attainment scores this does not appear to have been the case in this study. Measurable outcomes in terms of test scores were maintained at previously high levels throughout the intervention study. Other research (IAEEA, 1999) over longer time spans has shown that there is a direct relationship between attitudes to science and achievement. However it should be borne in mind that not all educational outcomes are as objectively measurable as test scores and no objective measuring mechanism exists for the measurement of the development of improved skills and confidence. Thus the assessment of development in these areas is, by necessity, subjective. Whilst it was observed that pupils took more time initially to get to grips with the subject matter using autonomous teaching and learning methodology, it was also observed that pupils were able to progress at their own rate of learning and that they avoided having to repeat work that they had done before simply because others in the class needed to do it. Able pupils were also allowed to make intuitive leaps in their thinking without having to laboriously follow all the steps in processes that other pupils needed to follow and this resulted in a faster rate of progress.

However the action research study also revealed that pupils needed to be ready to take on the responsibility for their learning if independent learning is to become a reality in the classroom. This requires that pupils possess a solid foundation of pre-requisite knowledge in order to establish a starting point for further progress and that they have confidence in their abilities. It was found that pupils who were not used to having the onus for their learning thrust upon them found the experience intimidating. This was more evident for year 10 pupils who had become more accustomed to being 'spoon fed' than the year 7 pupils who were willing to give anything a go. Year 10 pupils had a much greater fear of failure, perhaps because the stakes were higher in terms of external examination scores or perhaps due to the self-consciousness of adolescence.

For this reason the promotion of autonomous learning for able pupils and the resulting acquisition of the necessary related study skills may be most effective if employed from the earliest stages of secondary education (if not earlier!).

The recent ‘Secondary National Strategy’ reflects this and has outlined provision for autonomous learning from Year 7 amongst the Classroom Quality Standards for Gifted and Talented Education (DCFS, 2007b). The underpinning philosophy behind the derivation of these standards is that *all* teachers are teachers of able pupils and that therefore *all* teachers should engage with practices that promote good quality provision for able pupils as distinct from good quality provision for all children. To satisfy the success criteria for these standards, teachers are asked to evaluate to what extent able pupils are enabled to take charge of their learning and become ‘self-regulating’. However, embedded within the standards documentation is also the recognition that in order to achieve this end it will be necessary that teachers can also evaluate their own learning needs and be able to ‘self-regulate’. The implication is that before able pupils can become successful autonomous learners it is firstly necessary that their teachers engage with this practice for themselves.

Yet another benefit for able pupils arising from the action research study was that communication both between pupils and between pupil and teacher increased and more argument was evident. Both the quantity and the quality of the classroom dialogue were enhanced. Able pupils are amongst the most articulate in any school (Eyre, 2007b) and autonomous learning encourages this articulation. The 2002 Student Review of the Science Curriculum (Murray and Reiss, 2005) found that pupils were requesting more time for discussion in lessons. These findings were also echoed in the ROSE (Relevance of Science Education) project (Schreiner and Sjoberg, 2004). Such discussion, it was felt, would help pupils to learn from those other than their teacher and to develop their own ideas which would be more meaningful for them. ‘Meaningful learning' (Poncini and Poncini, 2000) was evidenced by the ability of pupils to structure and explain what they were doing and why, to remember what they had learned and to be able to use verbal and written fluency to present what they had learned within subsequent lessons. This contrasts with some of the less effective recall of learning observed in previous lessons using more teacher directed methodologies. This construction of new knowledge through social interaction was regarded by Vygotsky (1978) as an essential requisite for cognitive development. A recent action research project into assessment for learning, funded by the DfES as part of background work to inform the National Strategy for School Improvement (DfES, 2007b) also reported that fundamental to developing learning was developing the independent learner.

> "As the project progressed, the importance of developing pupils as independent learners became apparent, although few schools had mentioned it at the outset. It became increasingly clear that pupils need to move from being passive recipients of what they are being taught, to develop as independent learners who take responsibility for their own learning and are empowered to make progress for themselves" (p.20).

How is this empowerment of pupils to be achieved? The teachers in the action research project were not immediately persuaded to relinquish control of parts of their lesson and allow the pupils to have more decision-making powers. There was a fundamental belief that pupils would learn better if they were told information rather than allowing them the freedom to direct their own learning. Barriers to the introduction of independent learning were identified by teachers to be time constraints, performance targets and curriculum demand. Russell (2007) notes that teachers identify barriers to personalised learning for pupils as being 'rigid, fixed and non-negotiable' and emphasises the need for teachers to look beyond existing school systems if they are to achieve successful learning programmes. Such learning programmes need to actively involve the pupils in their construction if they are to genuinely address their personal learning needs. It is an important part of provision for able pupils that they should come to know their own strengths and weaknesses and gradually be able to determine their own learning needs (Eyre, 2007b).

The pressure upon teachers to maximise pupils' examination performance works against autonomous teaching and learning methodologies. This action research has demonstrated that even within the constraints currently experienced by teachers, it is still possible to switch pupils back on to science by using autonomous teaching and learning methodologies. However, this finding is localised to one school and one science department open to innovation. How generalisable the findings of this study may be to other school contexts remains to be seen.

8.2 What has been learned about the efficacy of action research as a means of enabling the engagement of teachers with such teaching and learning methodology?

At the beginning of the action research phase of the project the suggestion that science teachers may need to change their teaching and learning methodologies to better cater for their able pupils was met with resistance and even resentment by some teachers. Teachers cited the pressures of lack of time within lessons to cover content packed work schemes, lack of time outside of lessons to reflect on, evaluate and modify practice and the need to maintain high pupil attainment figures as part of their accountability to the Head teacher as the major constraints to achieving any changes in practice. The mindset of some of the teachers at the outset was that as long as test scores were high then they were doing a good job and any implication that their role as educators may involve more than this was a sleight on their professionalism. This view is understandable as explained by Taber (2007a),

> "When teachers are under pressure to 'cover' a syllabus and 'get results' and when they even suspect that students who appreciate the nuances and complexities of topics may be penalised in examinations (as the student who understands at a high level may not produce the 'stock' response assigned marks in the examiner's marking scheme), then the temptation to 'teach to the test' and encourage rote learning is strong." (p. xiv)

Considerations of how to improve attitudes to learning were not at the forefront of the minds of the teachers in this study at the outset. The Secondary National Strategy (DfES, 2007b) now recognises that,

> "Effective teaching pays attention to motivation and self esteem. This includes developing positive and supportive relationships by creating conditions for learning which form the overall context within which a teacher's knowledge, understanding and skills are applied and the learner's progress can be maximised" (p.2)

However teachers in this study expressed the view that the able pupils 'would do well anyway' and that it was the GCSE C/D borderline pupils who were more deserving of attention. Eyre (1999), in a review of ten years of provision for gifted children in Oxfordshire, also commented upon the 'giftedness will out' theory amongst the teachers in her study and a similar initial lack of enthusiasm for what was initially viewed as ‘elitist provision’. Eight years later, in an address to the World Conference for Gifted and Talented Education, Eyre (2007b) indicates that the role of the teacher in catering for the needs of gifted and talented pupils is still not well recognised and that such recognition,

> “ ...requires the development of a teaching force that has the knowledge, skills and confidence to play this role so that effective differentiation is an expected aspect of day to day lessons.” (Eyre, 2007b, p. 8)

The results of the pilot study had indicated that there was a mismatch between the teaching and learning methodologies employed by teachers in science lessons and those, which pupils, particularly able pupils, felt to be stimulating and effective in achieving learning. Pupils often felt as though they had been ‘frogmarched across the scientific landscape’ (Gilbert, 2006) with little chance to choose their route. One possible reason given by teachers in this study for not using more pupil-centred teaching and learning methodologies involved the behaviour management of classes. Such pupil centred strategies were regarded as more difficult to manage in the classroom and teachers who struggled with classroom control on a daily basis were hardly likely to hand over some of that control to pupils. West (2007) recognises this problem and advocates that all teachers should be supported through professional development training to help to overcome this problem. However, it was found in the study that teachers who had attended one-day training courses had enjoyed their stimulation but there had not been the anticipated impact on their own teaching and learning practice or on departmental practices as a result of this type of training. If such in-service training is proving to have a low impact on practice then what alternative professional development is likely to have a greater impact?

Early observations and discussions during the action research phase indicated that the findings from the pilot study were also typical of the action research school. Lessons were mostly teacher-led with most pupil talk consisting of answers to directed questions. Pupils were drilled in providing the ‘right answer’ to maximise test scores and any enquiring questions on their part were quickly closed down in order not to deviate from the planned lesson. Such ‘one way delivery’ from teachers has been shown to be ineffective in promoting learning for the majority of pupils (Gilbert,

2006) and grossly underestimates the capabilities of able pupils. A similar conclusion was expressed in the ‘8 Schools Project Report’,

> “A key factor inhibiting learning and progress within a significant number of lessons was the lack of pupil talk” (DfES, 2007b p. 25)

Science investigations observed were more often verifications of expected results than true scientific enquiries and there was little evidence of creative activity within lessons. Pupil worksheets were highly prescriptive in order to ensure equity of provision across classes no matter what the subject specialism of the teacher. Able pupils were observed to have to complete repetitive work for the sake of others in the class who had not understood it first time around and to have little autonomy over their methods of study. Expectations also varied greatly between teachers in terms of the level of work demanded from able pupils and able pupils delivered mostly what was expected and no more. On occasion when more was demanded it was observed that the able pupils were capable of giving much more than was being routinely demanded of them.

At the first ‘dialogue group’ meeting of science teachers, after the first classroom intervention exercise by the researcher, some of the science teachers put forward the view that there was nothing new in the autonomous teaching and learning methodologies demonstrated by the researcher and that they ‘did all this anyway’. Ebutt (1985) describes this perception as the ‘performance gap’, the gap between espoused theory and theory in action. Hopkins (2002) explains that there are often incongruencies between teachers’ beliefs and how they behave in the classroom and between their declared objectives and how the lesson is actually taught. Furthermore Hopkins identifies that there is often a discrepancy between a teacher’s view of a lesson and the views of other participants. The views of the teachers in this study were not borne out by the views of pupils who appreciated that activities within lessons had changed during the intervention period. There may have been a number of reasons why the science teachers in the study were initially negative about the research exercise but over a period of seven months, whilst the intervention study was underway, change in teaching and learning methodology on the part of these teachers did indeed evolve.

Once teachers began to perceive the benefits to both the pupils and themselves of the changes to their teaching and learning methodology and to appreciate that these changes produced no observable short-term deficits to pupils and may result in some long-term gains they became more open to change. Changes were brought about slowly over the seven month period as conviction grew that a greater emphasis on pupils' autonomy in the classroom enabled pupils to take greater responsibility for their own learning. In the '8 Schools Project Report' (DfES, 2007b) it was similarly noted that teachers gradually began to appreciate that effective teaching is only taking place when pupils are learning and that if the focus in lessons shifts from the teacher's objectives to the pupils' learning outcomes, then learning was achieved more effectively.

> "The rush to cover the curriculum within lessons can create an illusions of good teaching and sometimes intense pupil activity but can actually mean a slow pace of learning or no learning." (DfES, 2007b p. 24)

The changes in practice on the part of the teachers that emerged in this study were that lessons were designed with a greater focus on the individual needs of pupils rather than the 'whole class' approaches that had been seen previously. There was greater autonomy given to pupils in designing their own experiments and practical investigations involved more autonomous 'scientific enquiry'. Teacher expectations of their able pupils were raised with a higher level of demand being asked for within lessons. There was a move away from the 'right answer' philosophy with able pupils being asked for more prediction and interpretation of a number of possible outcomes of their work in class. Pupils were encouraged to analogise and model concepts as they learned and creative scenarios emerged which helped to breakdown misconceptions on the part of pupils in their understanding of scientific concepts. Many of the models and analogies observed were more contextually related to the pupils' own experiences of instances where they had observed the particular scientific behaviour under discussion. But perhaps most importantly pupils and teachers were observed to be *enjoying* the activities within the classroom with a resulting lessening in classroom tensions for some teachers. By the end of this action research period teachers had accepted that provision for able pupils in science was not an elitist activity best left to specialists delivering out of school provision but that it was a necessary part of the job of every classroom teacher and that its benefits were not only impacting upon able pupils but also upon all pupils and the teachers themselves.

8.3 What has been learned about the research process as a whole and the means by which teachers may be supported in using action research for continued professional development?

The progress of this research study has also been a 'reflective journey' for the researcher from rather naïve beginnings, through the tangled forests of the politics of action research and the storms of collaboration and professional argument to the calmer waters of the realisation of the personal educative distance travelled. It is not without irony that action research initially designed to help teachers to give more autonomy to able pupils through changes in teaching and learning methodology has also required the researcher to give more autonomy to able teachers in deciding upon research methodology. Action research is not something that you do <u>to</u> people it has to be something that you do <u>with</u> people and the first requirement is that all involved must feel convinced of the need for change. Cortazzi (1993) states that for any real change to occur teachers' views must be taken into account. Teachers do not simply 'deliver' a curriculum, they interpret, develop and refine it,

> "It is what teachers think, what teachers believe and what teachers do that ultimately shape the kind of learning that young people get." (Louden, 1991, p. vi)

At the outset of the action research study the science teachers did not feel the need for change and this was a concern initially only voiced by the Head of Science who felt that the department was 'good but coasting'. Possible reasons for the teachers' initial unwillingness to entertain ideas of change may have been due to the perceived threat that such changes could incur. Firstly they would have to acknowledge that their performance needed to be improved and this meant acknowledging that there was room for such improvement. This felt like an implied criticism and could potentially be damaging to self-esteem. Another possible reason for the resistance to change was low morale brought about by work overload and pressure to perform to externally imposed and often unrealistic attainment targets for their pupils. The reaction of 'not another change' echoes the weariness of teachers regarding the number of initiatives for change that they have had imposed upon them in recent years.

The concept of educational research for many of the teachers at the start of the study was that it was something done by educational researchers in University ivory towers and had little to do with them. This viewpoint on the part of teachers is widely held (Ratcliffe et. al., 2003) and unless the findings of educational research resonate with their own experiences teachers are unlikely to change their practice. The idea that teacher-researchers could make a difference to policy and practice was alien and one that had hardly been countenanced by any of the science teachers prior to the study. Was the study successful in challenging that view?

Evidence that the study was changing the viewpoint of the teachers on the value of educational research and the part that they could play gradually began to emerge from conversations taking place within the monthly dialogue groups. This dialogue group formed a ‘critical community’ (Campbell et al, 2004b), which helped to validate the research. The dialogue group proved to be a very effective tool for teacher development and teachers who raised questions about changes in practice were encouraged to go back to the classroom to try out changes and report back on how well they had worked. This reflected the ‘natural science’ model of research that many of the teachers held at the outset of the study (Ratcliffe, 2007). The involvement of the teachers in discussing their own classroom research outcomes helped to win hearts and minds regarding the potential efficacy of educational research. Despite the viewpoint of teachers that they reflect daily on their teaching, implementing effective reflective practice leading to professional action is not easy to achieve and requires an ethos of mutual professional acceptance which takes a long time to build up (Bright, 1995b). Over the course of the seven months (and beyond!) the atmosphere of the dialogue group meetings changed from one of suspicion regarding the research motivation into one of greater mutual respect and trust.

However, the most significant evidence that the study changed teacher perspectives on the value of educational research was the eventual recruitment of the Head of Science into the education department at the University and the resulting continuation and extension of the ‘Saturday School’ provision to other schools in the region by ‘word of mouth’ recommendation. Pupils from the action research school have continued to participate in the University science enhancement days and to take their experiences back into their classrooms for further development, thus establishing a 'bottom-up' model for continued autonomous learning methods. However, the provision for able pupils in science must not be diverted away from the everyday classroom. The inclusion of classroom teachers within the Saturday School enhancement activities has potential to change the expectations of teachers regarding both what able pupils are capable of achieving and the most effective methodologies to allow them to achieve. The transfer of these teaching and learning methodologies back into the classroom by teachers who have been enthused and stimulated through the Saturday School has provided one stimulus for effective teacher professional development.

The question remaining is how best to help more teachers to gain such knowledge, skills and confidence? There is a clear professional development requirement here. Leach et al (2007) emphasise that effective professional development is contextually relevant i.e. relates to teachers teaching science to *their* pupils in *their* school and is best done collaboratively by a group of teachers with similar interests and motivations. Hodson (2003) maintains that action research 'is probably the only coherent and viable way' of addressing the needs of teachers in this area.

> *"Action research also assumes that teachers can acquire the expertise necessary for effective curriculum development by refining and extending the practical professional knowledge they already possess through critical collaborative activity supported by researcher/facilitators." (Hodson, 2003, p. 666)*

However, this is reliant on high-quality, thoughtful and receptive teachers (Eyre, 1999), which produces something of a chicken and egg situation. Diezmann and Watters (2000) express concern as to how autonomous learning strategies can be adapted by teachers for use with able pupils within the classroom and acknowledge that many challenges exist in engaging teachers to become more reflective about how they teach able children.

> "The professional development of teachers that would enable them to engage in this type of teaching is difficult and requires prolonged engagement of practitioners working with academics in collaborative partnerships'. (Diezmann and Watters, 2000 p. 17)

The same finding is echoed by other researchers (Gertzman and Kolodner, 1996; Gallagher, 1997; Hmelo et al 1997) who emphasise that changing teaching styles and strategies requires a great deal of time and effort and can often seem overwhelming to teachers who are grappling with the demands of the curriculum and the acquisition of the new skills required. Just as pupil scaffolding is required in order for them to access and develop autonomous learning practices, so too teacher scaffolding is required to increase teacher effectiveness, confidence and positive attitudes. Thus effecting culture change in the science classroom is bound to be an uphill struggle. Pedder (2006) outlines the difficulties but also stresses the importance of such professional development,

> " If teachers find difficulty implementing this set of practices (and our data suggests they do), and if promoting learning autonomy is a central strand of learning how to learn then 'inquiry' (teachers' uses of and responses to different sources of evidence from more formal research and their own inquiries, together with their collaboration with colleagues in joint research and evaluation activity) is likely to be an extremely useful and important strategy supporting the classroom promotion of learning how to learn." (Pedder, 2006, p.14)

In order for teachers not to feel threatened by the change and for pupils not to feel insecure a great deal of underpinning support may be required. Participatory action research involving teachers and educational researchers creates a critically supportive environment within which teachers and researchers can reflect upon practice and the effects of change (Eyre, 2007c). Such action research also respects the professionalism of teachers who are enabled to refine and extend their practice by means of collaborative activity to the benefit of themselves, their pupils and their schools.

In order for any of these beneficial changes to happen it is vital that teachers are facilitated by a supportive school. This may require a great deal of self analysis by staff at all levels in order to work towards changing the pedagogical practice within the school. Research carried out by the Pollard and James, (2004) concluded that it is possible to design teaching sequences, informed by research, which result in better understanding by pupils of conceptual goals. They also found that the use of research-informed teaching materials can lead to small but cumulatively significant changes in the way that teachers deal with content and classroom interaction and furthermore that the teachers involved responded positively, provided that they had the perception that the changes were workable. The indicators are that collaborative action research projects within the school are influential upon the pedagogical practice of staff within an entire department and thereby influence the quality of interactions and attitudes of both staff and pupils. This approach also has the advantage that it is not just the most able pupils in the school who benefit but all pupils, indirectly, through the improved practice of their teachers.

8.4 Evaluation of the research process

The direction taken by this research study has changed many times enroute to its conclusion and many problems have been encountered and overcome. At the outset of the pilot study it was anticipated that the essence of the research would be about better provision for able pupils and that the pupils would form the primary focus. However it was perhaps a naïve assumption to think that pupils can be looked at in isolation from their teachers and in the end it was the mind set of teachers that was found to be the dominant factor in determining good provision for able pupils. It was felt necessary to conduct a pilot study because although the researcher had a gut feeling that there was something definitely amiss with the delivery of science education for able children, it was difficult to pinpoint exactly what that might be. The pilot study served a useful purpose in highlighting the concerns of both pupils and teachers regarding their perceptions of how well science education in schools was working (or not!). However, the pilot study was not without its problems.

The initial choice of schools by the LEA Science Advisor was perhaps politically motivated in that these were some of the lowest performing and most difficult to access science departments in the LEA and as such the research could be utilised as a means of reaching these difficult departments. Permissions to access staff and pupils in these schools were not easy to obtain and took some considerable persistence. The research was regarded suspiciously by teachers as LEA 'snooping' and that to some extent may have affected the veracity of the responses and was a threat to the validity of the exercise. However the resonance of the responses across the three pilot schools reassured the researcher that there was some validity to the outcomes of the exercise.

The unstructured interviews carried out with the senior staff from the pilot schools were time consuming to analyse but served a good purpose in that they provided the groundwork upon which to base the teacher and pupil questionnaires. The decision to adopt a pre-existing questionnaire used by Misiti, Shrigley and Hanson (1991) and adapt it for the purposes of this research proved to be an effective strategy. It had the advantage of having been pre-validated and leading or misleading questions eliminated. This is important because if the quality of the incoming data is poor then the action planning that is based upon that data will also be poor (Bright, 1995b). The practice of adopting pre-existing questionnaires is one advocated by Sudman and Bradburn (1983) as it helps to shortcut the pre-testing process. The items in this questionnaire had been reduced from 81 to 23 through rigorous pre-testing and it had been tested for cross-cultural validity, meaning that although it was American it could be adapted for English recipients. It was felt by the researcher that since the use of the questionnaire was only a preliminary to the main research, the adoption of one that had already been tried and tested was a good time management strategy.

Getting a good response rate to questionnaires can also be problematic. Since the sampling of the pupils in the pilot study was done at the end of the summer term of 2003, some of the pupils' responses were incomplete or spoiled, indicating that the pupils had not felt very motivated to complete the questionnaires. However since the questionnaires had been answered in school time the response rate was very high and even when spoiled scripts were discarded there were still enough responses to gain a reliable analysis. One further advantage of using a sample of three schools for the questionnaires was that it increased the generalisability of the findings and although the action research phase of the study took place in a completely different school, the findings from the pilot study were still applicable to the new school setting. The statistical analysis of the questionnaire data required the researcher to become familiar with SPSS analysis techniques and this meant that it was a full academic year before results were analysed and the next phase of the research could be embarked upon. However, the analysis demonstrated that the data set was reliable and that inferences could be analysed for statistical significance. Multiple regression analysis showed that 40% of the variance in pupil positivity could be explained by the factors investigated in this questionnaire and this is a high proportion for a quantitative model.

The use of mixed methodology does mean that the researcher has to identify and attempt to overcome the problems associated with both quantitative methods and qualitative methods as each research phase is travelled through. Whilst educative this can also be burdensome. Problems arising from the action research phase of the study were largely problems involving people and their reactions to the research. If one of the primary aims of action research is to impact on practice (Somekh, 1995) then by necessity it must be collaborative and this involves winning the hearts and minds of the teachers involved. Participants need to be confident of their abilities and willing to be self critical (Winter, 1996) and this was certainly not the case at the outset of the action research study. The process of engaging teachers with action research is slow and frustrating, as it requires teachers to see the need for change and then become committed to bringing change about. Initially teachers were very resistant to the idea that there was a need for change and for some weeks it was uncertain that the action research would get off the ground as effective, real collaboration within a group that has a common purpose was a primary necessity. Many teachers infer that the introduction of 'reflective practice' implies some degree of incompetence on their part (Bright, 1995b). However, through the support of the Head of Science and constant reassurances that the research was not an appraisal exercise, eventually an ethos of mutual respect and trust was established.

The ethical considerations of using up the time of teachers and pupils to the possible detriment of the education process was one consideration that had to be balanced against the potential benefits of the improvements that may come from research findings. However it was a consideration that weighed heavily with teachers since they felt that every moment of time that they could spend on preparing pupils for module tests and examinations should be used for the furtherance of the pupils' knowledge. All pupils throughout both phases of the research were informed of the purposes of the research and their consent obtained, in addition to the consent of their Head teacher. There was an inherent risk that by informing pupils of the nature of the research and their part in it, their natural behaviour may change (Cohen et al, 2003). This may have introduced errors into the research design. However, in the case of the action research it was felt that the time over which it was designed to run was sufficiently long that this effect would not be significant.

Other errors in action research may arise from the researcher ignoring or devaluing relevant information and making unjustified assumptions. The use of a 'dialogue group' helped to minimise these errors as the perceptions and views of the researcher were tempered by those of the teaching staff. The additional use of questionnaire data within the action research phase also lent a degree of objectivity to the conclusions reached. However, it was the 'dialogue group' that provided the forum for personal reflections which were sometimes uncomfortable but hugely developmental for all concerned. Bright (1995b) maintains that such reflective practice is vital to continuing teacher education and training.

Another concern with action research is the amount of time that needs to be devoted to the study if any kind of impact is to be hoped for. For a fully funded researcher this may be less of an issue but for a part time researcher who is also a full time University tutor, this is much more of an issue. It has at times proved difficult to mediate the demands of the research study with other teaching and administrative duties and this has led to a frustration regarding the time taken to get findings into the public domain, especially when similar findings are being published apace. Also the extended time for the research meant that one teacher went on maternity leave and some pupils changed sets in January on the basis of midyear examinations. These are all problems that action researchers must take in their stride.

One criticism often directed towards action research is related to the context specificity of the findings and the lack of generalisability of these findings to other contexts. Comparison with other studies can go some way to establishing the external validity of the research undertaken. The findings from this study do find common ground with those of other contemporary studies (Olsen et al, 1996; Millar and Osborne, 1998; Eyre, 1999; Osborne et al, 2003; Schreiner and Sjoberg, 2004; Betts and Kercher, 2005; Taber and Riga, 2006; James et al, 2006; Ratcliffe, 2007) and whilst the researcher would not claim that these findings are necessarily generalisable to other contexts, the indication is that there is sufficient evidence to make the exploration of other contexts through further research justifiable.

The overall judgement regarding whether any research process was 'fit for purpose' is formed from examining the consistency of its overall design quality. Within-design consistency requires the design and inferences of the research to be consistent with the research questions. In this case the research was designed to answer two questions.

1. What is the impact of teaching and learning methodologies utilised in the science classroom on the attitudes and aspirations of able pupils in science?

2. How might teachers be supported in changing their practice in the science classroom towards the adoption of more autonomous teaching and learning methodologies for able pupils?

The research design allowed these questions to be investigated in depth and the inferences from the research indicate firstly that within a particular context, with enlightened and well-motivated teachers, the promotion of autonomous teaching and learning methodologies does lead to greater self-reliance, improved aspirations and more meaningful learning for able pupils. The second indication is that the method of supported action research can prove to be an effective means by which teachers can become enabled to engage with processes leading to their continued professional development. However, care must be taken in ascribing the observed improvements entirely to the action research project as throughout the course of the academic year other staff development activity did take place for the whole teaching staff, which may have impacted on both pupils and teachers.

The second consideration is the conceptual consistency of the research design i.e. to what extent are the inferences from the various parts of the study consistent with each other and with external research. The inferences from both the pilot and action research phases of this project show very good agreement and are reinforced by a considerable body of external research. The triangulation brought about by using diverse methods of data gathering strengthens the conclusions of the research (Olsen et al, 1996). Finally, the design must be examined for interpretive consistency i.e. do all those involved agree on the interpretation of the findings. Although there have been many disagreements along the way, at the end of the project the researcher, teaching staff and pupils were all convinced that the promotion of pupil autonomy for able pupils in the classroom did lead to more effective learning and raised aspirations for further study of science, although impact on attainment was not evidenced. The changes in practice of the science department, the new resources brought in and their involvement with off-site activities, all served to strengthen the argument that not only are able pupils benefiting from this approach but also their teachers were seeing the benefits in improved classroom relationships with pupils.

A huge amount has been learned about how to go about (and how not to go about!) action research. Skills in data gathering and analysis have been acquired and lessons learned about effective teaching and learning for both able pupils and able teachers. Amongst these are that practice changes gradually amongst those convinced of the need for change. Teachers develop when they are able to be open and reflective with colleagues, they have a valuable role as action researchers and perhaps the most effective professional development may be achieved through these means.

8.5 Theoretical issues

One of the main issues arising within this study concerns how able pupils can best be facilitated in their construction of new knowledge. Science, as presented in schools is often a positivistic verification of known theories and the principles of constructivist scientific enquiry are not well embedded into classrooms. 'Teaching to the test' contravenes the established understanding of how children learn (Black et al, 2006). Theories of social constructivism require pupils to engage in building knowledge through collaborative discussion and interaction with others in order that thinking skills may be developed. As long as teachers suppress such discussion, skills in reasoning and problem solving will be inhibited (Mercer, 2000). Unless pupils are enabled to experience cognitive dissonance in the classroom (Piaget, 1972) their ability to assimilate and accommodate new concepts into their understanding is hindered. However, this research shows that the development of these new concepts is dependent upon a pre-requisite level of prior knowledge. Pupils are intimidated by the expectation that they should engage in autonomous learning when they do not possess this essential underlying knowledge and such expectations only serve to take them out of their zone of proximal development (Vygotsky, 1978) and experience anxiety.

One of the essential skills of good teaching is that the teacher should be able to differentiate for each pupil, ascertain what prior knowledge and understanding they have and to 'scaffold' their learning accordingly (Ausubel, 1968). However, many teachers find these skills difficult to apply. One means by which such personalisation may be achieved is for the teacher to allow the pupil to engage in autonomous learning practices as part of a range of classroom experiences. The use of autonomous learning has been shown by this study to be effective in uncovering pupil misconceptions and permits the teacher to ascertain the level of understanding that exists for each pupil and differentiate provision accordingly. This enables the teaching and learning relationship to become more strongly developed than the 'aiming at the middle' approach which was observed in the pre-intervention observation.

However, the application of constructivist approaches can be problematic. Pupils may not be ready to take on the responsibility for their own learning (Duit, 1994) and this proved to be the case for some of the pupils in this study. If we wish pupils to become more responsible for their own learning then we must devolve that responsibility to them, at least for short periods of time in the first instance. This means that pupils must be equipped to take on this responsibility by enhancing the study skills which enable them to engage with autonomous learning practices. Another essential skill required for pupils to take responsibility for their learning is that they must be able to engage in metacognition (Ambrose et al, 2003). By encouraging children to share how their minds are working they become better able to do this. Thus the onus is on teachers to provide opportunity for pupils to engage with personal research and extended writing and allow them to talk about what they have learned and bounce their ideas around in the classroom. Such practices not only improve metacognitive skills and study skills but also improve communication skills and confidence.

Fisher (2004) suggests that the quality of pupils' work is dramatically improved by autonomous learning and that their learning becomes more meaningful to them. It was certainly observed in this study that the retention of learning was more effective when pupils were allowed to work autonomously and the capacity for creative invention was certainly enhanced. Teaching for creativity involves autonomy and respect for emerging ideas (NACCCE, 2000). When pupils are listened to and allowed to put their ideas into practice they experience an empowerment that brings about confidence and creative outcomes. Such an approach to teaching and learning provides motivation for the pupil and the aspiration to take their learning to higher levels is dependent on this.

The work carried out in this study has identified a number of special needs associated with able pupils in science. These include a constructivist approach to teaching and learning that permits an engagement with authentic scientific enquiry, the development of thinking skills and knowledge building by collaborative discussion with others and the provision of appropriate personalised scaffolding by teachers. Alongside this able pupils must be enabled to engage in autonomous learning through the effective teaching of study skills, metacognition and communication skills. Most importantly pupils need to be empowered to take responsibility for their learning by allowing them the opportunity within the classroom to take control of tasks and make decisions regarding their individual learning objectives.

How can teachers be facilitated to provide these ideal conditions for learning? Amongst the many problems in implementation this study has identified reluctance on the part of teachers to accept a need for change, a sense of incapacity in acting as agents for change, a fear of 'losing control' rooted in problems of behaviour management, the pressure of performing to externally imposed targets and the overload of new educational initiatives which teachers need to assimilate and apply to their practice. Many teachers are not appreciative of the special needs of able pupils and regard special provision as elitist and of low priority (Eyre, 2007b).

Traditionally in-service training in provision for able pupils involves teachers in attending one day courses outside the school context but research has shown such a model of professional development to be largely ineffective in making an impact on the classroom (Black and William, 1998). Reasons put forward as to why this is the case include the theoretical nature of the research presented to teachers and a lack of relevance of such training to what takes place within the classroom (Marshall et al, 2006). This lack of knowledge and confidence on the part of classroom teachers has led to a model of provision for able pupils consisting of 'enhancement activities' in 'out of school' contexts (Newberry and Gilbert, 2007). Since this model does not involve the classroom teacher it cannot act as a medium through which teachers can develop their skills.

This study has demonstrated that action research can be an effective means of facilitating teacher engagement with culture change within the classroom. The action research exercise carried out within this study succeeded in identifying a need for change in teaching and learning methodology for able pupils and allowed teachers to experiment with their provision through a culture of collaborative enquiry. This resulted in an empowerment that enabled the teachers to see themselves as agents of change and educational research as a valid and *practical* means by which change could be brought about. The research was effective in raising teachers' expectations of able pupils and improving communication amongst teachers and between teacher and pupils. It is important to recognise that just as learning is a social process for pupils it is also the case for teachers and the action research provided a constructivist learning environment for them too. The extended nature of the project provided the necessary ongoing support (Van Tassel-Baska, 1998) for the teachers over a number of months.

Another advantage to the action research methodology as an agent for continuing professional development (CPD) is that it is locally specific. For the wider educational community this may be regarded as a disadvantage since what works locally may not work generally but for the teacher-researcher the localised nature of the research is an advantage since it is seeking local solutions to local problems. Also the research intervention was seen to have immediate benefit to pupils since it was activated directly by their own teachers. The beneficial effects included an improving relationship with pupils as they began to realise that their teachers were genuinely concerned about improving learning for them as individuals. For some teachers this had the unforeseen benefit of lessening classroom tensions and improving behaviour management. As the knowledge and skills of the teachers improved so did their willingness to try more adventurous approaches. This energising effect of the research had also been unforeseen at the start and it was curious to note that the motivational effects that had been hoped for on the part of the pupils were now evidenced by the teachers.

8.6 Recommendations

The recommendations arising from this research concern not just provision for able pupils in science but also the CPD implications for their teachers, as it is unlikely that the former can be achieved without paying attention to the latter. The positive outcomes observed for able pupils in the science classroom lead to the following recommendations.

- Able pupils should have the opportunity to engage in autonomous learning activities within the classroom, supported by personalised 'scaffolding' from teachers.
- In order that able pupils should be empowered to take responsibility for their own learning they should be taught enhanced study skills
- Able pupils should also be encouraged to develop skills in metacognition through sharing their thinking with their peers and their teacher in the classroom
- In order to achieve this able pupils will need to be encouraged in both oral communication skills and extended writing
- Schemes of work should allow time for autonomous creative work and extended scientific enquiry and able pupils should be encouraged in both of these pursuits.

In order that able pupils can be facilitated in these goals teachers will need to be supported through continuing professional development. This professional development will need to impact on *all* teachers as *all* teachers need to work towards the achievement of the Classroom Quality Standards for Gifted and Talented Education (DCFS, 2007a). The impact of this action research on classroom practice leads to the following recommendations.

- Enhancement activities for scientifically able pupils should include the participation of their classroom teachers and include an element of continuity into the school classroom.
- By this means science departments may be encouraged to engage with small scale action research projects within their own contexts and the outcomes disseminated within their schools.
- Experienced researchers who can act in a facilitating role should support such research initiatives.

8.7 Implications for further research

The implications for further research arising from this study naturally divide into those concerning provision for able pupils in science and those concerning the continuing professional development of their teachers. However it may not be possible to research the first in isolation from the second as the former is necessarily dependent upon the latter. In the past much of the provision for able pupils in science has taken place in out of classroom contexts and for much of this the classroom teacher has been somewhat sidelined. If a positive impact upon classroom practice is to be demonstrated then the focus of future research needs to be upon how that impact may best be effected. The four areas for further research identified from this study are

- Whether the promotion of greater autonomy in the classroom encourages more effective learning for able pupils in science, in a wider variety of school contexts and whether it may be the means by which such able pupils might be 'switched back on' to the study of advanced level science subjects, particularly physical sciences?
- What should be the balance between out of classroom provision and within classroom provision for able pupils and how may the two be made to interact to produce a more unified whole?
- Can the inclusion of the classroom teacher in out of classroom enhancement activities serve to develop the teacher's professional practice when back in the classroom?
- What role can action research projects play in the continuing professional development of teachers and potential teachers in initial teacher education?

The fact that there is much more work to be done is indisputable. Clarke (1999) expressed the viewpoint that,

> *" It is real change in thinking and practice that all providers of professional development whether the TTA, universities, LEAs or schools are most interested in." (p.23)*

It is also this 'real change in thinking and practice' that is hardest to bring about. Gilbert (2006) maintains that a nationally structured and financially rewarded programme of continuing professional development (CPD) should be provided as an entitlement for all science teachers in post and calls for more research focussing on how to increase pupils' engagement in science education. For real impact on classroom practice such research must link with educational policy, CPD and initial teacher education. James et al (2006) reinforce this view,

"The project team believed that unless some attempt was made to understand what the classroom conditions for effective learning look like, what teaching practices promote this, and what kinds of professional development and institutional conditions and cultures help teachers learn these new practices, there is little chance of spreading and sustaining the kinds of improvements observed in classroom studies. To our knowledge, no previous studies have brought school improvement research into alignment with such a specific but important area of pedagogical innovation." (p.32)

Thus both Gilbert (2006) and James et al (2006) identify a need for the type of research described in this study. Even the Royal Society Conference is in agreement with this need.

" There is a requirement for a stronger research agenda and associated funding programme that coordinates support for a relevant, high quality, sustainable evidence base to inform policy and practice and reverse the declining popularity of the sciences post-16" (Hyam, 2006 p. 6)

Such research is not only desirable it is essential in order for the future of quality physical science education to flourish. If we require young people to make good decisions concerning their future, they need to have experience of decision-making and taking responsibility for their own learning. Teachers have a clear duty to ensure that such decision-making powers are practised in the classroom using autonomous teaching and learning methodology. At the 2007 World Conference for Gifted Education, Eyre (2007b) called for more opportunities for professional development, to ensure that teachers have the knowledge, skills and confidence to allow the most gifted pupils to thrive in their classrooms. This call is echoed by many researchers (Taber, 2007b; Gilbert and Newberry, 2007; Coll, 2007). However, such professional development must be underpinned by an ongoing research agenda that is closely related to the classroom and classroom practitioners, in order for it to be credible not only for the research community and policy makers, but also most importantly, for the teachers who are to implement its recommendations.

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APPENDIX 1

PILOT STUDY QUESTIONNAIRE TO YEAR 9 PUPILS

This questionnaire is part of a study organised by Keele University.

The purpose of this questionnaire is to find out if the science education that you are receiving has been effective in improving your learning and thinking about science. The results will help to inform staff and researchers about possible ways to improve science courses and activities in future years.

ALL ANSWERS WILL BE TREATED CONFIDENTIALLY. PLEASE ANSWER AS HONESTLY AS YOU CAN.

NAME____

AGE____________YRS _____________ MONTHS

SCHOOL______________________________________

YEAR GROUP_________________________________

MALE/FEMALE____________

SET____________

SCIENCE TEACHER________________________

PART 1

Where the question asks you to make a choice please circle the answer. If the question asks you to write a response please write on the lines below the question.

1. Would you say that the work that you do in science classes is

BIOLOGY *very easy* *easy* *just about okay* *difficult* *very difficult*

CHEMISTRY *very easy* *easy* *just about okay* *difficult* *very difficult*

PHYSICS *very easy* *easy* *just about okay* *difficult* *very difficult*

2. When you have class science tests would you say that in your class your results were

7 **Well above average** **above average** **average** **below average** **well below average**

3. If you were stuck with your science homework who would you ask to help you?

7 **Your** *science teacher* **Another teacher** **Family member** **Friend** **No one**

4. Do any of your family work in science related jobs or follow science related courses

7 **Mum** **Dad** **Brother/sister** **Other family member** **No one**

5. Do you think that you would like to do a science related job or course after GCSE

7 **Definitely yes** **Maybe** **Don't know** **Probably not** **Definitely not**

6. Do you have any science books at home other than school text books

0 *1-5* *6-10* *11-15* *16+*

7. Have you taken part in any science activities outside the classroom this year. If so, what were they.

8. If you did take part in an out of school science activity did you think it was

Very interesting *interesting* *okay* *boring* *very boring*

9. Describe the best science lesson or activity that you have had this year

10. Why was it good

12 Describe the worst science lesson or activity that you have had this year

13 Why was it bad

PART 2

The following questions are designed to show how you feel about learning science. For each question circle the response which indicates your level of agreement with the statement.

1. I like to look at science books in the library

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

2. I hate to keep records of science experiments in a notebook

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

3. Science films bore me to death

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

4. I wish science class lasted all day

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

5. I dislike watching science programmes on television

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

6. I hate science class

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

7. Learning science facts is boring

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

8. Working with science equipment makes me feel important

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

9. I would like to go to a science club that meets after school

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

10. Looking through a microscope is not my idea of fun

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

11. Knowing science facts makes me feel good

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

12. I don't mind doing an experiment several times to check the answer

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

13. I feel like day dreaming during science class

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

14. Talking about science facts I know makes me feel great

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

15. I hate to study science out of doors

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

16. I like to talk to my parents about science

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

17. I like to make science drawings

7 **Strongly agree Agree Undecided Disagree Strongly disagree**

18. I wouldn't think of discussing science with friends outside of class

7 Strongly agree Agree Undecided Disagree Strongly disagree

19. I enjoy using mathematics in science experiments

7 Strongly agree Agree Undecided Disagree Strongly disagree

20. I look forward to science class

7 Strongly agree Agree Undecided Disagree Strongly disagree

21. I wish we didn't have science class so often

7 Strongly agree Agree Undecided Disagree Strongly disagree

22. Doing science projects at home is a waste of time

7 Strongly agree Agree Undecided Disagree Strongly disagree

23. Science is one of my favourite classes

7 Strongly agree Agree Undecided Disagree Strongly disagree

Please sign below

I agree to taking part in this data collection survey **Signed ___________________**
Your data is valued. Thank you for answering.

Appendix 2

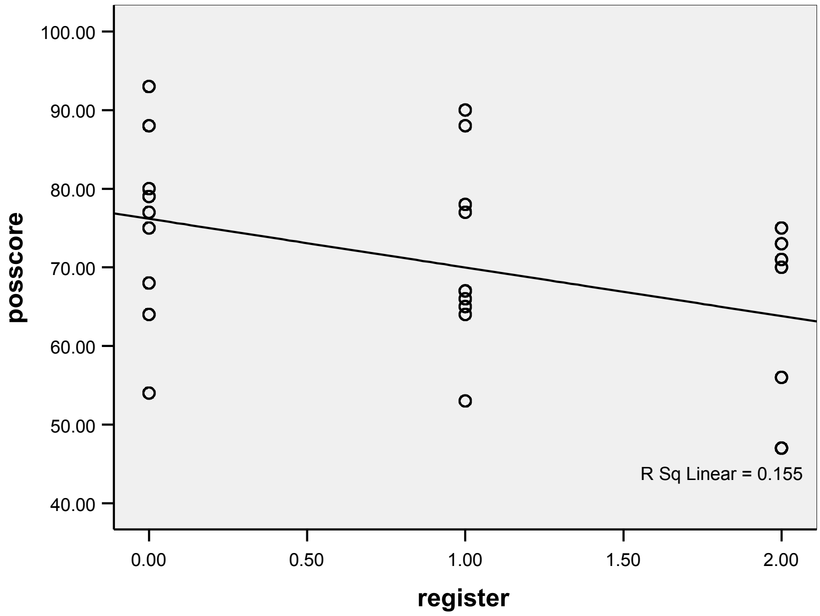
Correlation analysis for positivity to science with gender, presence on gifted register, perception of subject difficulty, parental scientific background, science aspirations and science books in the home

Correlations

		avposoct	gender	register	percepbio	percepchem	percepphys	sciencebackground	aspirations	books
avposoct	Pearson Correlation	1	-.180	-.395(*)	.237	-.211	.076	.240	.328	.243
	Sig. (2-tailed)		.379	.046	.243	.311	.711	.238	.102	.231
	N	26	26	26	26	25	26	26	26	26
gender	Pearson Correlation	-.180	1	.344	-.109	-.170	.056	-.139	.395(*)	-.338
	Sig. (2-tailed)	.379		.067	.589	.408	.781	.491	.041	.085
	N	26	29	29	27	26	27	27	27	27
register	Pearson Correlation	-.395(*)	.344	1	-.053	-.144	.071	.061	.136	-.275
	Sig. (2-tailed)	.046	.067		.793	.482	.726	.762	.499	.166
	N	26	29	29	27	26	27	27	27	27
percepbio	Pearson Correlation	.237	-.109	-.053	1	.311	.458(*)	-.200	.132	.357
	Sig. (2-tailed)	.243	.589	.793		.123	.016	.318	.511	.068
	N	26	27	27	27	26	27	27	27	27
percepchem	Pearson Correlation	-.211	-.170	-.144	.311	1	.191	-.144	-.035	.300
	Sig. (2-tailed)	.311	.408	.482	.123		.350	.482	.865	.137
	N	25	26	26	26	26	26	26	26	26
percepphys	Pearson Correlation	.076	.056	.071	.458(*)	.191	1	.076	.019	.411(*)
	Sig. (2-tailed)	.711	.781	.726	.016	.350		.706	.927	.033
	N	26	27	27	27	26	27	27	27	27
sciencebackground	Pearson Correlation	.240	-.139	.061	-.200	-.144	.076	1	.227	.350
	Sig. (2-tailed)	.238	.491	.762	.318	.482	.706		.255	.073
	N	26	27	27	27	26	27	27	27	27
aspirations	Pearson Correlation	.328	.395(*)	.136	.132	-.035	.019	.227	1	.015
	Sig. (2-tailed)	.102	.041	.499	.511	.865	.927	.255		.940
	N	26	27	27	27	26	27	27	27	27
books	Pearson Correlation	.243	-.338	-.275	.357	.300	.411(*)	.350	.015	1
	Sig. (2-tailed)	.231	.085	.166	.068	.137	.033	.073	.940	
	N	26	27	27	27	26	27	27	27	27

* Correlation is significant at the 0.05 level (2-tailed).

The only significant result was the register and positivity score (graph below)



Year 10 April data section

Correlations

		percepbio	avposapril10
percepbio	Pearson Correlation	1	.133
	Sig. (2-tailed)		.517
	N	26	26
avposapril10	Pearson Correlation	.133	1
	Sig. (2-tailed)	.517	
	N	26	26

Correlations

		avposapril10	percepchem	percepphys
avposapril10	Pearson Correlation	1	.335	.246
	Sig. (2-tailed)		.094	.237
	N	26	26	25
percepchem	Pearson Correlation	.335	1	.393
	Sig. (2-tailed)	.094		.052
	N	26	26	25
percepphys	Pearson Correlation	.246	.393	1
	Sig. (2-tailed)	.237	.052	
	N	25	25	25

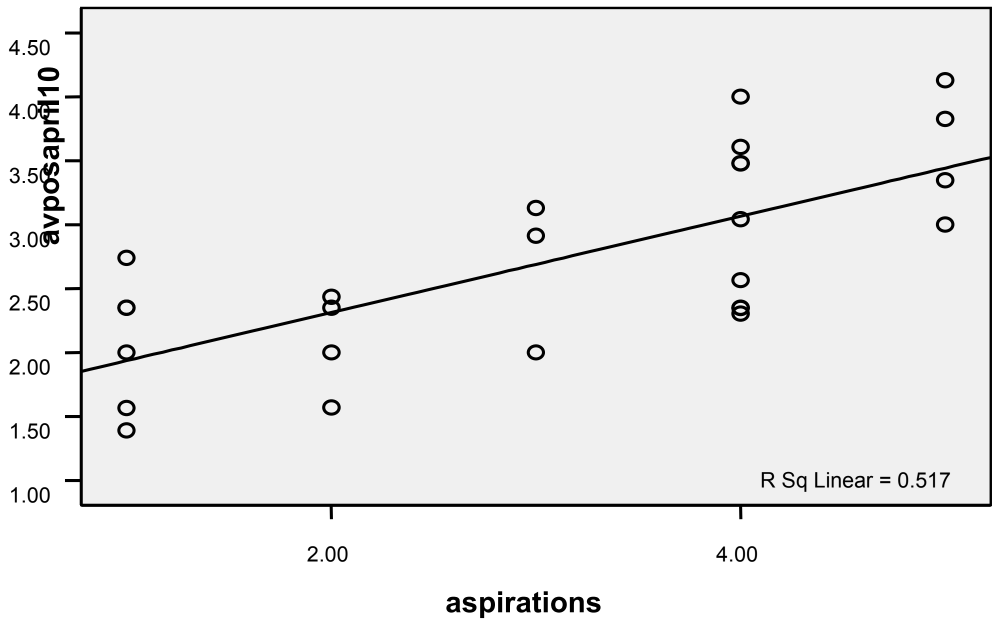
Correlations

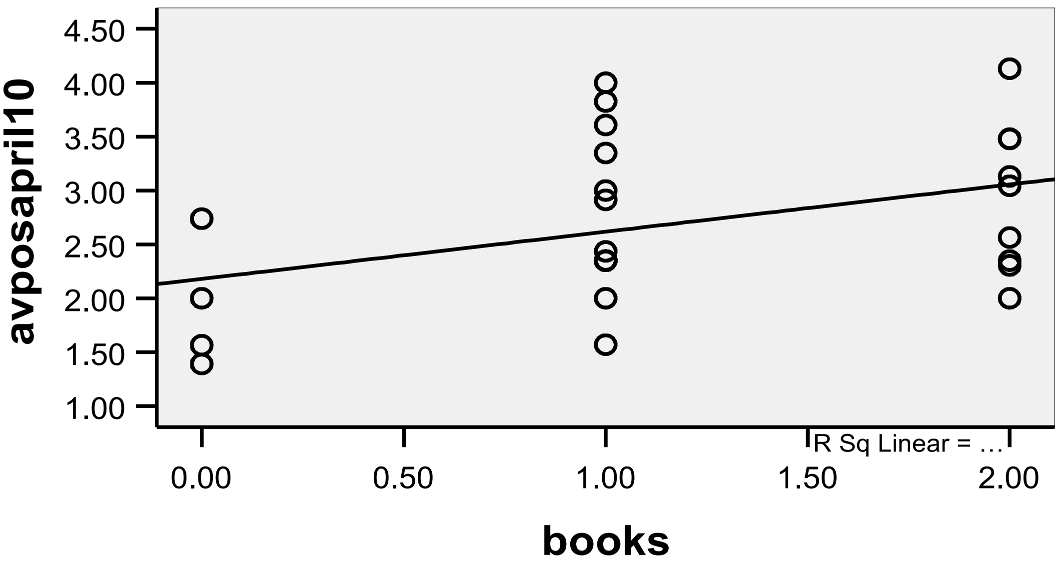
		avposapril10	scienceback ground
avposapril10	Pearson Correlation	1	.331
	Sig. (2-tailed)		.098
	N	26	26
sciencebackground	Pearson Correlation	.331	1
	Sig. (2-tailed)	.098	
	N	26	26

Correlations

		avposapril10	aspirations	books
avposapril10	Pearson Correlation	1	.719(**)	.399(*)
	Sig. (2-tailed)		.000	.044
	N	26	26	26
aspirations	Pearson Correlation	.719(**)	1	.507(**)
	Sig. (2-tailed)	.000		.008
	N	26	26	26
books	Pearson Correlation	.399(*)	.507(**)	1
	Sig. (2-tailed)	.044	.008	
	N	26	26	26

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).





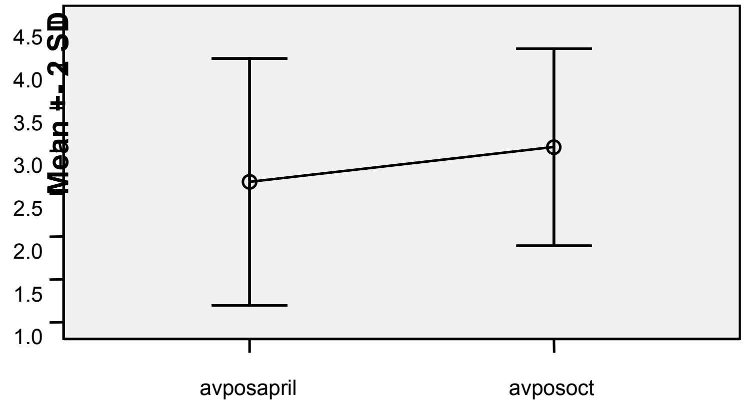
Comparison year 10 April/ October data

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	avposapril	2.6376	23	.72029	.15019
	avposoct	3.0432	23	.57493	.11988

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean					
				Lower	Upper			
Pair 1 avposapril - avposoct	-.40562	.61859	.12899	-.67312	-.13812	-3.145	22	.005

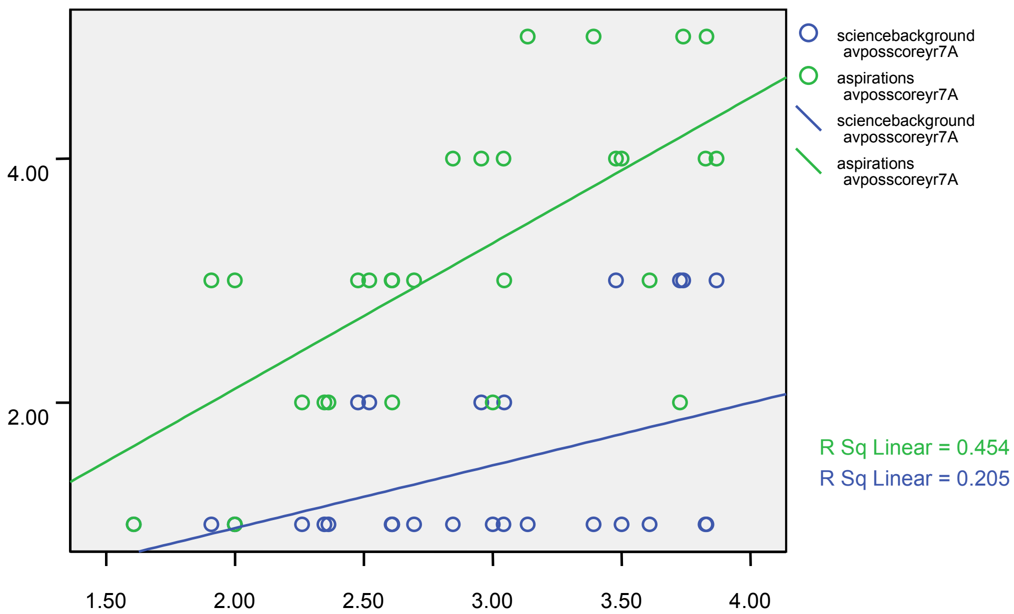


Questions Oct 7A data

Correlations

		avposscoreyr7A
avposscoreyr7A	Pearson Correlation	1
	N	28
gender	Pearson Correlation	.134
	Sig. (2-tailed)	.498
	N	28
register	Pearson Correlation	-.132
	Sig. (2-tailed)	.504
	N	28
percepbio	Pearson Correlation	.092
	Sig. (2-tailed)	.643
	N	28
percepchem	Pearson Correlation	.303
	Sig. (2-tailed)	.118
	N	28
percepphys	Pearson Correlation	-.148
	Sig. (2-tailed)	.453
	N	28
sciencebackground	Pearson Correlation	.452(*)
	Sig. (2-tailed)	.016
	N	28
aspirations	Pearson Correlation	.674(**)
	Sig. (2-tailed)	.000
	N	28
books	Pearson Correlation	.152
	Sig. (2-tailed)	.439
	N	28

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

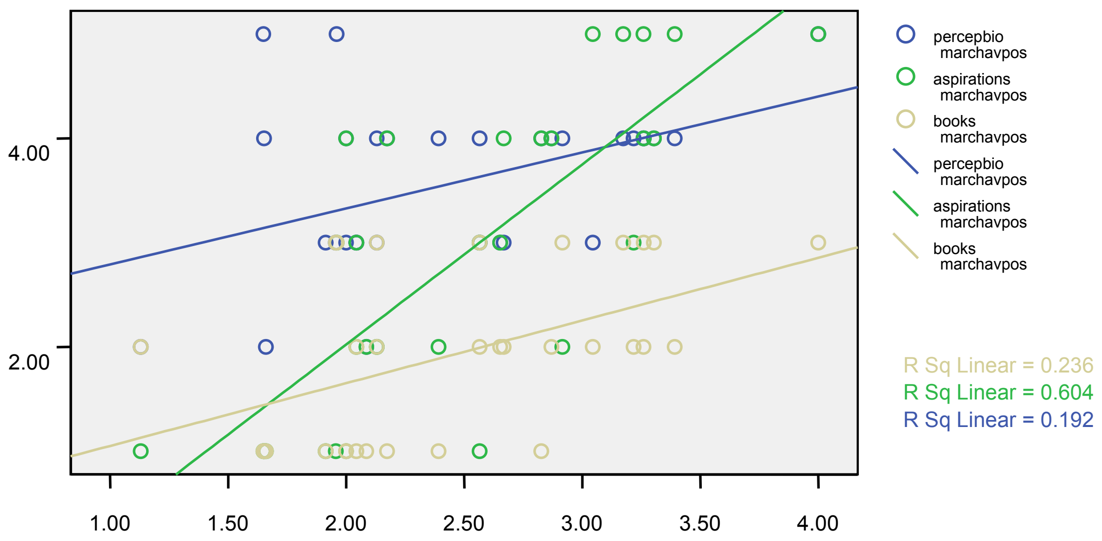


Questions March 7A

Correlations

		marchavpos
marchavpos	Pearson Correlation	1
	N	32
register	Pearson Correlation	.116
	Sig. (2-tailed)	.526
	N	32
gender	Pearson Correlation	.154
	Sig. (2-tailed)	.400
	N	32
percepbio	Pearson Correlation	.445(*)
	Sig. (2-tailed)	.011
	N	32
percepchem	Pearson Correlation	.278
	Sig. (2-tailed)	.123
	N	32
percepphys	Pearson Correlation	.218
	Sig. (2-tailed)	.230
	N	32
sciencebackground	Pearson Correlation	.290
	Sig. (2-tailed)	.108
	N	32
aspirations	Pearson Correlation	.743(**)
	Sig. (2-tailed)	.000
	N	32
books	Pearson Correlation	.486(**)
	Sig. (2-tailed)	.006
	N	31

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).



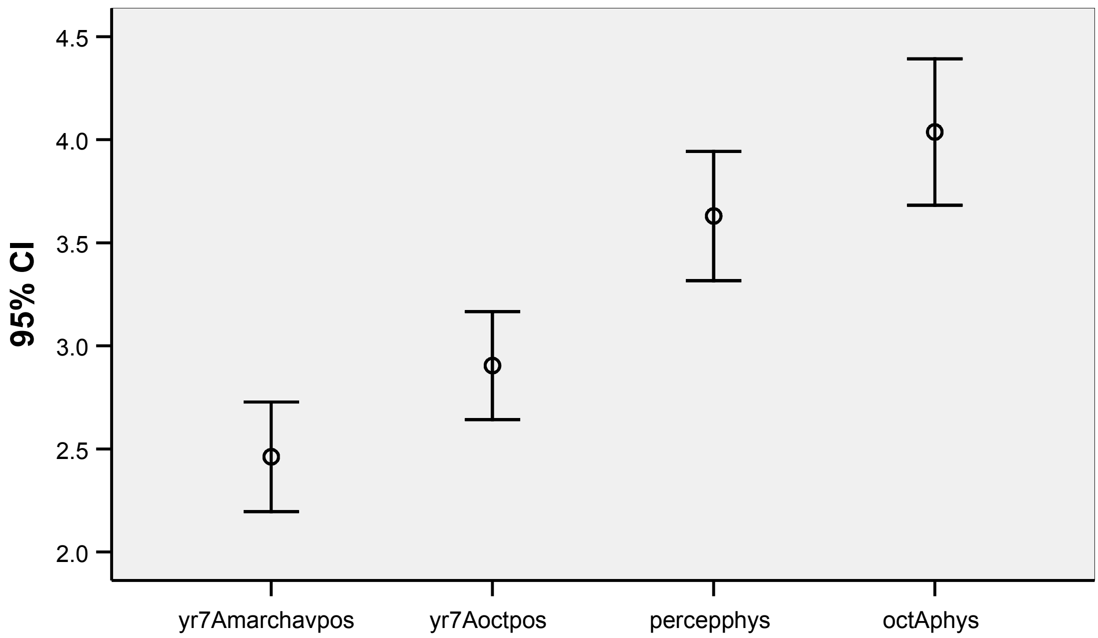
Comparisons for March/Oct for 7A

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	yr7Amarchavpos	2.4612	27	.67162	.12925
	yr7Aoctpos	2.9035	27	.66232	.12746
Pair 2	percepbio	3.6000	30	.81368	.14856
	octAbio	3.8333	30	.69893	.12761
Pair 3	percepchem	3.6333	30	.85029	.15524
	octAchem	3.6333	30	.61495	.11227
Pair 4	percepphys	3.6333	30	.76489	.13965
	octAphys	4.0667	30	.86834	.15854
Pair 5	aspirations	2.7667	30	1.43078	.26122
	OctAasp	3.1667	30	1.14721	.20945

Paired Samples Test

		Paired Differences			t	df	Sig. (2-tailed)
Pair 1	yr7Amarchavpos - yr7Aoctpos	-.44231	.49924	.09608	-4.604	26	.000
Pair 2	percepbio - octAbio	-.23333	1.10433	.20162	-1.157	29	.257
Pair 3	percepchem - octAchem	.00000	.87099	.15902	.000	29	1.000
Pair 4	percepphys - octAphys	-.43333	1.07265	.19584	-2.213	29	.035
Pair 5	aspirations - OctAasp	-.40000	1.40443	.25641	-1.560	29	.130

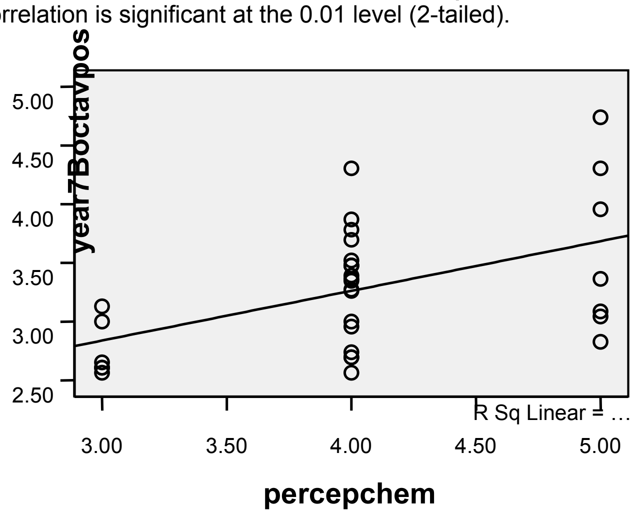


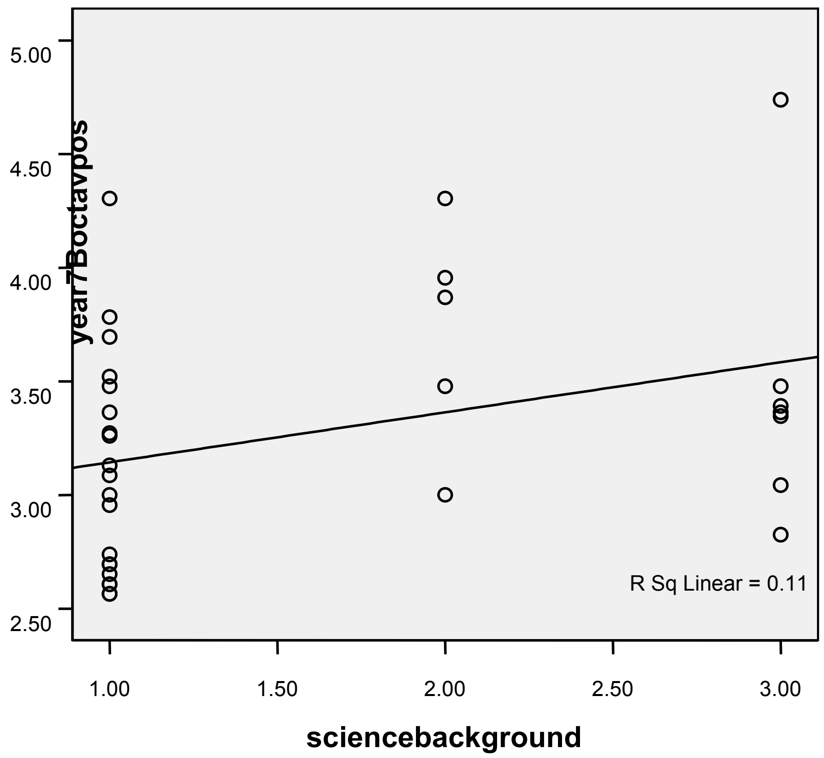
Questions for Oct 7B data

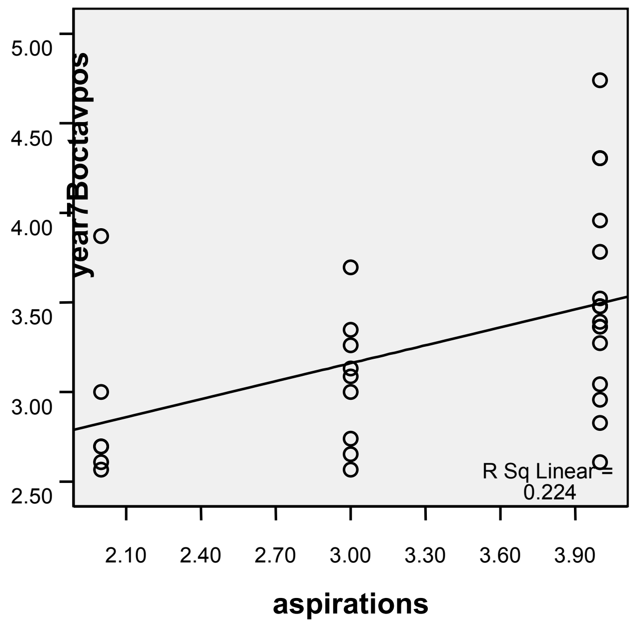
Correlations

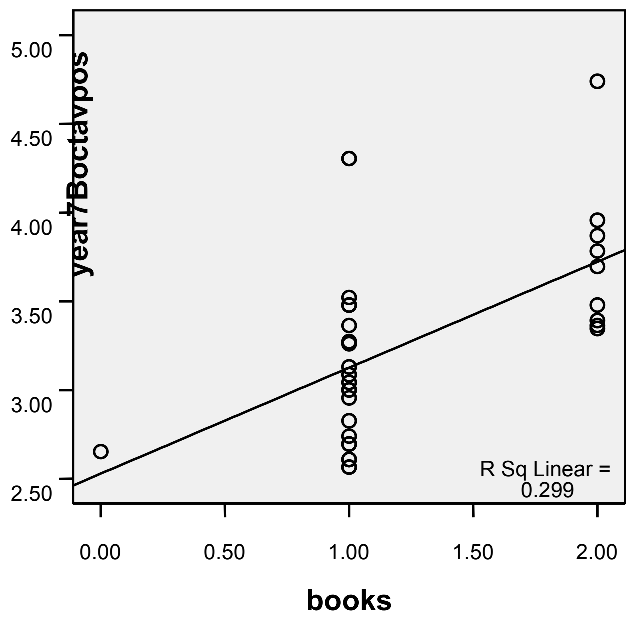
		year7Boctavpos
year7Boctavpos	Pearson Correlation	1
	N	32
register	Pearson Correlation	-.171
	Sig. (2-tailed)	.350
	N	32
gender	Pearson Correlation	.037
	Sig. (2-tailed)	.842
	N	32
percepbio	Pearson Correlation	.019
	Sig. (2-tailed)	.916
	N	32
percepchem	Pearson Correlation	.493(**)
	Sig. (2-tailed)	.004
	N	32
percepphys	Pearson Correlation	.142
	Sig. (2-tailed)	.439
	N	32
sciencebackground	Pearson Correlation	.332
	Sig. (2-tailed)	.064
	N	32
aspirations	Pearson Correlation	.474(**)
	Sig. (2-tailed)	.006
	N	32
books	Pearson Correlation	.547(**)
	Sig. (2-tailed)	.001
	N	32

** Correlation is significant at the 0.01 level (2-tailed).




year7Boctavpos
5.00
4.50
4.00
3.50
3.00
2.50
1.00
1.50
2.00
2.50
3.00
sciencebackground
R Sq Linear = 0.11


year7Boctavpos
5.00
4.50
4.00
3.50
3.00
2.50
2.10
2.40
2.70
3.00
3.30
3.60
3.90
aspirations
R Sq Linear = 0.224



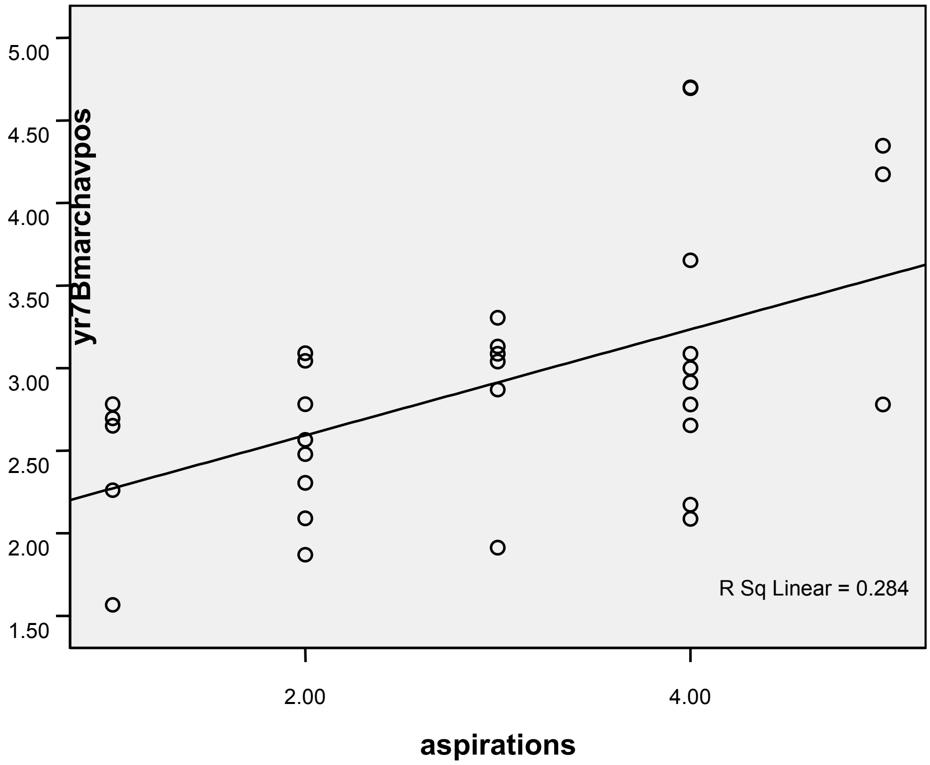
Questions for March 7B data

Correlations

		yr7Bmarchavpos
yr7Bmarchavpos	Pearson Correlation	1
	N	32
register	Pearson Correlation	-.162
	Sig. (2-tailed)	.376
	N	32
gender	Pearson Correlation	.028
	Sig. (2-tailed)	.879
	N	32
percepbio	Pearson Correlation	.139
	Sig. (2-tailed)	.449
	N	32
percepchem	Pearson Correlation	.218
	Sig. (2-tailed)	.230
	N	32

percepphys	Pearson Correlation	.253
	Sig. (2-tailed)	.163
	N	32
sciencebackground	Pearson Correlation	.262
	Sig. (2-tailed)	.148
	N	32
aspirations	Pearson Correlation	.533(**)
	Sig. (2-tailed)	.002
	N	32
books	Pearson Correlation	.276
	Sig. (2-tailed)	.127
	N	32

** Correlation is significant at the 0.01 level (2-tailed).



Comparison March/ Oct for 7B

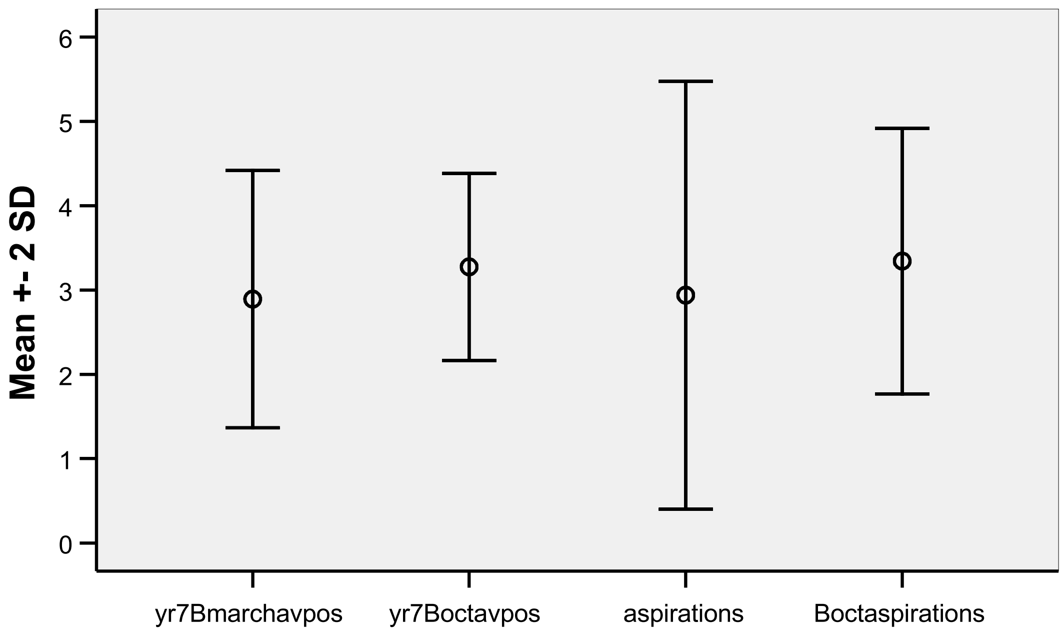
Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	yr7Bmarchavpos	2.8923	32	.76320	.13492
	yr7Boctavpos	3.2740	32	.55477	.09807
Pair 2	percepbio	3.7813	32	.60824	.10752
	Boctbio	3.9063	32	.64053	.11323
Pair 3	percepchem	3.8125	32	.59229	.10470
	Boctchem	4.0313	32	.64680	.11434

Pair 4	percepphys	3.9063	32	.68906	.12181
	Boctphys	3.8750	32	.70711	.12500
Pair 5	aspirations	2.9375	32	1.26841	.22423
	Boctaspirations	3.3438	32	.78738	.13919

Paired Samples Test

		Paired Differences		t	df	Sig. (2-tailed)
Pair 1	yr7Bmarchavpos - yr7Boctavpos	-.38175	.51808	-4.168	31	.000
Pair 2	percepbio - Boctbio	-.12500	.70711	-1.000	31	.325
Pair 3	percepchem - Boctchem	-.21875	.70639	-1.752	31	.090
Pair 4	percepphys - Boctphys	.03125	.59484	.297	31	.768
Pair 5	aspirations - Boctaspirations	-.40625	1.07341	-2.141	31	.040



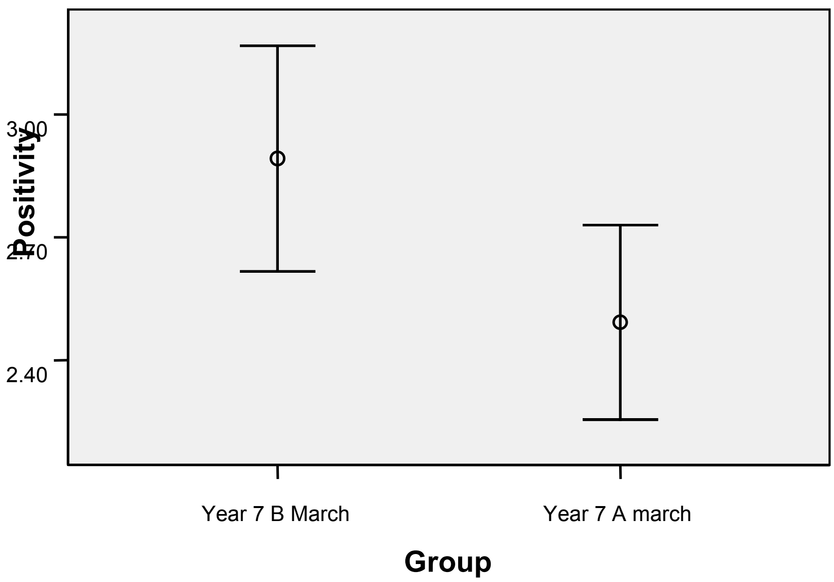
Comparison March 7A and 7B Positivity

Group Statistics

	VAR00009	N	Mean	Std. Deviation	Std. Error Mean
year7Bmarchavpos	1.00	32	2.8923	.76320	.13492
	2.00	32	2.4924	.65791	.11630

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
						Sig. (2-tailed)
year7Bmarchavpos	Equal variances assumed	.012	.912	2.245	62	.028
	Equal variances not assumed			2.245	60.682	.028



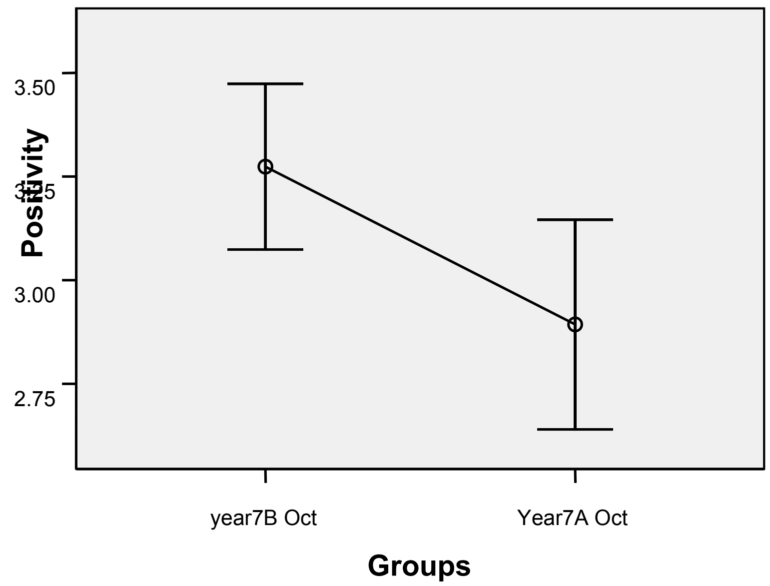
Comparison 7A and 7B Positivity score

Group Statistics

	VAR00009	N	Mean	Std. Deviation	Std. Error Mean
Year7Boctavpos	1.00	32	3.2740	.55477	.09807
	2.00	28	2.8930	.65230	.12327

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
						Sig. (2-tailed)
Year7Boctavpos	Equal variances assumed	1.618	.208	2.445	58	.018
	Equal variances not assumed			2.419	53.372	.019



Comparison 7A and 7B Aspirations March

Group Statistics

	VAR00009	N	Mean	Std. Deviation	Std. Error Mean
year7Bmarchasp	1.00	32	2.9375	1.26841	.22423
	2.00	32	2.8125	1.44663	.25573

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
						Sig. (2-tailed)
year7Bmarchasp	Equal variances assumed	1.297	.259	.368	62	.714
	Equal variances not assumed			.368	60.958	.714

Comparison 7A and 7B Aspirations October

Group Statistics

	VAR00009	N	Mean	Std. Deviation	Std. Error Mean
Year7Boctasp	1.00	32	3.3438	.78738	.13919
	2.00	31	3.1613	1.12833	.20265

		Levene's Test for Equality of Variances		t-test for Equality of Means		
						Sig. (2-tailed)
Year7Boctasp	Equal variances assumed	2.597	.112	.746	61	.458
	Equal variances not assumed			.742	53.466	.461

Appendix 3

Multiple Regression Analysis

Model Summary(d)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.381(a)	.145	.134	.55333	
2	.459(b)	.210	.191	.53500	
3	.520(c)	.271	.243	.51735	1.723

a Predictors: (Constant), scienceasp
b Predictors: (Constant), scienceasp, homebooks
c Predictors: (Constant), scienceasp, homebooks, perceptphys
d Dependent Variable: avposscore

ANOVA(d)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.252	1	4.252	13.886	.000(a)
	Residual	25.106	82	.306		
	Total	29.358	83			
2	Regression	6.174	2	3.087	10.785	.000(b)
	Residual	23.184	81	.286		
	Total	29.358	83			
3	Regression	7.945	3	2.648	9.895	.000(c)
	Residual	21.412	80	.268		
	Total	29.358	83			

a Predictors: (Constant), scienceasp
b Predictors: (Constant), scienceasp, homebooks
c Predictors: (Constant), scienceasp, homebooks, perceptphys
d Dependent Variable: avposscore

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.253	.155		14.521	.000		
	scienceasp	.173	.046	.381	3.726	.000	1.000	1.000
2	(Constant)	2.073	.165		12.533	.000		
	scienceasp	.129	.048	.284	2.687	.009	.875	1.143
	homebooks	.320	.123	.274	2.591	.011	.875	1.143
3	(Constant)	1.561	.255		6.115	.000		
	scienceasp	.120	.046	.264	2.580	.012	.870	1.150
	homebooks	.328	.119	.281	2.748	.007	.874	1.144
	perceptphys	.178	.069	.246	2.573	.012	.995	1.006

a Dependent Variable: avposscore

Appendix 4

SCIENCE TEACHER QUESTIONNAIRE

The purpose of this questionnaire is to assess the effect of the introduction of the Able and Talented programme on the working practices of teachers. The underlying area of interest is whether changes in provision and teaching methodology due to this programme have benefited the A&T cohort, the year group as a whole and the teacher.

All responses will be kept confidential. **You do not have to put your name on the front** but if you choose to it may help us to follow up interesting areas of good practice and innovation.The intention is to disseminate good practice and provide feedback to the LEA on **your** ideas for the improvement of provision for schools.

<u>This is not an inspection or appraisal exercise.</u>

School_______________________________________

Science Teacher________________________________

Main subject discipline___________________________

Subject disciplines taught_________________________

Please tick which year groups you have taught this academic year

Year 7
Year 8
Year 9
Year 10
Year 11

7 PART 1

1. Please detail below any training that you have received on the special needs of able children over the last 3 years.

Date **Training received**

___________ ______________________________

___________ ______________________________

___________ ______________________________

2. Do you run or take part in any extra curricular science clubs? Yes/No

If yes please give following information

Year group____

Average no. attending______________________________

Time of week held________________________________

3. Do you mentor any A&T science pupils Yes/No

If yes please give following information

Year group_____________________

No. of times seen termly_________________

4. Do you mentor any other science pupils Yes/No

If yes please give following information

Year group_____________________

No. of times seen termly______________

5. Have you run or helped with any out of school science visits this year. Yes/No

If yes please give details below

____

____

6. Please tick which of the following activities you would use in lesson planning during an average week.

a.	**filling in worksheets**	**b.**	**instructed practical work**
c.	**copying from board or book**	**d.**	**investigations**
e.	**internet research**	**f.**	**dictation**

g.	quizzes/games	h.	field work
i.	pupil presentations	j.	discussions/debates
k.	videos	l.	study skills enhancement
m.	problem solving exercises	n.	demonstrations
o.	tests	p.	self assessments
q.	use of CD rom or websites	r.	data logging
s.	use of interactive whiteboards	t.	pupil interviews

7. Do you prepare extension work for A&T children in your classes Yes/No

If yes please give examples of the kind of task set.

____

____

____

8. Do you prepare enrichment work for A&T children in your classes Yes/No

If yes please give examples of the kind of task set

____

____

____

9. Have the learning styles (e.g. visual, auditory, kinaesthetic) of children in your classes been identified Yes/No

If yes how would you use this information

____

____

____

____

10. What are the constraints upon you as a science teacher that you would like to see addressed.

____

____

____

____

PART 2

In this section please circle the response, which reflects your own viewpoint. The questions refer to children who are on the departmental A&T register.

1. **Able children in science do not need any different provision from other children**

Strongly agree agree undecided disagree strongly disagree

2. **Able children in science should be taught in a special set**

Strongly agree agree undecided disagree strongly disagree

3. **Able children in science should undergo accelerated exam entry**

Strongly agree agree undecided disagree strongly disagree

4. **The extra funding allocated for able children is unfair**

Strongly agree agree undecided disagree strongly disagree

5. **Questions from able pupils can be stimulating for the teacher**

Strongly agree agree undecided disagree strongly disagree

6. **Able children should have more funding than is currently provided**

Strongly agree agree undecided disagree strongly disagree

7. **Able children need more contact time with teachers**

Strongly agree agree undecided disagree strongly disagree

8. **Able children in science should be taught in mixed ability groups.**

Strongly agree agree undecided disagree strongly disagree

9. **The achievements of able children give others something to aspire to**

Strongly agree agree undecided disagree strongly disagree

10. **Not all able children in science are high attainers**

Strongly agree agree undecided disagree strongly disagree

11. **Able children in science are more likely to be disruptive in lessons**

Strongly agree agree undecided disagree strongly disagree

12. **Able children in science do not motivate other children**

Strongly agree agree undecided disagree strongly disagree

13. **Questions from able children in science can be intimidating for the teacher**

Strongly agree agree undecided disagree strongly disagree

14. **Able children in science can help teachers to raise the level of the lesson**

Strongly agree agree undecided disagree strongly disagree

15. **High attainers in science are all able children**

Strongly agree agree undecided disagree strongly disagree

16. **Able children in science are disadvantaged by accelerated exam entry**

Strongly agree agree undecided disagree strongly disagree

17. Able children in science need different class work to other children
Strongly agree agree undecided disagree strongly disagree

18. Able children in science are more likely to do independent study
Strongly agree agree undecided disagree strongly disagree

Appendix 5

Teachers' Perceptions of Constraints on Teaching and Learning in the Classroom from Questionnaire Responses

Constraints upon science teachers, question 10

School T

Teacher 1	Narrow curriculum, SATS driven teaching
Teacher 2	Boring, over prescriptive curriculum, lack of respect for professional judgement, lack of flexibility, SC1 is mechanistic – just to get marks
Teacher 2	Time for prep and able extension work
Teacher 3	Time and materials to support independent study
Teacher 4	Time and opportunities to try new things
Teacher 5	Student co-operation
Teacher 6	Time and help to prepare pupil resources

School J

Teacher 1	Time, training, resources
Teacher 2	Time, training, resources
Teacher 3	Time – need workload guidance
Teacher 4	none
Teacher 5	Time for new initiatives

School S

Teacher 1	Size of groups, lack of time
Teacher 2	Size of groups
Teacher 3	Size of groups
Teacher 4	Size of groups
Teacher 5	Size of groups

Appendix 6

Raw Responses to Teachers' Attitudinal Questionnaires

In this section please circle the response, which reflects your own viewpoint. The questions refer to children who are on the departmental G&T register.

19. **(N)Able children in science do not need any different provision from other children**

Strongly agree agree undecided disagree strongly disagree

1 1 1 9 5

Most (14/17) teachers agree that able children need special provision

20. **(P)Able children in science should be taught in a special set**

Strongly agree agree undecided disagree strongly disagree

2 6 2 5 2

Opinion is fairly evenly divided about whether able children should be put into a 'top set'

21. **(P)Able children in science should undergo accelerated exam entry**

Strongly agree agree undecided disagree strongly disagree

1 8 6 1 1

The majority of teachers are in favour of accelerated exam entry but a large no. are undecided.

22. **(N)The extra funding allocated for able children is unfair**

Strongly agree agree undecided disagree strongly disagree

0 4 5 4 3

More teachers are in favour of special funding for the able than not but the number undecided may indicate that teachers are not aware of how the funding for this works in schools. Should this be more transparent?

23. **(P)Questions from able pupils can be stimulating for the teacher**

Strongly agree agree undecided disagree strongly disagree

6 9 2 0 0

Most teachers find able pupils' questions stimulating

24. **(P)Able children should have more funding than is currently provided**

Strongly agree agree undecided disagree strongly disagree

2 2 10 2 1

The majority are undecided as in question 4 Perhaps a even greater indication that teachers don't know where this funding goes.

25. **(P)Able children need more contact time with teachers**

Strongly agree agree undecided disagree strongly disagree

2 1 8 6 0

Most teachers do not agree with this statement. Why? Is this down to fear of greater workload or is this point not being made in training. This conflicts with the general feeling in q1 that able children require special provision. Does this indicate that teachers are in favour of special provision as long as they don't have to do the work?

26. **(N)Able children in science should be taught in mixed ability groups.**

Strongly agree agree undecided disagree strongly disagree
0 2 5 7 3

Few teachers agree with able pupils being in mixed ability groups but as in question 2 there are a large number undecided. Taking the two questions together there appears to be a slight majority in favour of special sets. Why is this so slight? Is it to do with the effect on the other sets of 'creaming off the top'?

27. **(P)The achievements of able children give others something to aspire to**
Strongly agree agree undecided disagree strongly disagree
1 10 4 1 1

The majority of teachers agree that other pupils' aspirations are affected by the achievements of the able.

28. **(P) Not all able children in science are high attainers**
Strongly agree agree undecided disagree strongly disagree
0 11 4 2 0

Most teachers recognise the existence of underachieving able pupils.

29. **(N) Able children in science are more likely to be disruptive in lessons**
Strongly agree agree undecided disagree strongly disagree
0 0 5 12 0

Most teachers disagree that the able are likely to be disruptive in lessons.

30. **(N)Able children in science do not motivate other children**
Strongly agree agree undecided disagree strongly disagree
1 5 1 9 1

Most teachers do think that able children motivate others. This agrees with the result in question 9. This begs the question that if this is the case why the disinclination to have able pupils in mixed ability sets. Does this imply that although this may be good for others it may disadvantage the able child themselves? Perhaps a comparison of the performance of able children in mixed ability groups could be compared with performance when setted?

31. **(N) Questions from able children in science can be intimidating for the teacher**
Strongly agree agree undecided disagree strongly disagree
0 1 1 10 5

Most teachers do not find the questions of able children intimidating. This agrees with the result form question 5

32. **(P) Able children in science can help teachers to raise the level of the lesson**
Strongly agree agree undecided disagree strongly disagree
3 11 2 1 0

Strong agreement that the presence of the able children improves the quality of the lesson. This is underpinned by the view from question 11 that able children are less disruptive. Again the question of setting vs mixed ability groups arises

33. **(N) High attainers in science are all able children**
Strongly agree agree undecided disagree strongly disagree
0 2 5 8 2

Most teachers agree that high attainers are not necessarily able. Is this an indictment of the assessment system. Do exams test ability????

34. **(N)Able children in science are disadvantaged by accelerated exam entry**

Strongly agree agree undecided disagree strongly disagree

1 1 4 9 2

Again reinforcement of the view that able children should undergo accelerated exam entry. This agrees with the result from question 3. What are the issues here? What happens to these children next?

35. **(P)Able children in science need different class work to other children**

Strongly agree agree undecided disagree strongly disagree

0 3 8 6 0

Few would agree that the work of the able child in class need be different to the others and yet if the majority believe in special provision as indicated by question 1 then what sort of provision do they support?

36. **(P) Able children in science are more likely to do independent study**

Strongly agree agree undecided disagree strongly disagree

1 8 6 2 0

Few would disagree that able children are more likely to do independent study but the large number undecided may indicate that there is little evidence of it. Why? Are they not motivated to do this? Why not? What would motivate them? How does this relate to question 7 where most teachers thought the able did not require more contact time. Is this because they think that they will 'get on by themselves'

Appendix 7

Outline of lessons for year 7 intervention 1

7A Environment Module

Time specified 8 hours Teaching Time 8 hours (including test)

Aim
In addition to Knowledge and Understanding try to provide opportunities for Bloom's higher order skills of Application, Analysis, Synthesis and Evaluation with the aim of giving greater ownership of task to the pupils.

Date	Topic	K&U	Additional skills
1/11	Habitats and environments	1.Different habitats have different features. 2. Different habitats support different organisms 3. The environmental factors that affect habitats	1.How to form a question to be investigated. Decisions about variables. 2.Consideration of an appropriate sample size 3.Consideration of the importance of fair testing 4. Evaluation of results of investigation
3/11	Adaptations for survival	1.Knowledge of different environments 2.Knowledge of different adaptations for different organisms 3. Understand why organisms gradually become adapted to their environment	1.Analysis of observations of different organisms 2. Systematic recording of observations and analysis in tables 3.Application of learning to creation of new organisms for specified habitat
4/11	Monitoring the Environment	1.Know a number of instruments used for monitoring environmental conditions 2. Understand how to use these instruments 3. Understand that conditions within an environment change daily and seasonally.	1.Planning an investigation into environmental change over 24 hours 2. Prediction of how they would expect a graph of a specific environmental condition to change over 24 hours.
10/11	Response of organisms to daily and seasonal changes	1.Know that there are daily and seasonal changes in habitat conditions 2. Understand how this affects the organisms in that	1.Evaluate how their predicted results for environmental change compare with actual results. 2. Analyse the differences

		habitat 3. Understand how organisms respond to environmental change	between the two graphs and explain them
11/11	Food Chains	1.Know that a food chain consists of producers and consumers. 2.Understand how energy is transferred through a food chain	1.Analysis of information to devise a food chain. 2. Presentation of their conclusions to the rest of the class
15/11	Predator/prey relationships	1.Know the meaning of 'predator' and 'prey' 2. Understand the relationship between the populations of predator and prey 3. Understand how environmental changes can affect both prey and predator	1.Analyse the results of 'The Hunting Game' by plotting graphs 2. Explain what the shape of the graph is telling them about the relationships between predator and prey. 3. Explain what the effect of environmental change would have on the shape of their graphs
17/11	Food Webs	1. Know that populations of organisms in a food web are interdependent 2. Understand how an ecosystem can be represented by a food web 3. Understand the relationships between the populations of organisms in a food web.	1.Make decisions using IWB about changes that will affect populations within a food web 2. Predict the effects of a change in the population of one organism 3.Explain why other populations change in a food web when one population changes
18/11	Study skills and end of topic test	1. Know additional study skills that help with topic revision	1.Make decisions about key words and links in drawing Mind Maps of a topic. 2.Apply their K&U to creation of Mind Map 3. Analyse a Mind Map for interlinking relationships between topic areas 4. Use colour and signposting to aid memory skills

Appendix 8

Questions to Teachers on Science Enhancement Day

We are interested in the effectiveness of enhancement days in changing attitudes to teaching and learning for both teachers and pupils. We would be grateful if you would consider some of the issues raised below and give us your thoughts, as fully as possible, about them.

1. Has your experience today given you any ideas, which you will incorporate into your science teaching? If so what were they?

2. What do you see as the advantages or disadvantages for pupils of enhancement days?

3. What do you see as the advantages or disadvantages for teachers of enhancement days?

4. Has the way in which pupils have approached their work on the enhancement day changed any perceptions that you may have had regarding their capabilities?

5. Would you wish to run activities similar to those seen today
    a. in science lessons

    b. in lunchtime or evening clubs

    c. as ‘science days’ in school

Appendix 9

Questions to Pupils on Science Enhancement Day

We are interested in the effectiveness of enhancement days in changing attitudes to teaching and learning for both teachers and pupils. We would be grateful if you would consider some of the issues raised below and give us your thoughts, as fully as possible, about them.

6. How are the activities that you have done today different to those that you would do in science lessons?

7. Have today's activities made you feel more confident about your science knowledge and skills. If so why do think this is?

8. What decisions did you make today regarding what you were going to do? How did this make you feel?

9. Do you prefer doing science activities, which require you to make decisions or do you prefer being instructed exactly what to do? Explain why you feel this way.

10. Has taking part in the Saturday School changed your attitude towards science? If so, how has it changed?

Appendix 10

Questions to Returning Sixth Formers on Reunion Evening

Review Evening 28th February

Name___________________________

Establishment where you are doing your science further education

Courses being followed (including any given up)

What motivated you to choose to do science 'A' levels?

What science visits or trips did you go on during your secondary schooling?

How do your 'A' level courses compare with your prior expectations?

Do you intend to study science related courses or work in a science related job after 'A' levels?