Secondary school students' attitudes to practical work in school science

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Education

November, 2012

Abstract

Practical work is seen as having an important role in school science. In particular many have claimed that it has an essential role in determining students' attitudes to school science and science beyond the classroom. However, whilst there has been much research into students' attitudes to science there has been little research into their attitudes to practical work in particular. This study considers students' attitudes in terms of the cognitive, affective and behavioural analytical framework developed by Rosenberg (1960). The study is based on data collected from three English secondary schools within Key Stages 3 and 4. It involved questionnaires in biology, chemistry and physics as well as school visits that involved lesson observations, semi-structured interviews and focus groups with students. Field notes and audio-recordings were made throughout these visits for subsequent analysis. The findings suggest that secondary students' attitudes to practical work are, generally speaking, positive. However, what also emerged was the extent to which such attitudes to practical work differed, not only across the three sciences, but also showed a statistically significant decline as students progressed through their secondary school education. The reason for this being that the relative importance of the cognitive, affective and behavioural domains changed as students moved away from a focus on the enjoyment of science towards one that was examination orientated. The implications of this study suggests that teachers need to be far more aware that students' attitudes to practical work need to be consider according to the science they are studying and their age, rather than seeing their attitudes to practical work being unchanging and uniform across the three sciences.

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Acknowledgements

I would like to sincerely thank my supervisors, Professor Judith Bennett and Dr Ian Abrahams for all their support and guidance, as well as for the opportunities they gave me during my PhD: all were invaluable. I wish to express my thanks to Ian for those endless days of discussion as well. Indeed, I am grateful for the time and friendliness of all members of staff and colleagues in the Education Department at the University of York. I would also like to send my thanks to the schools involved for their contribution to my study. Indeed, I think it fitting to acknowledge all the staff and my dear friends during my time at secondary grammar school, as I feel they nurtured my love of learning and developed me into the person capable of such a feat. Beyond the academia, it would be difficult to name all my family and friends that have helped me through both the happy and taxing times of my study. However, I especially would like to thank my Grandmother, Joan, for being such an exceptional and special person in my life; highlighting the importance of education to me since I can remember! Also, I would like to affectionately thank: my parents, Janet and Ian; my brother, David for believing in me; and my dear friends, Gemma for proof-reading it and Emily for such interesting discussions. I thank them all dearly for their love, encouragement and support they gave me throughout.

I would like to dedicate this thesis to all those I hold dear to my heart; those that have inspired my love of education; and those I love unconditionally. Therefore, I would especially like to dedicate this thesis to my Grandfather, George Edwin Sharpe, who was my inspiration but sadly, was unable to see me reach such heights.

All my love forever.

And now these three remain: faith, hope and love. But the greatest of these is love.

(1 Corinthians 13:13)

Author's declaration

The author, Rachael Sharpe, declares that no part of this PhD thesis has been publicly published anywhere else.

Chapter 1

Introduction

1.1: The scene

> Among educators and researchers alike, it is commonly assumed that students' attitudes in science influence their learning outcomes, their science course selections, and their future career choice (Koballa, 1988; Laforgia, 1988). Thus, changing attitudes should lead to changing behaviour.
>
> (Nieswandt, 2005, p.41)

Practical work is defined to be any science teaching and learning activity which involves students, working individually or in small groups, manipulating and/or observing real objects and materials, as opposed to the virtual world (Science Community Representing Education (SCORE), 2008). This practical work has become a well established part of secondary school science within England as part of the National Curriculum (Office for Standards in Education (OfSTED, 2008). Indeed, since 1988, the National Curriculum has brought about 'practical work by order' (Wellington, 2002, p.57) and current science teaching involves students carrying out practical work within their biology, chemistry and physics lessons. As is currently practiced, students claim to find practical work an 'enjoyable and effective way of learning science' (Hodson, 1992, p. 115) and this has been reported in many previous studies (Osborne & Collins, 2001; Jenkins & Nelson, 2005).

Many studies (Kerr, 1963; Beatty & Woolnough, 1982; Hodson, 1990; Swain, Monk & Johnson, 1999) have examined the aims of practical work. One common theme that emerges from these studies is the need 'to arouse and maintain' positive attitudes in students' in order to improve the likelihood of their continuing to study science post compulsion. Whilst there are concerns about the decline in the number of students continuing with science (Osborne, Driver & Simon, 1998) there have been no studies that have specifically focused on students' attitudes to practical work within biology, chemistry and physics.

1.2: The purpose of the research

The purpose of this research, in contrast to previous studies that have looked at students' attitudes within the broader context of their attitudes to science (such as Barmby, Kind & Jones, 2008; Bennett & Hogarth, 2009; Cerini, Murray & Reiss, 2003; Jenkins & Nelson, 2005; Osborne et al., 1998; Osborne & Collins, 2001), is to specifically investigate the affective value of practical work in biology, chemistry and physics. In doing so this study aims to provide an insight into secondary school students' attitudes to practical work that will be of use to those involved with classroom teaching as well as amongst science educators. Prokop, Tuncer and Chudá (2007) highlight the importance of understanding students' attitudes in order to positively affect their achievement and interest within a particular discipline. Thus, by researching into students' attitudes to practical work, this study will hope to support teachers in supporting their students to achieve in their subject. One of the main issues with previous studies has been the fact that the claims tend to be generic and go little further than reporting that practical work is seen as enjoyable. Indeed, as is reported by Toplis (2012), practical work is rated highly by students in terms of their attitudes to, and enjoyment of, school science. Certainly, SCORE (2008) explained that whilst students' attitudes to practical work in science were seen positively, the evidence is currently "equivocal" (ibid, p. 10) and therefore this area would be benefited from further research. Therefore, this study aims to separate students' attitudes to science in general from their attitudes to practical work in particular amongst students across the secondary school age range and three sciences.

Further to the gap in the research on students' attitudes to practical work, this study aims to contribute to knowledge on what it really means when students claim to enjoy practical work – that is to investigate further the affective reasons for these claims. Previous studies have reported on the affective value of practical work, claiming that it motivates students (Wellington, 2005), that it is better than writing (Abrahams, 2009) or helps support their understanding of theory (Toplis, 2012) but the claims rarely go further to explain why students hold the views they do about practical work. This study aims to understand what it is about practical work that students feel positive or negative about and why it is the case. That is, to understand why students may find it better than writing or why it helps them understand theory.

A further important reason for undertaking this study is a concern that the potential motivational value of practical work is not being fully utilised due to a lack of clarity regarding students' attitudes towards it in each of the three sciences. By better understanding students' attitudes to each science it might be possible to better structure the use of practical work so as to generate personal enduring interest that would lead to increased uptake in the post compulsion stage of their education.

The study focuses on three areas. The first relates to examining students' attitudes to practical work in secondary school science and understanding what these attitudes actually are. The second area compares and contrasts students' attitudes to practical work across the three sciences, biology, chemistry and physics, and how these differ, if at all, within secondary school. The third and final area, also compares and contrasts students' attitudes to practical work within the year group and how these attitudes differ, if at all, between biology, chemistry and physics.

1.3: The origin and reasons for the study

> Why do we do so much practical work in science in English schools? Perhaps because there are so many laboratories.
>
> (Nott, 1997, p. 60)

My interest in students' attitudes to practical work arose initially as a consequence of my own experiences as a student in secondary school during which time I spent a considerable amount of my science lessons doing practical work. Whilst I no longer remember the exact details of the conversations I had with my friends and my teachers what I do recollect quite clearly was the fact that, for some of us at least, practical work was not, despite the exhortations of our science teachers that it was, the best part of school science. Certainly during my General Certificate of Secondary Education (GCSE) science course, and subsequent A-level in physics, I became increasingly aware that many of my science teachers seemed to use the promise of future practical work as a 'carrot' to elicit either good behaviour and/or perseverance during theory lessons which were often portrayed as the 'stick'. Indeed, the 'stick' of theory was often wheeled out in the event of perceived misbehaviour or an unwillingness on our part to engage within a practical lesson. On many occasions, and not just with my own class, I recall our chemistry teacher calling us to attention to inform us that if certain students would not stop misbehaving she would stop the practical lesson and we would have to continue to work from our textbooks. Whilst this certainly worked well for the majority of students – probably the reason why this approach was used consistently by all of my science teachers throughout my seven years at the school – it did not work for all of the students all of the time or, indeed, for some of the students any of the time. Certainly, many of my friends and I did enjoy doing practical work in the lower years (Year 7 to Year 9 inclusive) because it offered us the freedom to chat and, of course, avoid writing. However, we were beginning to be concerned from Year 10 onwards, with the realisation that our GCSE examinations were looming on the horizon and so, for us, this meant that we became more focussed on wanting to do well in the exams rather than necessarily having an enjoyable time chatting in a practical lesson. Indeed, on some occasions, particularly towards the end of Year 11, I recollect that we challenged our science teachers as to why we had to do practical lessons – similar questions have been reported in Woolnough and Allsop (1985) and Reid (2003). Instead, we really wanted to do a revision lesson because we saw that as being of more benefit to success in our up-coming written examinations. A comment that I recollect from my physics teacher was that we were doing practical lessons because science was principally a practical subject.

My personal interest in attitudes to practical work might have ended had it not been for a chance experience during my undergraduate studies degree when, as part of my final degree dissertation, I was able to take up a small but informative study into students' attitudes to practical work. My interest was re-kindled after reading comments that practical work was "absolutely essential in creating enthusiasm" (House of Commons Science and Technology Committee, 2002a, question 514) for students, along with other similar articles (see Cerini et al., 2003; Hodson, 1992; and Osborne et al., 1998). Therefore I decided that it would be interesting to examine what students in Year 9, Year 11 and Year 13 thought about practical work and, in so doing, explore the extent to which my own attitudes had been either typical or atypical. Whilst the study was only of a very small-scale I found myself frustrated that the study did not provide the scope or opportunity to probe in much greater detail the reasons why they felt the way they told me they did about practical work. Indeed I found that the study posed more new questions than it answered. Also, in particular, I found myself asking whether, as Bennett (2005) suggests, some of the positive student attitudes to practical work could not be better understood in terms of the fact that it provided them with the opportunity to work in a more relaxed atmosphere in which it was possible to chat with friends; a feature that had, in the lower years, endeared practical work to me. However, some of the comments made by students in that study seemed to suggest that for some of them practical work was only liked when it 'matched' up with theory and that this positive attitude to it could be lost if its use confused rather than clarified the situation. Most influential in my thinking at the time was a study by Abrahams (2005) in which he made the strong claim that many students did not like practical work in any objective sense but merely preferred it to other methods of teaching and that when given the chance to opt out of science many would do so despite having claimed to really enjoy doing practical work.

Whilst I was aware that practical work was seen as being an integral part of the science curriculum for secondary students in England and Wales (and indeed in many other countries too) it concerned me to read that Hodson (1991) saw much of it as being "ill-conceived, confused and unproductive" (p. 176). What I found particularly interesting was that despite the large amount of practical work undertaken in secondary schools in England, as reported in the Trends in International Mathematics and Science Study (TIMSS) (Sturman et al., 2008), there had been no research that looked specifically at the issue of students' attitudes to practical work. I was therefore pleased to take up the offer to undertake a full time PhD at the University of York into students' attitudes to practical work and whether these attitudes changed, as mine had, between Year groups and/or between the three sciences in secondary schools and this thesis is the result of that research.

1.4: Overview of the thesis

Having considered my reasons for this study in Chapter 1, Chapter 2 moves on to examine the nature and purpose of practical work in England as well as current attitudes towards it, whilst Chapter 3 discusses attitudes and terminology relating to students' attitudes to practical work. Chapter 4 discusses the research methodology, which includes the design of the instrument, an account of the pilot study, and the changes made to the main study in light of the pilot study. Also, in this chapter, along with details of the methodology used in the main study, the following is included: details of the schools involved, the modified research strategies, the analytical framework and the initial and revised research questions for the study. In Chapter 5 and Chapter 6 the findings and answers to the research questions are discussed and addressed. Chapter 5 addresses students' attitudes to practical work in science. Chapter 6 focuses on investigating students' attitudes to practical work in secondary school science as well as their attitudes to practical work in biology, chemistry and physics. Chapter 7, the final chapter, draws together and discusses the key findings that have emerged from the study. Further to this, the chapter discusses the internal and external reliability and validity of the findings as well as the constraints of the methodology used within the study. The chapter concludes by discussing how the study contributes to educational knowledge and understanding, and the implications it has for science education.

1.5: The structure of the educational system in English schools

Schools were selected for the study from within England and for the main study this was on the basis that they were state maintained comprehensive schools. In order to better understand the structure of the schools within this study it will be useful to describe the current educational structure in English schools.

All students between the ages of four and eighteen in England that study at a state maintained school, whatever the type of school, are taught in accordance with the National Curriculum that was introduced into schools in 1988. Students between four and eleven attend primary and junior schools and are referred to as Reception, Year 1 and Year 2 for Key Stage 1, followed by Year 3, Year 4, Year 5 and Year 6 for Key Stage 2. When students are aged eleven they attend secondary school where Year 7, Year 8 and Year 9 are referred to as Key Stage 3 and by the time they complete Year 9, students have selected subjects that they wish to continue to study for Year 10 and Year 11, Key Stage 4. At Key Stage 4 students study those selected subjects for their GCSE public examinations. Whilst they have choice over a few subjects, at GCSE level, Science, along with English and Mathematics, is a statutory compulsory subject until the end of Year 11. Science teaching, along with English and Mathematics, are taught following the National Curriculum and this includes biology, chemistry and physics.

Currently, during Key Stage 4, students are taught biology, chemistry and physics by the same teacher if they are studying a combined science whilst those students that are studying Triple Science, i.e. biology, chemistry and physics are taught, ideally, by specific science specialist teachers.

Chapter 2

Literature review on practical work

2.1: Introduction

Whilst the value and purpose of practical work has been continuously debated, it has nevertheless remained a core component of school science education. Indeed, the inclusion of practical work within an academic subject is a significant feature that distinguishes science from the majority of other subjects in secondary schools. The use of practical work in England is clearly recognised as important (Science Community Representing Education (SCORE) 2008), yet remains rather atypical in terms of the quantity and amount of time devoted to it compared to some other countries (Bennett, 2005; Woolnough, 1998). For most teachers, practical work encompasses what teaching and learning science is all about (Woodley, 2009). However, there is a growing debate surrounding the effective and affective value it has on students, and their learning (Abrahams, 2009; Abrahams & Millar, 2008; Hodson, 1991; Millar, 1998).

Within England, it appears difficult to speak of science education without considering practical work. As Abrahams and Millar (2008) indicate, many teachers view practical work “as central to the appeal and effectiveness of science education” (p. 1946). Indeed, reference is often made to the adage, ‘I hear and I forget, I see and I remember, I do and I understand’ written originally by Confucius. However, Driver (1983) explained how doing practical work does not always indicate progression in learning science. Indeed, practical work does not always produce the results or the phenomena desired by the teacher. This then has the potential to either confuse or disengage students as they may begin to think either that the theory is incorrect or that the practical is providing them with incorrect or contradictory results to those predicted by the scientific theory. This then shapes the adage, “I do and I am even more confused” (Driver, 1983, p. 9). Yet despite the debates about the affective and effective value of practical work (primarily due to the concern over student uptake of science post compulsion), it continues to be integrated into science lessons. It has been suggested that teachers find using practical work to be a method of behaviour management (Wickman, 2002). Thus, practical work may not consequently be used to effectively enhance the learning process for students (Abrahams & Millar, 2008). Furthermore, there may be possible implications on students’ decisions to continue with science post compulsion from this use of practical work. Yet, Hodson (1991) states, “as practiced in many schools” (p. 176) practical work:

> …is ill-conceived, confused and unproductive. For many children, what goes on in the laboratory contributes little to their learning of science or to their learning *about* science and its methods. Nor does it engage them in *doing* science in any meaningful sense.
>
> (ibid, italics in original)

Clearly, as Nott (1997) concludes, somewhat sceptically, “Why do we do so much practical work in science in English schools? Perhaps because there are so many laboratories” (p. 60).

2.2: An overview of practical work in secondary school science

The overview of practical work begins by examining back to 1693 with the Lockiean ideology and onto the Thomson and Norwood reports of 1918 and 1943 respectively. The review then moves on from the Norwood report to the Nuffield approach in 1966, that relied on practical work as a means of discovery-based learning (Matthews, 1994), and finally discusses practical work as it is currently practiced in English schools.

2.2.1: Preceding the Thomson Report of 1918

In the history of science there has been continued support for some kind of practical work in the teaching of science in schools, even though there have been differing attitudes regarding the nature and justifications for its use. Arguments for students conducting practical work in school can be traced back to Locke in 1693. Known as the Lockeian ideology, it involved the idea that children should be reasoned with because this was seen as the most effective means of disciplining them (Farrell, 2006). Locke's ideology was also used to support arguments for the inclusion of science in school during the latter part of the eighteenth century (Gee & Clackson, 1992). The demand for practical work in schools was further emphasised by Edgeworth and Edgeworth (1855) who commented:

> The great difficulty, which has been found in attempts to instruct children in science, has, we apprehend, arisen from the theoretic manner in which preceptors have proceeded. The knowledge that cannot be immediately applied to use, has no interest for children, has no hold upon their memories; ... if they have no means of applying their knowledge, it is quickly forgotten and nothing but the disgust connected with the recollection of useless labour remains in the pupil's mind. It has been our object in treating of these subjects, to show how they may be made interesting to young people; and for this purpose we should point out to them, in the daily, active business of life, the practical use of scientific knowledge. Their senses should be exercised in experiments, and these experiments should be simple, distinct, and applicable to some object in which our pupils are immediately interested.
>
> (pp. 518 – 519)

Edgeworth and Edgeworth (1811) additionally acknowledged the nature of applying practical work in science:

> ...we do not imagine that any science can be taught by desultory experiments, but we think that a taste for science may early be given by making it entertaining, and by exciting young people to exercise their reasoning and inventive faculties upon every object which surrounds them.
>
> (p. 40)

There have since been many similar comments in literature, noticing some links between the use of practical work and students engagement/enjoyment of science (Cerini et al., 2003; Gilbert, 2006; The House of Lords Science and Technology Committee, 2006; SCORE, 2008)

There was enthusiasm for practical work in schools prior to the 1850s due to the Great Exhibition of 1851 where Great Britain began to see the importance of science and the importance of it in schools (Song & Cho, 2002). However, the inauguration of implementing it in school science lessons did not occur until the state provided grants for science equipment (there were no well-resourced laboratories or trained teachers prior to the funding), aided by the Department of Science and Art shortly after the Great Exhibition of 1851 (Gee & Clackson, 1992). Practical work that was performed during the 1850s had strong emphasis on teacher-led demonstrations, primarily for the "illustration of particular concepts" (Gott & Duggan, 1995, p. 17). This approach was far from perfect in engaging students in learning science through practical work. After the 1880s the execution of individual practical work had increased primarily due to the increase in funding that provided the required resources and teacher incentives (Gee & Clackson, 1992).

The focus on teacher-led practical work lasted until Armstrong, in 1884, proposed a heuristic method, or discovery approach, to scientific practical work at a lecture at the international conference on education (Jenkins, 1979). Armstrong strongly believed that experience should precede the theoretical, factual, knowledge of science and saw the focus of examiners on facts as being detrimental to the experience of students' learning in science (Armstrong, 1903). Matthews (1994) believes that "this was one way of saying that science learning should be practical; students should be familiar with the phenomena to which scientific theory is applied" (p. 21). By the early nineteenth century, the heuristic approach to science had rapidly become a major part of school science. This was primarily due to the authority Armstrong had within science education and the growing need to use "both didactic and experimental apparatus" (Gee

& Clackson, 1992, p. 79) in science lessons with the hope being to facilitate student autonomy.

Even though Armstrong's heuristic method was implemented extensively throughout English schools by 1908, it soon faced criticism. Indeed, most untrained teachers were incorrectly using it in schools (Jenkins, 1979). The heuristic approach, with the purpose to teaching scientific skills and understanding scientific method, greatly divided opinion among educators. Armstrong created an expectation that students were to discover science autonomously but this was seemingly misinterpreted. Armstrong wanted the learner to be able to *see* directly and *understand* exactly how scientific discoveries were made (Jenkins, 1979) but this was not put across to practicing teachers. Armstrong's approach to school practical work may have been inadequate, but he initiated a practice that included "inquiry teaching, historical study, pupil activity and investigation" (Matthews, 1994, p. 22), aspects that would later be revisited in school science education.

2.2.2: The Thomson Report in 1918 to the Norwood Report in 1943

Prior to the 1918 reformation of practical work, professionals considered its primary importance to be to excite and attract students' personal interest in learning science. This arose from teaching about the history of science prior to any factual details of science (Cajori, 1899; Lodge, 1905). By learning the history of science, it was hoped science would be presented as a more human and realistic subject (Leite, 2002). Ironically, around this time it was Armstrong's heuristic approach that was used and views about teaching the history of science were in fact criticised. Livingstone (1916) explained that knowing about the history of science was, initially, more important than science facts, suggesting it was far more important to know oneself before knowing anything about physical factual aspects of science. Indeed, teachers were begining to discourage some students from continuing with science (Thomson report, 1918). This then influenced changes in approach to practical work and science education entirely. The British Association for the Advancement of Science (BAAS) enforced a larger focus on the history of science in the curriculum and a more realistic approach:

> There should be more of the spirit and less of the valley of dry bones, if science is to be of living interest, either during school and afterwards . . . . One way of doing this is by lessons on the history of science, biographies of discoverers with studies of their successes and failures and outlines of the main road along which natural knowledge has advanced.
>
> (BAAS, 1917, p. 8)

Such comments, by the BAAS, were the catalyst for a turning point in science education within England. This was known as the Thomson Report of 1918, which brought about a greater focus on learning the essence of science. The pure conceptual content of science rather than the scientific method concentrated on in Armstrong's approach. The implication for practical work meant that it was no longer solely justifiable in terms of learning about the processes of science. The Thomson Report (1918) criticised Armstrong's heuristic approach to teaching, holding it responsible for the detrimental restrictions on a student's learning of general principles of science. Furthermore, the report declared that the approach, in which students were to discover all scientific ideas within the constrained school environment, was a misuse of time and opportunity (Thomson Report, 1918). Instead, practical work reverted to primarily consisting of teacher demonstration (Hodson, 1993). Any practical work done by students was mainly to support the learning process and skill acquisition.

Furthermore, the Spens Report (1938), aimed at retaining a tripartite system of schooling, expressed that in technical high schools, "practical work would be required in all suitable subjects, and the staff must contain a reasonable proportion of members with practical trade experience of the occupations for which the individual school prepared" (The Spens Report, 1938, p. 83). Although trade was not directly influencing what was being taught, the concept of utilising trade experience within school science education showed similarities back to the mid 1800s (Gee & Clackson, 1992). However, the Spens Report was supporting scientific enquiry as teacher-led demonstration rather than individual, student-led practical work. However, the support for teacher demonstrations was not established from any scientific verification, merely in support of the previously published Thomson Report (1918) (Clackson & Wright, 1992).

One of the three main aims of the Spens Report was to provide "children an introduction to scientific methods of thought and investigation" (The Spens Report, 1938, p. 245). This aim became increasingly concentrated through the application of practical work within schools. However, this had been due to the slight demise of teaching students the essence of science as a subject. The Spens Report requested that teachers taught science with an "appeal to wonder and to interest, as well as to utility" (The Spens Report, 1938, p. 244). The utility aspect became the area that science teachers focused their teaching on along with the use of practical work (Leite, 2002). This ultimately influenced the 1943 Norwood Report to reassess practical work and its implementation in schools.

2.2.3: The Norwood Report in 1943 to the Nuffield approach in 1966

The Norwood Report (1943), entitled 'Curriculum and examinations in secondary schools', in supporting the view of a tripartite system as recommended by the Spens Report in 1938 also upheld the importance of practical work. The Norwood Report (1943) supported a practical work curriculum, justifying its existence as enabling students to acquire scientific and transferable skills. The Report also suggested that the science course be split into two, with:

> Some schools, we should suggest, should arrange two courses of 'General Science'; one of them would be designed with appropriate time for pupils not likely to treat Natural Science as one of their major subjects; the other, though still General Science, would go further and deeper and no doubt would emphasise one or more of the constituent Sciences; it would serve the needs of pupils likely to make Natural Science one of their chief subjects in the Sixth Form. The choice of General Science as appropriate for the whole of the main school would depend upon the sympathies and qualifications of the staff and upon the laboratory accommodation available. In other schools it might be preferred to have a course in General Science for some pupils and for others, a course in which the subjects Physics and Chemistry and Biology would be taught on more independent lines than is contemplated in General Science.
>
> (The Norwood Report, 1943, p. 109)

Therefore, the Norwood Report proposed a course suitable for students who wished to advance further within science, as well as a course suitable for public understanding of science; a science for all students.

Within the years that followed advocacy towards practical work holding a prominent place in school science grew (Song & Cho, 2002). By the 1950s, the introduction of the General Certificate of Education attempted to:

> ...correct the ‘unfortunate impression’ that earlier reports had encouraged the use of demonstration experiments at the expense of individual laboratory work conducted by pupils themselves, by including a chapter dealing with practical work and by incorporating a schedule of suggested experiments and demonstrations.
>
> (Jenkins, 1979, p. 91)

However, the popularity of the general science course was only apparent in higher academic societies. These societies tended to influence the educational system. Therefore, the majority of students studying General Certificate of Education were those in grammar and public schools with secondary modern schools following separate courses (Jenkins, 1979).

Gradually the number of students studying general science courses inspired by the Norwood Report, declined. This then led to a sudden reappearance of the heuristic approach to practical work that by the late 1960s, the Nuffield discovery-based learning courses revived the investigation aspects but largely abandoned the historical dimension (Matthews, 1994). This time the heuristic method involved students learning with a hands on approach, where they could "become scientists for a day" (Jenkins, 1998, p. 46). The method was connected with the work of Bruner who stated, "the school boy learning physics *is* a physicist, and it is easier for him to learn physics behaving like a physicist than doing something else" (Bruner, 1977, p. 14). This led to the well-known phrase linked to Nuffield, "the pupil as scientist" (Jenkins, 1989, p. 40). The courses were aimed at the development of conceptual understanding through the use of practical work (Gott & Mashiter, 1991), utilising the "great motto of...'I do and I understand' (Hicks, 2001, p. 117) as adapted from the Confucian proverb.

However, it was not long before the Nuffield courses received criticism due mainly to the way in which the pedagogy focused on learning the process of science (Jenkins, 1989). Alongside this, educationalists expressed concern that students might have been conducting practical work within Nuffield courses, but not mentally understanding what they were actually doing (Hicks, 2001).

2.2.4: After the Nuffield approach in 1966

The Nuffield courses were keen to provide teachers with sample practical experiments in a recipe format. However, by the end of the 1960s, there were clear problems with the expenses and applications of this format within the restricted environment of a school laboratory (Woolnough & Allsop, 1985). There was increasing concern that science courses were not convincing students to continue with science either. This led to the 1968 Dainton Report, which was prompted by the reduction in numbers of science students in Higher Education. The report found that the number of sixth form students studying full science courses "was not increasing *pari passu* with the growth of sixth forms" (The Dainton Report, 2006, pp. 327-328). The report suggested a need for changes to school science, such as less specialisation within topics, in order to prevent a further fall in the number of students studying science.

By the 1970s and 1980s, evidence showed that the Nuffield courses, with their discovery-learning approach, were inappropriately suited to the majority of mainstream students and instead were mainly aimed at the more academically able students (Grafton, Miller, Smith, Vegoda & Whitfield, 1983). Students' attitudes towards school science and science within society also showed no improvement since the implementation of the Nuffield approach (Gott & Duggan, 1995). The pedagogy was seemingly too focused on obtaining results from experiments, rather than allowing students to become interested in science by the enquiry of scientific processes. The learning process for students involved the acquisition of fragmentary pieces of knowlege that students could only remember in the circumstances to which they had been taught (Gott & Mashiter, 1991). Due to this approach, research was finding a growing disbelief about the claim that doing could lead directly to the understanding of science (Gott & Duggan, 1995). In fact, observations by Driver (1983) suggested the apparent motto of the Nuffield curricula, ' I do and I understand', be replaced with "I do and I am even more confused" (p. 9). For students, the difficulty arose in linking the practical work to the scientific understanding of the concepts to be learnt

By the 1980s, doubts over the value of the discovery approach led English schools to use a different approach that focused on the processes and skills associated with science.

This approach had arisen in America in 1967 and was called Science-A Process Approach (SAPA) that later became part of the Warwick Process Science by Screen (1986). The approach began the change from content to process, with the Department of Education Policy Statement (DES, 1985) conveying that the "essential characteristic of education in science" is that it enlightens students into the of science in order to develop their scientific competencies. The approach took the view that all students would enjoy and study science, if there was more focus on the reality of working like a scientist rather than just scientific content. Indeed, Jenkins in 1987 as quoted in Wellington, (1989) suggested in the Times Educational Supplement, "if not everyone can understand scientific ideas, almost everyone, it seems can be taught to observe, classify or hypothesise" (p. 9). However, this view was then contradicted by Jenkins himself who explained that it was possible that scientific knowledge could be appealling and accessible if delivered to students in an exciting and stimulating way (Jenkins, 1989).

The 1980s onwards saw increasing criticism of the process-led approach to science practical work (Wellington, 1989). The criticism was aimed mainly at the lack of scientific content and the basic idea that scientific method could not be taught as the skills of observing, hypothesising, classifying were seen as abilities obvious from childhood (Hodson & Bencze, 1998; Millar, 1989; Wellington, 1989). The introduction of the National Curriculum in 1988 also brought forward a laboratory science for all approach, whereby the demand that "all schemes of assessment must allocate not less than 20 per cent of the total marks to experimental and observational work in the laboratory or its equivalent" (DES 1985). The following period since the National Curriculum of 1988, has taken science teaching into a variety of different foms but at the core, practical work has consistantly been an aspect. However, Jenkins (1998) argues that despite this "while school science teaching without laboratory work may be unthinkable, attributing to laboratory activities outcomes that cannot realistically be met, or that might be met more effectively in other ways, is no longer an option" (p. 49). It seems there is an ever-growing need to find a form of practical work that can effectively assist students' learning process in science and in doing so, effectively engage students to continue learning science (Abrahams, 2009; Abrahams & Millar, 2008; Wilkinson & Ward, 1997).

2.3: The nature of practical work

There have often been agreements about the place of practical work in the learning of science education but there seems little agreement of the nature of this practical work conducted in secondary schools. Indeed, the statement made nearly thirty years ago by Solomon (1980) seems ever valid today "science teaching must take place in a laboratory; about that at least there is no controversy. Science simply belongs there as naturally as cooking belongs in a kitchen and gardening in a garden" (p. 13). This may encapsulate an argument for the majority of science teachers' attitudes for why they think they do practical work. However, it still begs the question of how best this practical work could be conducted. The debate regarding the nature of practical work (the method of practical work that would suit the learning of science best both effective and affectively) has taken a variety of forms throughout history including "the discovery approach, the process approach and 'practical work by order'" (Wellington, 2002, p. 56).

The discovery approach to practical work was criticised for providing a seemingly false view of science (Kirschner, 1992): the idea of reaching theoretical conclusions solely from observations, known as the "inductive process" (Wellington, 2002, p. 56). This style, similar to the heuristic approach, became overly focussed on the physical application of doing practical work. Instead of understanding scientific concepts it made doing science appear as a method, a set of rules, that could be applied to determine any scientific theory. As Jenkins (1979) explains:

> As the concepts and imagery of science were seen to be removed further and further from ‘common sense’, it became increasingly difficult to argue convincingly that pupils must be put in the position of an original discoverer and to maintain that science owed its achievements to a method which was merely ‘a game’ whose rules could be learnt and applied.
>
> (p. 50)

Moreover, there were problems for teachers in applying the approach in science lessons. More often than not, students were unable to observe the desired (or expected) phenomenon. Such problems may have been due to the “fallacies in the assumptions underlying the approach” (Millar, 1989, p. 50) rather than the teacher’s capability amongst other reasons. To whatever extent the criticisms are placed there are still a number of experiments with new items of apparatus which have become customary in today’s science lessons (Wellington, 2002). Although some recipe method experiments have become iconic of current teaching, there is little acknowledgement that doing leads to students’ understanding or that engagement in science increased with such an approach (Millar, 2004; The Dainton Report, 2006; Woodley, 2009).

The process approach, to some extent, had more extensive criticism than the discovery approach (Wellington, 2002; Millar, 1991). The model involved the notion that science could be a set method of discrete processes whereby skills and processes could be separate from the natural theoretical aspects of science (Millar, 1991). The approach was trying to provide a science for all abilities. There was the view that if students were less able, learning scientific transferable skills would be more appropriately suited to them, over any scientific content (Wellington, 2002). Such an approach to scientific practical work seemed to provide an unbalanced view of what it meant to study science. For Millar and Driver (1987) explained how “the aims should be the development of a deeper understanding of the concepts and purposes of science. For science, we would argue, is characterised by its concepts and purposes, not by its methods” (p. 56). Furthermore, Gott and Mashiter (1994) noted that “while acknowledging that the methods of science are important, the methods are those of induction and operate whithin a concept acquisition framework”(p. 182). Furthmore, they continue to suggest that this is a possible reason for the possible limitation of practical work in influencing students’ attitudes in studying science. According to Chalmers (2006), the model of science that is constructed within a process approach, such as the Warwick Process Science in 1967, is based on a naive inductivism that many view as unsound (such as Leach, Millar, Ryder & Séré, 2000; Segal, 1997). Moreover, the process approach was teaching skills learnt naturally from an early age (Hodson & Bencze, 1998; Millar, 1989; Wellington, 1989), such as observing that a plant grows if it is provided with the right amount of nutrients or the classification of objects according to certain properties.

The final approach that Wellington (2002) refers to regarding practical work by order, relates to the more recent situation since the National Curriculum was introduced in 1988. In 1988 the Department for Education and Science stated five components with practical work being include in the form of investigations. Even though the National Curriculum was adapted in 1992, 1995, and 1999, practical work was, and still is, a major part, constituting Attainment Target 1 or later Sc1 scientific enquiry (Jones & Roberts, 2005). From the 1992 version of the National Curriculum, the problem was regarding discrepancies in the assessment of practical work (Daugherty, 1995). If students were being assessed on their scientific facts then the question arose regarding what the students were actually investigating and what was being examined. These problems have continually been faced by teachers and has led to criticisms such as those made by Donnelly et al., (1996):

> What did it test: the scientific idea or the pupil's experimental procedures? If, as must surely be the case, the latter, then why make the linkage to the former at all? And if, as again seems likely to have been the case, the established scientific outcome was clear, in what sense was the investigation open?
>
> (p. 47)

The nature of the practical work in the context of the National Curriculum since 1988 has provided one specific model which has been noticed as being flawed by some (Kelly, 1990; Wellington, 2002). Furthermore, the different approaches current teachers use to conduct practical work can have an influence on the learning outcomes. The approaches can be either inductive or deductive in nature with explicit or implicit instructions given by the teacher on conducting the practical work (Hodson, 1990). The National Curriculum for Science has often been remarked as being burdened by too many facts and concepts primarily required for examinations (Gummer & Champagne, 2006). Indeed, SCORE (2008) explained how teachers found the science curriculum content as the major barrier for limiting the amount of practical work conducted. Furthermore, it has been observed that for some students this focus on content has led them to be disengaged with learning about science (House of Commons, 2002a; Kind & Taber, 2005).

2.4: The aims and purposes of practical work

In reviewing the aims and purposes of, or indeed reasons and justifications for, practical work, referring back to the comment made by Solomon (1980) can generally encapsulate most teachers' first thoughts. Practical work is an important part of science as cooking is in the kitchen, but to what value is practical work as part of *science education*? Since then, there have been many educational researchers who have produced categories of reasons for conducting practical work within science education, such as Shulman and Tamir (1973) and Anderson (1976), who both proposed aims of practical work. Whilst both were unique in their own right, there were common themes, such as appeal to students, improvement of scientific skills and promoting the scientific culture:

> Shulman and Tamir (1973):
> (1) To arouse and maintain interest, attitude, satisfaction, open-mindedness and curiosity in science;
> (2) To develop creative thinking and problem-solving ability;
> (3) To promote aspects of scientific thinking and the scientific method (e.g., formulating hypotheses and making assumptions);
> (4) To develop conceptual understanding and intellectual ability; and
> (5) To develop practical abilities (e.g., designing and executing investigations, observations, recording data, and analyzing and interpreting results).
>
> Anderson (1976):
> (1) To foster knowledge of the human enterprise of science so as to enhance student intellectual and aesthetic understanding;
> (2) To foster science inquiry skills that can transfer to other spheres of problem-solving;
> (3) To help the student appreciate and in part emulate the role of the scientist; and
> (4) To help the student grow both in appreciation of the orderliness of scientific knowledge and also in understanding the tentative nature of scientific theories and models.

However, by 1982, Hofstein and Lunetta suggested that the purposes, as stated above, were rather similar to the purposes for science as a whole that distinct reasons for practical work were needed, especially at a time when there had been a shift from student-led work. This provided less time and experience in the science laboratory, primarily due to the need to meet examination requirements (Gott & Duggan, 1995). The conclusions by Hofstein and Lunetta (1982) found that when suitable activities are used in laboratories then effective development and promotion of logic, inquiry and skills for problem-solving might occur. Although to what extent such skills and inquiry could be learnt just as effectively through other pedagogic methods and indeed in other subjects has been raised (such as Clackson & Wright, 1992).

In 1985, Woolnough and Allsop claimed there were three essential aims that are the principals of scientific activity, and justification for the use of practical work, these were: “a) developing practical scientific skills and techniques; b) being a problem-solving scientist; c) getting a ‘feel for phenomena’” (p. 41). Surprisingly, the aims they proposed did not include the motivational, stimulating and enjoyable aspects that practical work has since been claimed to promote or produce (The House of Lords Science and Technology Committee, 2006). However, there had been comments made before this time about the use of practical work to encourage and motivate students according to teacher opinion, such as in Kerr (1963), Selmes, Ashton, Meredith, and Newell, (1969), Kelly and Monger (1974) and Ben-Zvi et al. (1976). According to Woolnough and Allsop (1985), it seemed that the motivational aspect of practical work for students was far too restrictive and generally only favoured because the alternatives were presented in a negative way by teachers to students. According to Swain, Monk, and Johnson (2000), this approach of using practical work as a means of behaviour control has been used by teachers in the United Kingdom as a strategy for dealing with mixed achieving classes. Due to this strategy, Swain et al. (2000) suggested three further aims as reasons for teachers doing practical work. The aims included, “to reward pupils for good behaviour; to allow students to work at their own pace; to add variety to classroom activities” (Swain et al., 2000, p. 288). Even though students may hold an interest and want to conduct practical work, it does not necessarily imply cognitive learning purely because the context of that learning has become seemingly more relevant to the student (Adey, 1997). Indeed, just because students find doing practical work ‘enjoyable’ does not mean that students will be thinking or learning about what they are doing, rather the opportunity to have the freedom of something different in learning science. In such a case, a possible purpose to enhance scientific knowledge via practical work seems difficult to attain. This is especially true where doing is ineffective at enhancing students' understanding, or learning, of science (Driver, Squires, Rushworth & Wood-Robinson, 1994).

Hodson (1990) suggests five possible aims of the purpose and justification of practical work taken from teachers' responses. These are:

> 1. To motivate, by stimulating interest and enjoyment.
> 2. To teach laboratory skills.
> 3. To enhance the learning of scientific knowledge.
> 4. To give insight into scientific method, and develop expertise in using it.
> 5. To develop certain 'scientific attitudes', such as open-mindedness, objectivity and willingness to suspend judgement.
>
> (p. 34)

However, after critical analysis of the above aims, Hodson (1990), found that "theoretical arguments and research evidence have reinforced the view that practical work in school science –as presently organised – is largely unproductive and patently unable to justify the often extravagant claims made for it" (p. 39). Indeed, Clackson and Wright (1992) drew a similar conclusion, although they suggested there might be an argument for having practical work as a subject in its own right. The reasoning behind this was that the acquisition of skills was rather generic and thus not primarily concentrated within science education. The problem that many educational researchers had found was that due to the undefined nature of what and how best practical work should be conducted in schools, meant difficulties arose with pedagogy and learning (Clackson & Wright, 1992; Hodson, 1990). According to SCORE (2008), the problem with understanding the true purpose of practical work within science education is still an issue. This unclear focus may lead to an array of different approaches of practical work in schools that potentially will influence the learning outcomes for the students (Millar, 1998).

2.5: Research studies examining the nature and purpose of practical work in secondary school science

From an historical perspective, there have only been three major studies into the nature and purpose of practical work in England and Wales: Kerr in 1963; Thompson in 1975; and Beatty in 1980. Even though their questionnaire-based studies are specific in terms of both, cases and times in history, they are continually referred to and analysed. The studies are primarily used in the debate regarding the nature, aims and purposes of practical work (see for example Hodson, 1993). The three key studies will now be explored.

2.5.1: The Kerr Study, 1963

The study by Kerr (1963), sponsored by the Gulbenkian Foundation, was conducted to look into the nature and purpose of practical work in school science teaching in England and Wales in 1960. However, the study only investigated 151 schools, all of them selective: Grammar schools of which 56% were from boys' schools, 26% girls' schools and 18% co-educational. There were 701 teachers, comprising of 218 chemistry teachers, 258 physics teachers and 225 biology teachers. In addition, 624 student questionnaires were analysed. The main aim of the study was to determine the nature of the practical work that was being conducted and to research the reasons why teachers conducted practical work in secondary schools (Kerr, 1963).

However, a major problem with the methodology of this study, as Abrahams and Millar (2008) point out, was that it looked primarily about teachers' attitudes on the nature and purpose of practical work using questionnaires alone; it did not investigate or observe the actual implementation of practical work within the schools. Questionnaire based studies alone are not likely to highlight areas outside the parameters of the questionnaire, this can restrict the research, as Justi and Gilbert (2005) explain it is important to use a variety of methods and instruments in order to gain a better understanding of the reality within science education. The study was conducted at the end of the period where practical work was conducted “following ‘recipes’ to verify theory or to illustrate concepts” and concern was hightened that this form of practical work was “routine and repetitive” (Gott & Duggan, 1995, p. 18). Whether these concerns influenced the commisioning of the study or not, the study did provoke the need to re-assess the nature and purpose of practical work. What followed was the Nuffield approach.

However, the findings from teachers’ attitudes did show substantial agreement on the purpose of practical work. For the lower years, that was aim 9, “to arouse and maintain interest in the subject”. Conversely, for Year 12 to 13 aim 1, “to encourage accurate observation and careful recording” was highly ranked (Wellington, 1994, p. 129). Yet, it is important to note that there seemed to be less agreement between teacher opinions concerning the reason for practical work in sixth form. It was clear that teachers’ attitudes of the purpose of practical work changed from the start to the end of secondary school, from generating interest in science in the early years, to teaching the scientific applications and methods in the middle years, to being used to enhance observation skills and aid the learning of science in the sixth form (Hodson, 1993). The overall ranking of the ten aims of practical work can be seen in table 2.1, which shows the highest rank given to improving investigative skills, with the process of meeting the needs of practical examinations coming last; something that should not indeed “influence the practical work, but we know it does” (Kerr, 1963, p. 30).

Table 2.1: The ranking of Kerr's ten suggested aims (purposes) in the study for each science at sixth form level (adapted from Kerr (1963, p. 27).

Kerr's Ten Aims, or Purposes, of practical work with overall ranking from the study				
		Physics Teachers 6th forms	Chemistry Teachers 6th forms	Biology Teachers 6th forms
1.	To encourage accurate observation and careful recording.	1	1	1
2.	To promote simple, common-sense, scientific methods of thought.	4	4	4
3.	To develop manipulative skills.	6	5	5
4.	To give training in problem-solving.	8	7	9
5.	To fit the requirements of practical examinations.	10	8	8
6.	To elucidate the theoretical work so as to aid comprehension.	2	2	2
7.	To verify facts and principles already taught.	5	6	7
8.	To be an integral part of the process of finding facts by investigation and arriving at principles.	3	3	3
9.	To arouse and maintain interest in the subject.	9	10	10
10.	To make biological, chemical and physical phenomena more real through actual experience.	7	9	6

Yet, when students were asked about practical work, few seemed to identify the purpose and significance of the learning from it that their teachers were intending them to learn; such as scientific thinking or behaviour. Kerr's report explained how teachers should try to be more direct to students about the learning outcome and the expectations that are to be brought about through doing practical work. Kerr concluded that this was an area that needed further attention within science education. The conclusions here have indeed been commented on as being ever valid today, over forty five years on, with more recent studies showing similarities with Kerr's findings (Abrahams & Saglem, 2010; Jenkins, 1998; Wellington, 2005).

2.5.2: The Thompson Study, 1975

The study conducted by Thompson in 1975 was a further investigation following the findings from the Kerr study. The study looked into the purpose and nature of practical work in the sixth form (Year 12 to 13). It involved a nation-wide survey with the use of parallel questionnaires similar to the Kerr study, with responses from 221 physics, 220 chemistry and 214 biology sixth form teachers this time ranking twenty aims of practical work according to their importance. The findings reported substantial changes since the Kerr report in 1963 with regards to the purposes of practical work in sixth form. The Thompson study (1975) found that only the aim relating to teaching skills of observation and description remained of primary importance. The ranking of the other aims changed, with those held higher by Kerr's teachers being held considerably lower by Thompson's teachers. The most noticeable increases in the ranking of the aims related to practice problems, arousing and maintaining interest, promoting logical thinking and making phenomena tangible.

Furthermore, the apparent emphasis that the teachers in Thompson's study put on the aim to arouse and maintain interest is substantial in comparison to Kerr's study. The change may have reflected a change in either the attitude of the teacher or the sixth formers or a change in the need to maintain students' interest post compulsion. However, it is important to note that the majority of sixth form students studying Nuffield courses were conducting more practical work than any other sixth form science course even with the absence of a practical examination (Thompson, 1975). The study found that all Nuffield biology teachers conducted practical work, compared to only a portion of the Nuffield chemistry and physics teachers. The exact figures showed that one hundred percent of biology teachers were spending more than thirty percent of their teaching time on practical work compared to only eighty-seven percent and ninety-six percent for physics and biology respectively (Thompson, 1975, p. 20). These figures were dramatically different from those teachers not following the Nuffield courses as there were fifty percent of non-Nuffield teachers spending less then thirty percent of the time on practical work compared to seventy-seven percent of chemistry and seventy-five percent of biology non-Nuffield teachers who were spending more than thirty percent of the time on practical work (ibid).

When the study looked further into the type of practical work conducted, discovery experiments, where students would work the experiment themselves, seemed far less popular in the sixth form with standard exercises (those completed solely by the student) being most popular for all sciences (67% of physics teachers, 74% of chemistry teachers and 81% of biology teachers) (Thompson, 1975, p. 22). The findings also suggested that in general, science teachers were, by the late 1970s, no longer agreeing to the statement ‘I do and I understand’ with practical work being seen “much more as a distinct activity, no longer concerned predominantly with the transmission of specific syllabus content, as illustrated by the considerable drop in position of Aim 10” (Thompson 1975, p. 72).

According to Yung (2006), the method used by Thompson and Kerr studies utilised a reductionist approach, where the list of aims was “set *a priori* and teachers were asked to rate their relative importance…and no attention was given to individuality and variation due to differences in local context” (p. 243). This meant that the results of the study would not demonstrate the realities of what the teachers actually did nor would it show teachers actual attitudes to practical work in science education (Yung, 2006). Indeed, the methodologies used in the Thompson and Kerr studies, did not involve any follow-up observations of actual practice done by teachers (or that received by students) in the schools that provided responses to the questionnaires (Abrahams, 2009). Certainly it has been claimed (see for example, Briggs & Coleman, 2007; Cohen, Manion & Morrison, 2000) that a methodology should implement three or more data collection techniques, although in most cases it is two methods of data collection. Indeed, at the time of Thompson's study, teachers were experiencing changes in how they conducted practical work, from heuristic to processes and skills approach (Gott & Duggan 1995). Therefore, by only reporting the responses from teachers regarding certain aims, the actual reality of the practice carried out in school science may not have been shown (Abrahams & Saglem 2010; Bennett, 2005).

2.5.3: The Beatty Study in 1980

The study by Beatty researched the attitudes of teachers regarding the amount of time spent on, type of and reasons for conducting practical work for students aged between eleven and thirteen (Beatty & Woolnough, 1982). The methodology used was a questionnaire involving four distinct sections: 238 questionnaires were completed and analysed. The first section involved background information; the second, the science teaching system at the school; the third, the type and frequency of practical work conducted; and the fourth, the ranking of twenty aims according to importance for conducting practical work. The twenty aims for ranking included Kerr's ten aims and ten more as used in the study by Thompson in 1975 (Beatty & Woolnough, 1982). The respondents were chosen using a stratified sample of all schools and the 53% return rate paralleled this: 56% comprehensive schools, 10% secondary moderns, 6% grammar schools, 10% middle schools, 10% preparatory schools, 8% independent schools (Beatty and Woolnough, 1982). The results for the overall ranking of the twenty aims from all respondents included in the study can be seen in table 2.2.

Table 2.2: Rank order of the twenty aims as answered from all respondents, from the Beatty study in 1980 (taken from Beatty & Woolnough, 1982, pp. 24-25).

Order of the aims for 'all' respondents in the 11-13 age range		
Aim order	Aim (In abbreviated form)	Aim Order [From respondents]
1	* To encourage accurate observation and description	7
2	* To arouse and maintain interest	12
3	* To promote a logical, reasoning method of thought	6
4	* To make phenomena more real through experience	2
5	To be able to comprehend and carry out instructions	9
6	* To develop specific manipulative skills	16
7	To develop certain disciplined attitudes	15
8	To develop an ability to communicate	13
9	* To practice seeing problems and seeking ways to solve them	4
10	To help remember facts and principles	3
11	* For finding facts and arriving at new principles	8
12	To develop a critical attitude	18
13	To develop an ability to co-operate	14
14	To develop self reliance	11
15	To give experience in standard techniques	19
16	As a creative activity	1
17	* To elucidate theoretical work as an aid to comprehension	10
18	* To verify facts and principles already taught	17
19	To indicate the industrial aspects of science	5
20	* To prepare the student for practical examinations	20
*Aims used by Kerr in 1962		

A problem with both this study and the Thompson study was that they could not be directly compared to the Kerr study; this was due to the inclusion of a further ten aims. Nevertheless, the findings from the study alone showed that the rhetoric attitudes and ranking regarding practical work did not differ in accordance with the diversity of teachers involved. Indeed, the results seemed to show conformity of opinion regarding the ranking of aims in order of importance for practical work (Beatty & Woolnough, 1982).

The Beatty study also found that 83 percent of the schools spent 40 to 80 percent of their lesson time on practical work (Beatty & Woolnough, 1982), showing teachers thought highly of it as a teaching tool. Nevertheless, as Beatty and Woolnough (1982) conclude, the findings “may not necessarily reflect what is taking place in the laboratory and the question which must be posed is 'are they doing it?'” (p. 29). It is “only by closer scrutiny of the work in schools can the nature of actual practice be determined", an investigation requiring the researcher to encounter the reality of the laboratory directly because then "it would be possible to extend or refute the insights revealed in this survey": that of Kerr and Thompson (Beatty & Woolnough, 1982, p. 30).

2.6: Practical work outside the United Kingdom: Nature, purpose and attitudes

The United Kingdom has a very strong emphasis on practical work unlike the majority of other countries (Woolnough, 1998). It has been found that teachers in England are more frequently adopting the hands-on approach to teaching and as a consequent; their students are spending more lesson time on practical work over their International counterparts (Woodley, 2009). Certainly, according to the House of Commons (2002a), students in Hong Kong and Thailand are the only countries where students spend more time undertaking practical work than England. According to the study by Swain et al., (1999) teachers in Egypt infrequently carried out practical work primarily, due to lack of resources and equipment. For this reason the method of learning science in those countries, was first and foremost through class discussion. During this study, Egyptian teachers found it challenging to comment on such aims of practical work, largely due to the lack of it in their schools. Indeed, the results showed that the Egyptian teachers were less confident at selecting aims and thus rated generic aims like, creativity and skills higher. Moreover, in countries such as Greece and Ireland teachers rarely conduct practical work, mainly due to the scarcity of resources. Yet even where resources are abundant, such as in Germany, the routine seems to be more teacher-led practical work than any other approach (Alsop, 1991; Solomon, 1998). Martínez-Losada and García-Barros (2005) found that practical work in Spanish schools was insufficient primarily due to the nature of the culture tending to inhibit any innovation or change. Similar findings in the Trends in International Mathematics and Science Study (TIMSS) (2000) stated that the “Czech Republic’s intended curriculum had minor or no emphasis on any aspect of practical work” (p. 174) along with many other countries having little emphasis in their curricula.

With regards to attitudes to practical work, studies such as Murphy, Ambusaidi, and Beggs, (2006) found “teacher-pupil discussions in Oman and Northern Ireland indicated strongly that students in both countries preferred practical work in science to “textbook” learning” (pp. 414-415). The study by Murphy et al., (2006) was primarily researching students’ attitudes to science at the primary school level but the findings that students tend to *prefer* practical work over other methods of teaching science has been noted (Abrahams 2009). Wilkinson and Ward (1997) reported on student and teacher attitudes to the purpose and effectiveness of practical work in science at the equivalent Year 10 level of secondary school in Australia. This study found that generally teachers’ and students’ attitudes about the importance of practical work were statistically different. Also, the school laboratories in Australia were under-resourced which meant that teachers were unlikely to conduct practical work or see it as a highly effective means of learning science. Certainly, this study by Wilkinson and Ward (1997) as with the majority of studies in the UK, involved the ranking of aims as a key methodology rather than questioning the attitudes to the rankings or their reasoning for the rankings. This is an area that Wellington (2005) suggests needs further research.

Whilst a number of studies have found that students’ *claim* to enjoy practical work they differ with regards to the nature of that enjoyment, for example, whether that enjoyment is relative to other subjects, as a preference, or of practical work per se (such as Abrahams & Saglem, 2010; Cerini et al., 2003; Wilkinson & Ward, 1997). Yet, whilst there have been criticisms in some countries, such as the UK, regarding the effectiveness and affective value of practical work (as Abrahams & Millar, 2008). There are countries, such as Italy and Greece, which are intending to increase the use of practical work as a pedagogical method (Leach & Paulsen, 1999; Wellington, 2005). Seemingly, if more students are conducting practical work in science (TIMMS 2000), and claim enjoyment of it, the implication should mean an increase in the number of students opting to continue with any or all three sciences (biology, chemistry and physics) post compulsion. Indeed, recently there have been noticeable increases in science entries at AS-level with physics and chemistry positively increasing and biology remaining high up the list of most popular subjects at A-level (JCQ, 2009a).

2.7: Recent attitudes to practical work from educationalists in the United Kingdom

Practical work in school science has consistantly been a part of the National Curriculum since the 1999 version and until recently has been an essential part of the assessment of science. However, the nature of practical work conducted in accordance with the National Curriculum resulted in teachers conducting routine practical work due to the perceived assessment requirement that teachers had to ensure their students met (Millar & Osborne, 1998). Indeed, the assessment criteria, known as Sc1, led some teachers to focus primarily on meeting the needs of the assessed types of practical work (Kind and Taber, 2005), rather than using it as a method of learning science. A comment made by a science teacher in Donnelly and Jenkins (2001) encapsulated the dullness that had come from the assessment of students' practical work (Sc1) at the time, "we now teach to pass the exam, and not for enjoyment" (p. 135). More recently, changes in the way Sc1 is assessed has to some extent changed the way teachers see practical work, from being on the one hand, entirely focussed on meeting the needs of assessment, and on the other, using it as a teaching method to aid general learning of science (Abrahams & Saglem, 2010).

According to Wellington (2002), the types of practical work that are currently used in schools include:

> ...teacher demonstrations; class practicals, with all learners on similar tasks, working in small groups; a circus of 'experiments', with small groups engaged in different activities, rotating in a 'carousel'; investigations, organized in one of the above two ways; and problem-solving activities.
>
> (p. 63)

These variations have then been grouped into five categories, namely: "skills, observations, enquiry, illustration, investigations" (Gott & Duggan, 1995, p. 21). Yet prior to the National Curriculum, Woolnough and Allsop (1985) classified practical work into three categories, "exercises, investigations, experiences" (p. 47). Regardless of how the types of practical work are grouped, they all bring about different learning outcomes. It has been suggested that for effective learning using practical work, teachers are required to select the type of practical work appropriate for the particular science learning objective; it is meant to aid (Kind & Taber, 2005). Often practical work has been seen as an ends rather than a means to learning. It has been suggested it should help the process of learning but not be the sole end of learning (Driver, 1983; Harlen, 1999; Scaife, 1994).

A report by the Office for Standards in Education (OfSTED) (2008) stated that the nature of most practical work in current secondary schools seems to be dictated rather heavily by the teacher with the continued use of recipe style practical work or worksheets. These appear to restrict the progression of students' enquiry skills and theoretical understanding of science due to the reliance on "transmitting knowledge about science" (OfSTED, 2008, p. 35). The reason for such emphasis, OfSTED (2008) believe, is the competancy of the teacher. Yet educational research has suggested that:

> ...*activity* is not, in itself, any guarantee of focussed learning. Students may be on their feet in a laboratory, handling scientific apparatus, talking and listening to each other, writing observations and so on, but this guarantees very little about the nature of the learning that is taking place. Activity may be necessary for some forms of knowledge construction but it is by no means sufficient...
>
> (Scaife, 1994, p. 54)

This suggests that doing does not alway initiate learning, there is a need to ensure the activity is purposeful to the learning outcome. The other aspect is that some students tend to see practical work as an opportunity presented for general conversation rather than engaging in meaningful on-task discussion (Parkinson, 2004). Practical work alone does not necessarily mean students are on task with both hands and minds. Indeed, Sutton (1998) argues that there is a need for practical work to focus more on discourse and discussion, in order that there is a physical hands on approach combined with a mental, minds on approach. This style then has the potential to enable the scientific conceptual understanding and the scientific observable phenomena to be amalgamated in the students' minds. This then has the potential to enhance their learning of science and motivating them towards school science as OfSTED (2008) believe, that more effective learning and sustained application of students to science can be achieved through effective practical work.

Back in 1992, Clackson and Wright argued that the approaches to practical work have often been criticised for being a poor use of time and money with alternatives, like the media, being more effective. However, they believed that more research on the actual effective performance of different types of practical work was needed to be carried out, such a stance seems appropriate for today's situation. A study by Abrahams and Millar (2008) that looked into the effective nature of practical work determined a significant "separation, in teachers' thinking and planning, of the teaching of substantive scientific knowledge and of the procedures of scientific enquiry" (pp. 1964-1965). Furthermore, there was an implied belief that students do not always need to be taught scientific skills and processes, some are just able to understand and do them (Abrahams & Millar, 2008). This seemed to lead to a conclusion similar to that of Clackson and Wright (1992), that there is still a need to improve the nature of school practical work so that it is more effective in developing its own role in school science education. According to Young (1987), "Science is a practice. There is no other science than the science that gets done" (p. 18). However, this still leaves us with questions as to what is the most effective way of doing school science practical work. It appears that the real nature of practical work requires improvement so that it is conducted effectively in supporting the learning process in science for students (Abrahams & Millar, 2008; Woodley, 2009).

Recent attitudes to the purpose of practical work have produced an array of reasoning for its inclusion within science education. Although there is not one archetypal categorisation of the purposes for practical work, there is an overlap of similar reasoning. It is important to acknowledge, as SCORE (2008) explains, that if "a variety of terms exist to describe practical work, many of which are frequently used with little clarification" (p. 5), the issue of its purpose then becomes challenging to determine. Certainly, the majority of current reasoning dates back to the work of Kerr in 1963. The aims that were implemented in Kerr's study were determined from current literature rather than the actual practice of teachers in schools at the time. The "ten statements, referring in particular to practical work, were collected from published reports on science teaching methods and, after slight amendments, were used to estimate the opinions of various groups of teachers" (Kerr, 1963, p. 21). However, it is important to note that as the aims used in such studies were based purely on literature, they may not have been a true account of the realities of practical work in schools at the time.

Besides the variations between the aims proposed by Kerr (1963), Beatty and Woolnough (1982) amongst others, showed similarities between the aims with the following being perceived by teachers as the most important aims:

- To encourage accurate observation and description;
- To mage scientific phenomena more real;
- To enhance understanding of scientific ideas;
- To arouse and maintain interest (particularly in younger pupils);
- To promote a scientific method of thought.

(Bennett, 2005, pp. 78-79)

From the perceived lists of the most important aims, practical work seems to fall into three areas for debate. As Wellington (1998) suggests, the three are cognitive, skills and affective domains. The debate surrounding each domain will now be summarised, with primary emphasis on the affective domain due to the nature of this thesis.

Firstly, the cognitive domain. This argument refers to the aims that demonstrate practical work as a means of improving students' conceptual understanding of science, scientific ideas, and allowing them to see and experience scientific phenomena (Wellington, 1998). According to Clackson and Wright (1992), the evidence suggests that the use of practical work in enhancing students understanding of concepts is of little benefit. However, this may not be down to practical work alone but the application of it by the teacher: as Woodley (2009, p. 49) explains, "good-quality" practical work can be effective in this domain. However, for this to occur there needs to be a mixture of discussion during and after practical work as well as it being implemented. There needs to be the time spent for the hands-on approach as well as time for the consideration of what has actually been done (Millar, 2004; Woodley, 2009). Whilst it has been recognised that effective learning through practical work can potentially occur, educational researchers (such as Abrahams & Millar, 2008) believe this only happens when students make effective connections between the tangible and intangible worlds. These two worlds are regarded as “two distinct domains: the domain of real objects and observable things, and the domain of ideas” (Millar, Le Maréchal, & Tiberghien, 1999, p. 39). However, the transfer between domains may only occur through effective practical work but the extent of its effectiveness depends on factors implemented within the lesson (Millar & Abrahams, 2009). It appears teachers should implement “clear identification of learning objectives, informed analysis of the learning demand of tasks, and the design and presentation of tasks” to ensure students apply their minds as well as their hands.

Secondly, the skills domain. It suggests that practical work can develop “manipulative or manual dexterity skills” as well as specific scientific skills, such as, accuracy of observation, recording, evaluating and the like (Wellington, 1998, p. 7). The key problem with this domain is what is meant by the term ‘skill’: it has different connotations within different studies. Hodson (1990) explains that there are two forms of skills: those relating to crafts, such as using an ammeter, and those skills independent of content, such as observing and recording. Hodson (1990) continues to explain that there is no argument that these skills should not be taught, but that there should be better selection of the type of skills to be taught and the learner should understand the benefits of such practical work experience. Yet, despite the differences, it has been noted by Clackson and Wright (1992) that such skills are so general, they could be taught through an entirely “craft based” (p. 40) approach. Mainly because it seems, practical work has little benefit to students’ development of conceptual understanding of science. Millar

(1989) has stated that such skills, independent of content have been argued as abilities that students have from a young age, and therefore these can not be taught. Before the recent changes to the National Curriculum assessment component of practical work, the criteria meant that most teachers use "the same small set of practical tasks from year to year, chosen to make it as easy as possible for their students to include those features for which the teacher can award marks" (Millar, 2004, p. 14). The majority of students were therefore being taught how to work with the same equipment which rather restricts the development of a variety of manipulative and scientific skills (Roberts & Gott, 2008). More recently, with the assessment removed for practical work, this may cause teachers to focus now on either its replacement or perhaps devote less lesson time to it.

Finally, the affective domain. This relates to practical work as a means of arousing and motivating students to become interested and enthusiastic towards studying science (Wellington, 1998), potentially engaging them to continue their science studies post-compulsion. There have been widespread claims that practical work is highly favoured by students (Bennett, 2005; Ben-Zvi et al., 1976; Cerini et al., 2003; Wellington, 2005). Yet as a reason to continue with science post-compulsion there is uncertainty as to the extent of its influence. According to the House of Lords Science and Technology Committee (2007):

> It is clear to us that some decision-makers are not sufficiently conversant with the needs of practical science, or are easily persuaded that a reduction in the performance of practical work is not ultimately harmful to standards. We strongly believe this to be a false argument and, given the Government's drive to persuade more students to take sciences at A level, entirely counter-productive.
> (p. 13)

This statement infers that practical work is essential in mainting students' interest in science to continue to A-level. However, Abrahams (2009) has argued that practical work was ineffective in maintining students' interest in science and did little to ensure students continued post-compulsion. Nevertheless, throughout the array of proposed aims and purposes from the literature on teachers' views, the affective domain, involving the motivational and enjoyment aspects of practical work, has often been included. Teachers continue to believe if students are enjoying practical work they will enjoy science, and if they enjoy science then they will continue learning post-compulsion. This has led to many teachers implementing more practical work (Sturman, Ruddock, Burge, Styles, Lin & Vappula, 2008) but with the slightly idealistic notion that it may ensure student retention post-compulsion (Abrahams, 2009; Cleaves, 2005; SCORE, 2008; Wilkinson & Ward, 1997). Although, there had been slight increases in numbers continuing to study science, primarily in physics, according to the Joint Council for Qualifications (2009a), to what extent this is due to practical work alone is questionnable. A study by Cerini et al., (2003) found that only 50 percent claimed to enjoy practical work with only 32 percent finding it useful in learning science. Evidently some students do enjoy practical work but not all. Furthermore, it has been noted that more boys than girls enjoy practical work and with the keen interest by the govenerment to encourage more girls into science (Jenkins & Pell, 2006; Ramsden, 1992), it begs the question whether less practical work should in fact be conducted. Although it seems students in England are spending considerably more time on practical work than anywhere else (SCORE, 2008; Sturman, et al., 2008; TIMSS, 2000; Woodley, 2009).

More recently, Abrahams and Saglem (2010) conducted a similar study to Kerr in 1963 to examine any differences in current teacher attitudes regarding the perceived importance of practical work in science for students from age 11 to 18. The study involved 393 teachers, ranking the same ten aims as used by Kerr (1963). In comparing their results with those from Kerr's study, surprisingly the only changes were those found in Key Stages 4 and 5; Key Stage 3 findings showed similarities with both the Kerr (1963) and Beatty and Woolnough (1982) studies. In Key Stage 4, the main change was the degree of importance that physics teachers had given the aim "to arouse and maintain interest in the subject"; seemingly taking the stance that enjoyment through practical work will mean students continue to study physics post-compulsion. This is something which, according to JCQ (2009a) has proved to be of some success. Such an issue has been of little importance to biology, where numbers have been increasing but surprisingly less practical work is completed (Abrahams, 2009).

According to Abrahams (2009), the affective domain within practical work refers to the motivational and interest aspects that it claims to produce for students. The motivational aspect that this refers to is defined as "an inner drive to action" (Bandura, 1986, p. 243). So if this is hightened by the use of practical work for the student, it may mean the student continues to study science post-compulsion. With the amount of motivational influence practical work claims to have (such as Cerini et al., 2003; Ramsden, 1992; Wellington, 2000), it stands to reason that it could be said, all students should be studying science post-compulsion, but as the House of Commons Select Committee on Science and Technology, (2002b) state, "it seems that recent reforms to post-16 education have not produced a significant increase in the number of students studying sciences". Clearly the motivational aspect is not as effective as claimed as seemingly "'actions speak louder than words'" (Abrahams, 2009, p. 2338).

The second aspect within the affective domain relates to interest, which relates primarily to interest in objects (Dewey, 1920). Where objects denotes an umbrella term and includes, personal interest and situational interest (Eccles, Roeser, Wigfield &

Freedman-Doan, 1999). Personal interest refers to the students' opinion and stance to an issue but the difference to situational interest is that this interest lasts longer; it seemingly acts as a passion rather than a momentary liking. Situational interest relates primarily to the students' liking, such as of a specific pracitcal task, but only within that *specific* lesson. The emotion does not last longer than the situation permits and does not continue into future lessons; unlike personal interest it is very unstable (Anderman & Wolters, 2006). Therefore, it is necessary to re-stimulate those students with a situational interest for science with the use of practical work. In contrast, those who already hold a personal interest for science will be more likely to continue studying the subject because they will hold a long lasting interest in the subject (Krapp, 2002). The differences between motivation, personal interest and situational interest can explain the pedagogical problems with associating students' continual enjoyment of practical work and their subsequent continuation within science education. This can then explain why students may enjoy practical work but have no intention of continuing with science post compulsion: they are not personally interested in learning science, just the situation (the lesson) in which the practical work is being applied (Abrahams, 2009).

2.8: Recent teacher attitudes on the nature and purpose of practical work

Since the three research studies into teacher attitudes, Abrahams and Saglem (2010) have conducted the most recent study researching teachers' attitudes to the nature and purpose of practical work. Indeed, educationalist have noticed the peculiarity in that there has been more research into teachers' attitudes than students' attitudes to practical work (Wellington, 2005), this is surprising considering it is the students themselves that are experiencing the practical work and therefore would provide a more valid opinion. Indeed, studies into student attitudes on the nature and purpose of practical work within an affective domain seem rather vague. According to Ormerod and Duckworth (1975), previous studies, such as Kerr (1963) and Selmes et al., (1969), were around the time when students were conducting “extremely dreary” practical work (p. 45). Thus, the affective domain of practical work would have been very limiting for students to experience. More recent studies have researched students’ attitudes to practical work but these findings are “historically sensitive and often significantly different” (Jenkins, 2006, p. 52) from their science teachers (such as Boud, 1973; Denney & Chennell, 1986; Hodson, 1993; Jenkins, 2006; Kerr 1963; Lynch & Ndyetabura, 1983; Psillos & Niedderer, 2002; Wellington, 1998).

Whilst there are variations between these studies, differences in: age of participant; the science subject of the practical work; time of study as the studies were all conducted at a majority of different times in history where the curriculum for practical work was changing. Thus, the results of students’ attitudes from them could be misleading and irrelevant to other situations. The studies did not consider, perhaps due to the situation of science within education at the time, the influence of the affective domain for the students’ attitudes on practical work concerning students continuing with science post compulsion. Furthermore, excluding Hodson (1993), Jenkins (2006), Psillos and Nieddere (2002) and Wellington (1998) the studies were all conducted before “the 1991 National Curriculum for England..., [where] one of the prescribed assessment categories in science was ‘scientific investigation’” (Laws, 1997, p. 49). Since at the time of the policy change, the implementation of this new policy involving practical work in the form of scientific investigations proved problematic for some teachers and students. Therefore, studies referenced in reviewing teacher and student attitudes to practical work will only include those conducted after 1991. Teachers’ attitudes to the nature and purpose of practical work will now be discussed.

2.8.1: Teacher attitudes on the nature and purpose of practical work

Some educational researchers have noticed that teachers are surprised when asked to consider the purpose of practical work in school science (Such as Donnelly, 1995 and Wellington, 1998). It appears that practical work has become a typical component of science education within English schools. So much so that teachers see no reason to question why they do what they do with practical work. Indeed, according to Gott and Duggan (1995) teachers were “confused as to the role and purpose” (p. 63) concerning the investigations that had become part of the Science National Curriculum. Perhaps the fact teachers are not thinking about the reasons for the implementation of practical work would explain for the appeared confusion. Such an issue also places uncertainty on the reliability of their attitudes within studies relating to attitudes of the purpose of practical work. Certainly, Parkinson (2004, p. 185) justifies a variety of factors from personal to societal issues (relating mainly within their respective schools) for how teachers’ attitudes of practical work are formed.

A study by Swain et al. (1999), reported the “attitudes to the aims of practical work given by science teachers from Egypt, Korea and the UK” involving 66 UK science teachers from 58 secondary schools (p. 1311). The study involved teachers ranking each of the twenty aims, which came from the studies by Beatty and Woolnough (1982) and Kerr (1963), on a four point scale (1 being least important and 4 being most important). The study found the UK teachers to respond with the attitude of practical work as, being a way for students to work through an investigative process: “the seeing and solving of problems, critical attitude and logical reasoning… [emphasizing]…the manufacture of new knowledge rather than the rehearsal of existing knowledge” (Swain et al., 1999, p. 1315). However, all science teachers from all three countries acknowledge within the top ten aims that “to arouse and maintain interest” (ibid, p. 1318) was a component of practical work but rated the scientific skills acquired from doing practical work higher: “Empirical work is the defining feature of science” (ibid, p. 1317). Yet all UK teachers explained that the implementation of practical work was essential in benefiting students in their understanding of scientific concepts. This is not surprising considering the amount of practical work being conducted at this time and the assessment of student practical work constituting “about 20% of the terminal examination mark” at General Certificate of Secondary Education (GCSE) level (Black, 1995, p. 163). In conclusion, the analysis by Swain et al., (1999) demonstrated the problem of collecting attitudinal data at a specific moment in time from a range of different settings and where the approach to school practical work also differed - not primarily due to the variance between countries. Incidentally, these differences along with the specificity of time may have influenced teachers’ decisions regarding the aims of practical work and ultimately their general attitudes to it: “different opinions on the aims of practical work arising from different national, educational and social contexts *at one point in time* and these may change because of societal pressures (Swain et al., 1999, p. 1322, italics added).

A further study by Donnelly (1998) involved interviews with secondary science teachers from five schools with forty interviews being analysed. The results found:

> Subjectively, it seems that science teachers experience not the laboratory but its absence as a constraint. And, while it might be said that access to a laboratory provides science teachers with greater flexibility, it appears that both materially (in what the laboratory encourages and what it resists), and pedagogically (through the ways teachers construe laboratory work against other forms of activity), such flexibility is often experienced as a tension between negative and positive alternatives.
>
> (p. 595)

It seems to imply that teachers were in a situation where the pedagogy of practical work was difficult to portray in a positive manner, meaning that not all aims were effectively achieved at once. As Wellington (2002) suggests, teaching one form of practical work continually will not be successful or effective in learning. There is always a need for the teacher to accommodate for the need of the learning outcome, so it is important to apply the form of practical work that links to the learning outcome. An analogy to Wittgenstein's (2001) understanding of a game is useful in understanding the importance of linking the practical work to the learning outcome. According to Wittgenstein (2001), it would be possible to explain what is meant by a 'game' and to describe the general themes but it would be harder to describe the rules. This is because each specific game includes specific, individual rules: there are no generic rules for all games. Similarly, it is possible to describe practical work but would be harder to ascertain a single format of practical work suitable for all learning outcomes. Indeed, as each type of practical work is unique, teachers have a range of purposes, or learning objectives to meet in science. Therefore how teachers approach each purpose will determine the type of practical work they indeed do conduct. However, at times teachers explain there is a need, especially at Open Evenings, to present "*eye catching and exciting"* practical experiments with the aim of attracting students to the image of science as a "hands-on fun activity" (Abrahams, 2007, p. 120).

The more recent study by Abrahams and Saglem (2010) which compared current teachers' attitudes with those teachers in the twentieth century in the study by Kerr (1963), found that, regardless of the changes within the last 46 years, teachers' attitudes on the important aims of practical work remained constant. Similar finidings were noted in Swain et al., (2000) that found after 35 years teachers had been "fairly consistant in their attitudes to the aim of practical work" (p. 291). Abrahams and Saglem (2010) justify the similarities by explaining that it is merely "a reflection of the fact that there is less perceived competition between the aims" (p. 13) but not across all Key Stages.

Bennett (2005) also explains that the aims can be linked and summarised in a variety of ways. Abrahams and Saglem (2010) found that teachers' attitudes at Key Stage 5 explained how there was a need to "make science real and relevant in order to maintain an interest in what was a much more conceptually demanding subject than it had been at Key Stage 4" (p. 12). Though there is uncertainty on such reasoning, it may be necessary for encouraging students to study science post compulsion and thus the aims relating to scientific skills seem rather irrelevant to the teaching of practical work at this level. One teacher in the study stated "If they don't know how to do it by the time they're doing 'A' level [Key Stage 5] they shouldn't be doing 'A' level physics" (ibid). This could imply that teachers are keen to engage students to continue with science, yet, it could be argued that at A-level especially, students should personally want to study the subject and not require motivation from the teacher that seemingly is needed at Key Stage 4, (Abrahams, 2009). Unlike the study by Swain et al. (1999), Abrahams and Saglem (2010) did not find changes in educational and societal settings constituting for the changes in teachers' attitudes. Instead, Abrahams and Saglem (2010) found that "changes in the working environment have the *potential* to lead to changes in pedagogy if those changes generate pressure on (or removed it from) teachers" (p. 13, italics in original).

According to Yung (2006), teachers' attitudes on practical work differs according to their opinion of "fairness" within education. The findings showed that "teachers holding views of fairness in the context of providing students with an all-round education and/or providing students with the chance to learn the subject matter" were inclined to view practical work as a means of "developing students' affective / cognitive / motor skills" (p. 216). Yet, teachers appear drawn between two views of practical work- motivating students and providing the skills for continuation in science and meeting the needs of the practical examinations (House of Commons, 2002a). Although the key to better practical work, in meeting the effective and affective claims, does not come solely from "doing *more* practical work, but of doing *better* practical work" (Millar & Abrahams, 2009, p. 64, italics added).

It appears that the research carried out into teachers' attitudes of practical work have primarily focused on teachers arranging aims in rank order of importance. There seems to be little investigation into why they believe such an aim is of such an importance or what they actually do within their practical sessions concerning the affective domain. Studies, such as the above, have found teachers commenting on practical work as motivating, exciting and attractive to students alongside viewing it as useful in improving their skills of observation and developing conceptual understanding. However, the use of practical work as a means of attracting students in order that they continue studying science post compulsion has potentially limited effect. Indeed, it would appear that teachers are overestimating the actual reality of the motivational and affective value that practical work claims to hold. A comment made by a teacher in Abrahams (2009) summarises the reality:

> I think in most instances it's short-term engagement for that particular lesson rather than general motivation towards science. In general I think it's very difficult to motivate kids in Year 10 and 11 into thinking about engaging in science and thinking about science in terms of 'that's a career that I want to follow'...
>
> (p. 2336)

This statement is similar to the findings in House of Commons (2002a). Yet, Parkinson (2004) found that teachers' attitudes of practical work were different to those of their students. Indeed, it has been noted that there is a need for teachers to convey the purpose of the practical task to the students to enable them to see and understand what it is that they are expected to achieve. As Driver et al., (1994) suggests, “there is a case for ‘letting learners into the secret’ of why they are asked to do different types of practical work in school” (p. 6) in the hope that it will aid the learning process. According to Hart, Mulhall, Berry, Loughran, and Gunstone (2000) it appears that there is evidence to suggest failure of learning from practical work is possibly due to teachers “claiming too much for laboratory work” (p. 672), regarding the effective and affective domain for students, to the point that teachers can seem to miss what realistically can be achieved.

2.8.2: Student attitudes to the nature and purpose of practical work

There have been many studies that have looked into students’ attitudes towards science entirely (such as Barmby et al., 2008; Bennett & Hogarth, 2009; Cerini et al., 2003; Cleaves, 2005; Osborne et al., 2003), and how they perceive science in comparison to other issues and subjects. Yet, in reviewing the literature surrounding students’ attitudes on the nature and purpose of practical work, what is reflected is how there is no research specifically, into what, and why, students think and feel about practical work as well as whether practical work has an affective value in influencing students’ decision to continue with science post compulsion. It appears that practical work is seen as motivating by teachers, as shown through the vast amount of empirical data Holstermann, Grube, and Bögeholz (2009). However, there is a need to ask students direct questions regarding their affection to practical work, such as “do they enjoy practical work? Does it motivate them?” (Wellington, 2005, p. 101) and probe further as to what is it that they are indeed motivated to do and why this is so?

Before the twentieth-first century, the few studies that mentioned students’ views on practical work seemed to show that whilst claiming to enjoy it, students saw it above all as a means of confirming scientific theory and as a teaching method used to prevent them from being bored (Such as Denny & Chennell, 1986). Driver et al. (1994) found that the majority of students did not know “the purpose of practical activity, thinking that they ‘do experiments’ in school to see if something works, rather than to reflect on how a theory can explain observations” (p. 6). Indeed, according to Watson and Wood-Robinson (1998), there is a disagreement between what students and what teachers understand are the aims of practical work. This in turn meant that students would rarely take advantage of any effective or affective value that it could have on their learning of science, with cognitive engagement being rare (Watson, 1994). In contrast, Hart et al., (2000) discovered that students “made strong links between the teacher's intentions and the tasks they were given…. [and this] had an impact on students' thinking about the practice of science” (p. 672).

By 2000, Hart et al., found that students around Key Stage 4 were at the age where social communication was of high importance, so students would enjoy the chance to interact during practical work. Yet, as has been explained by Bennett (2005) this interaction may have been far from the chance to discuss the science of the practical work but instead to interact about their social life. Hart et al., (2000) also found that for the majority of students, “acting out the role of the scientists helped them derive a better understanding than merely reading or talking about it” (p. 671). However, Hart et al. (2000) are unclear whether students’ had better understanding of the scientific concepts or of the role of a scientist in the practical work they were undertaking. Hart et al., (2000) also found that for effective engagement by students with the practical work they needed to bring some prior knowledge of the scientific concepts to the practical work.

Students need to possess a personal interest in practical work to engage fully in the process of learning science. As Bergin (1999) explains, if a student has a low personal interest they might enjoy the embellishments of learning in this case practical work but not master the course content unlike those students who have a strong personal interest who may even become annoyed by such embellishments because they do not require the same stimulation in order to be attracted to the scientific content. Indeed, Hodson (1998b) explains that students who are aware of their ability have stronger control and confidence in their learning. Therefore, those students that have a personal interest and are academically able may ironically be irritated with practical work, especially so if their laboratory skills are of a high ability also, as laboratory skills are necessary for students to engage effectively in practical work (Hodson, 1998a). The House of Commons (2002a) report explained the concern that practical work:

> is frequently uninteresting and demotivating....As a result, many students lose any feelings of enthusiasm that they once had for science. All too often they study science because they have to but neither enjoy nor engage with the subject. And they develop a negative image of science which may last for life.

However, according to the JCQ (2009b) science numbers have actually increased in recent years with biology ranking third most popular General Certificate of Education Advanced Subsidiary level, with 6.55% of the total number of students in England studying the subject and chemistry ranked eighth. Physics had shown an increase in student numbers, but was only ranked ninth, with a 4.77 percent change from 2008 to 2009 (JCQ, 2009b). What appears from the data is that the recent uptake in biology seems far more prominent than in physics and chemistry. Indeed, chemistry and physics are the two subjects that have been argued to contain the most practical work throughout Year 7 to Year 11 in schools (Abrahams, 2009).

The House of Commons (2002a) reported that students perceived practical work as a helpful way of linking theory and practical knowledge as well as providing the manipulative skills. Such aims are similar to those that Abrahams and Millar (2008) explain *effective* practical work can achieve. In reality of course, the report observed that not all students enjoyed, or were motivated by, practical work, some students commented that a better range of practical work approaches was needed, helping students to experiment and investigate more (House of Commons, 2002a). In addition, students found a problem in achieving the desired result and for some there was disaffection in carrying out practical work that was merely in a recipe style or where they already knew the result. The House of Commons (2002a) explain how students view practical work rather negatively but suggested that students should have the a variety of exciting opportunities to experiement and investigate. Regardless of the apparent flaws noted by the students themselves at the time, it appeared that practical work was still seen as a major affective part of science by teachers. Osborne et al., (2003) found that 71 percent of students who stopped studying science still valued it as interesting and more importantly 79 percent saw it as interesting. This could possibly be suggesting the link between practical work and enjoyment in school science but not the link to student retention post compulsion. These findings support the claim made by Abrahams (2009) that practical work may generate enjoyment for individual science lessons but is rather ineffective at prolonging this motivation to study science post compulsion or influence a personal interest in it even though it is often thought to be the case.

Cleaves (2005) analysed transcripts from four interviews that were conducted over a three year period involving seventy-two secondary school students of high academic ability. Though Cleaves’ study was looking into students general formation of post-16 choices and did not focus primarily on their views about practical work (a problem with the majority of research studies into such areas), Cleaves discovered that students thought that they carried out less practical work in Year 11 and comments, such as the following example were made:

> I don't enjoy science very much here. Not all teachers can hold our attention. The practical is pedantic. We know that to get high marks you have to put in a lot if detail, but we are not experimenting anywhere near the level of the write-up
>
> (Cleaves, 2005, p. 476)

It is perhaps important to note that in Cleaves (2005) the students, from six mixed comprehensive schools in England, were well above average in their academic ability across all subjects, including science. As the students were of high academic ability in science, there is the possibility that this factor alone could, as Cleaves (2005) suggests, influence them to continue with science post compulsion. Indeed, Cleaves (2005) notes that despite their somewhat negative comments, the student quoted above still opted to study science post compulsion. There have been suggestions of the many factors that influence students deicisions to continue with science subjects, such as: future career or univeristy aspirations (House of Commons, 2002b), the value students and parents place on the relevance of the subject to the students' life (Jenkins & Pell, 2006) and, the traits of the individual teacher, and other members of staff, that impact on students' learning of science (Jarvis & Pell, 2005; Reiss 2005). Cleaves (2005) also found that whilst many students claimed to enjoy practical work, there was widespread criticism that there was less time devoted to conducting practical work in science lessons as they progressed through the schooling system.

It therefore seems that even though students wish to conduct more practical work, possibly because they enjoy it over other methods of learning science, they do not feel that what is taught in their classes is the best that it could be. Moreover, this is an influencial finding considering the nature of the students involved were higher ability students, because despite their concerns about practical work some of them are still opting to study science post compulsion. The implications of the use of practical work on lower abilty and dissafected students in science may influence them to hold a slightly less negative image of science (Abrahams, 2009).

More recently, Barmby et al., (2008) have reported students' attitudes towards practical work decrease from Year 7 to Year 9, but only slightly. Nevertheless, the decrease did mean that the study found students to perceive school science as boring because practical work was essential to them for enjoyable science and they conducted little. Yet, it appears that students only preferred practical work to *other* means of learning science; as one student commented "I like science when you do practicals rather than when you're writing stuff" (Barmby et al., 2008, p. 1088), such findings were similar to a more recent study by Abrahams (2009). As the paper by Barmby et al., (2008) was primarily based on students' attitudes to science and the perceived decline in their attitudes to science, it did not question the students, either about practical work or what they meant by 'boring'. Furthermore, the method of data collection involved the students ranking each of the attitudes measures on a five-mark scale (5 = strongly agree, 4 = agree, 3 = neither agree nor disagree, 2 = disagree and 1 = strongly disagree) and so a more detailed evaluation of students' opinions could only be ascertained from the 4 percent of students subsequently interviewed. Furthermore, there is a need for caution when using such Likert scales and the need to be aware of the many limitations that their use entails because they do not express the overarching picture of students' attitudes of practical work in this case (Cohen, Manion & Morrison, 2007).

It is clear from the research that the majority of comments regarding students' attitudes towards practical work are generally found as a by-product of researching other areas of students' attitudes towards science or decision making post-compulsion (such as Barmby et al., 2008; Cleaves, 2005). As Wellington (2005) has suggested there is a need to question students more candidly if we are to fully understand the reasons why they claim to be motivated by, and enjoy doing, practical work and yet so many of them chose to not pursue the study of science post compulsion.

2.9: Summary of the chapter on practical work

This chapter has focussed on the history, nature and purpose of practical work in school science. The value of practical work in meeting the aim of arousing and maintaining interest of the students involved has been frequently claimed by teachers (SCORE, 2008). Indeed, educationalists have used the aim as part of their research looking into teachers' attitudes to the value of practical work (Abrahams & Saglam, 2010). Yet, there are still no defined aims and purposes of practical work that the entire science education community agrees on (SCORE, 2008). Further still, there has been no in depth study that has given evidence of asking students directly if practical work does arouse or maintain their interest in science nor have there been any studies that have looked as in depth as those on teachers' attitudes to practical work. This is a cause for concern and students' attitudes to practical work do require deeper and more probing research (Toplis, 2012). If there is a better understanding of what students' attitudes are to practical work, similar to the knowledge that is reflected in the extensive studies on teachers' attitudes, then teachers and educationalist alike can better understand how to effectively engage students in science preventing alienation, or flight, from studying post compulsion (Osborne et al., 2003).

Whilst the chapter has highlighted the considerably amount of studies into attitudes outside the United Kingdom and the three large studies (Kerr, 1963; Thompson, 1975;

and Beatty & Woolnough, 1980) into teachers' attitudes into the nature and purpose of practical work, there is a lack of studies into students' attitudes to practical work. Indeed, what is reflected in the literature here is how teachers' attitudes to practical work have been investigated separate to science but for students' this appears to be carried out as part of their attitudes to science (Barmby et al., 2008; Cerini et al., 2003; Osborne et al., 2003).

It is now necessary to investigate and define of what is meant by the term 'attitudes' and explore further the components of an attitude. The next chapter, Chapter 3, will discuss this as well as reporting on students' attitudes to practical work in light of the definition of an attitude.

Chapter 3

Literature review on attitudes

3.1: Introduction

Students' attitudes to science and how students' view the contents of science are extremely influential for having the potential to significantly affect their disposition towards attainment and their retention within science both in and out of school (Bricheno, Johnston & Sears, 2001; Gardner, 1975; Kind, Jones & Barmby, 2007; Lakshmi, 2004; Osborne, et al., 2003; The Royal Society, 2008). There has been an ongoing focus in attempting to understand students' attitudes to science within science education research (for example, Barmby, Kind & Jones, 2008; Schibeci, 1984; The Office of Science and Technology and the Wellcome Trust, 2000), along with the struggle to actually define and differentiate these attitudes towards science (Zain, Rohandi & Jusoh, 2010). Such areas have had a greater focus in the social world more recently with the view regarding a shortage of science graduates (House of Commons, 2002a) alongside the claims that employers are feeling graduates have a lack of practical experience and laboratory skills which is becoming a barrier to recruitment of Science, Technology, Engineering and Mathematics (STEM) staff (Confederation of British Industry, 2011). These concerns, alongside the fluctuating number of student post compulsion in science (Taylor, 2009), suggests that more research is needed to understand students' attitudes to practical work, especially when students spend "between one third and a half of all lesson time" (SCORE, 2008) doing practical work in secondary school science. Research has suggested the need to understand why students think the way they do to better understand and hopefully benefit student uptake as well as enhancing student engagement and enjoyment in science (Barmby et al., 2008). Also, researchers have often discussed (Chen & Howard, 2010; Kim & Song,

2009) the potential links between positive student attitude and its influence on continued participation and attainment. It could be understood that positive attitudes towards science may mean students are more inclined to participate and/or be more motivated to achieve.

In order to understand attitudes to science, it is important to understand what is meant by an ‘attitude’ although it is a concept that is not easily definable. Indeed, White (1988) has commented on how the term is rather ambiguous both in the psychological and the everyday sense of the word. There have since been attempts to define attitudes, but these seem to be rather specifically related to individual research objectives and thus restricting transferability to other studies (Barmby et al., 2008; Nieswandt, 2005). This problem, along with the lack of standardised means of measuring these attitudes, makes it difficult to compare findings in research studies. Although, in research the vast amount of instruments used to measure different aspects of students’ attitudes to science, such as Likert and Thurstone scales (Barmby et al., 2008), carry individual reliability and validity problems. These will be discussed further within the methodology chapter, Chapter 4. However, prior to analysing the findings of attitudes towards science held by students, it is necessary to explore the definition of, and the terminologies associated with attitudes.

3.2: Defining attitudes

The common definition of attitudes, that seems apparent from the literature, is one that concentrates on the notion that an attitude involves the communication of an evaluative judgment about a stimulating object, where the evaluation is the essential aspect of the attitude concept (Maio & Haddock, 2010; Olson & Kendrick, 2008; White, 1988). However, the concept of an attitude was originally commented on by Allport (1935) as an unique and essential notion where a positive attitude held by one person could equally be seen negatively by another or the reason for the actions of another. Since Allport, the popularity of attitudes has led to the increase in research which is, perhaps, the reason for the inconsistency in definitions and measurements (Haddock & Zanna, 1999). Within science education, Gardner (1975) has often been referred to as providing clarity over terms relating to attitudes towards science. Gardner (1975) explained how an attitude always consists of a specific ‘attitude object’ which stimulates the subjective response. It has been largely agreed that an attitude is held intrinsically within the individual, and thus, is inaccessible to direct observation. However, it is observable on the basis of a measurable response to an attitude stimulus (Ajzen, 2005). An ‘attitude object’ or stimulus can be anything that can be distinguished and considered by anyone. The ‘attitude object’ can be concrete, abstract, inanimate, people or groups, and it may involve any form of information that possesses evaluative implication (Bohner & Wänke, 2002). Attitudes are private and specific to individuals, organised through single or multiple experiences, and influence actions to be completed by the person either intrinsically or extrinsically (Rajecki, 1990). As a consequent it can be difficult to measure an attitude effectively. Attitudes can be prescriptive or evaluative and not universally accepted, such as ‘we should do more practical work’ or ‘practical work is a waste of time’. They are also descriptive, such as ‘practical work requires me to use a lot of scientific skill’. These propositions can influence a positive or negative association: a student may dislike learning scientific skills in which case the previous comment would be spoken negatively and likewise, the reverse is true. The same descriptive proposition held by two students can influence opposing attitudes (White, 1988). Generally propositions that are acquired through direct experience or social transmission are of a more stable nature (Greenwald, 1989) because students are able to personally engage with the issue, thus potentially increasing predictability in behaviour when measuring their attitudes (Kim & Song, 2009).

Related to attitudes, are opinions. According to Kim and Song, (2009) an opinion is a verbal expression of an attitude. Yet research has still identified an 'attitude towards science', as an attitudinal construct. However, Koballa and Glynn (2007) define attitudes as a general expression of either positive or negative feelings towards something and this distinguishes it from other terms like value, belief or opinion. Indeed, Koballa and Glynn (2007) discuss how an attitude has been defined in a variety of ways with the unfortunate use of being interchanged with words like interest, value, motivation and opinion. This situation, they believe, is unnecessary because of the rather specific definitions in the literature relating to attitudes towards science. However, it has been noticed (Maio & Haddock, 2010) that it is difficult to effectively measure an attitude because of the variety and the uniqueness of the definition of an attitude. An individual's attitude can only be inferred from his or hers response to a particular, specific stimuli. This has led to a range of methods being used in measuring attitudes along with a range of terminologies relating to attitudes. Certainly, the research looking into students' attitudes to science (Ramsden, 1998) and practical work (Abrahams, 2009) have referred to such terms as 'motivation' and 'interest' have been used. Therefore, due to this common usage, the terms 'motivation' and 'interest' will now be defined and explored.

3.2.1: Motivation

Motivation within an educational context, has been defined (Palmer, 2009) as any means that commences and sustains learning behaviour, a pre-requisite and co-requisite for meaningful learning to occur. Therefore, motivation has the potential to be influential to the student's learning process in science. Within the definition, two distinct areas have been highlighted within motivation (Lin 2007), these are extrinsic motivation, which focuses on the achievements from doing the activity and intrinsic motivation which focuses on the innate satisfaction derived from doing the activity. According to Deci and Ryan (1985), intrinsic motivation has been referred to by psychologists as the non-drive-based motivation, where if motivation is referred to in terms of energy, the student holds the energy intrinsically, within themselves. The student participates purely for the interest of the activity alone. Indeed, as Bandura (1986) explains motivation as "an inner drive to action" (p.243) relating primarily to an intrinsic motivation, rather than one where an external reward would influence motivation. Conversely, according to the Organisation for Economic Co-operation and Development (OECD, 2000), extrinsic motivation occurs when there is an external factor or reward, influencing the act unlike intrinsic motivation where the action is completed without any obvious external factors and/or rewards. Yet, Hidi and Harackiewicz, (2000) have discussed how it is important to deal with all aspects of an individual's motivation especially for those who are un-motivated within academia because this has the potential to optimise academic motivation. It is important to note that motivation is *not* a stable concept within any individual. Indeed, the level of motivation depends on the environment along with other extrinsic and intrinsic factors (Barkoukis et al., 2008) and it is domain-specific (Linnenbrink & Pintrich, 2002). Therefore, this means that a student's motivation can fluctuate, in turn this can make it difficult to measure either by observation or direct questioning; this presents limitations to the researcher and the research obtained (Hardré, Davis & Sullivan, 2008).

Extrinsic motivation (Barkoukis, Tsorbatzoudis, Grouios & Sideridis., 2008; Deci & Ryan, 2000; Vallerand et al., 1992), as defined in the self-determination theory tradition (this highlights important points of motivated behaviour in humans), includes: external regulation, introjections and identification. ‘External regulation’ is the most representative form of extrinsic motivation and involves the person undergoing an activity to gain a reward or avoid punishment (Barkoukis et al., 2008). ‘Introjection’ involves an individual self involved with the activity where the individual is beginning to understand the reason to their actions (Barkoukis et al., 2008; Deci & Ryan, 2000). Finally, ‘identification’, this is the completed form of internalised extrinsic motivation because the individual values their behaviour and so, engagement is taken as being decided upon by the individual (Barkoukis et al., 2008; Deci & Ryan, 2000; Vallerand et al., 1992). According to Barkoukis et al., (2008) and Vallerand, Pelletier, Blais, Briere, Senecal & Vallieres, (1992), intrinsic motivation includes: “the *intrinsic motivation to know*, to *accomplish* and to *experience stimulation”* (Barkoukis et al., 2008, p.40, italics in original). ‘Intrinsic motivation to know’ refers to the engagement in an activity to improve cognition and is representative of intrinsic motivation in education because it links to conventional educational settings (Barkoukis et al., 2008). ‘Intrinsic motivation to accomplish’ refers to engagement in an activity for the satisfaction when trying to achieve (Barkoukis et al., 2008). Whilst ‘intrinsic motivation to experience stimulation’ refers to someone engaging in an activity in order to experience stimulating sensations such as aesthetic appeal (Vallerand et al., 1992).

Researchers (Barkoukis et al., 2008; Deci & Ryan, 2000; Vallerand et al., 1992) also discuss ‘amotivation’ as third aspect of motivation as defined in the self-determination theory. This third component to motivation (originally taken from Deci & Ryan, 2000) refers to the absence of how to behave. Amotivation is when the individual does not observe the effects between their actions and the outcomes (Barkoukis et al., 2008; Deci & Ryan, 2000; Vallerand et al., 1992). This type of motivation has strong links to "learned helplessness, where individual withdraw effort because of perceptions of incompetence and loss of control" (Barkoukis et al., 2008, p.40). Amotivation in an individual may mean they discontinue participation within education or any academic activity (Vallerand et al., 1992). The three concepts of motivation (intrinsic, extrinsic and amotivation) are placed on a 'self-determination continuum' running from amotivation, where there are low levels of self-determination, to extrinsic motivation with medium levels of self-determination, through to intrinsic motivation where the individual's behaviour relates to high level of self-determination(Barkoukis et al., 2008 and Deci & Ryan, 2000). When measuring the above types of motivation Vallerand et al., (1992) have discussed how there is yet to be an instrument that can measure all three and effectively.

3.2.2: Interest

Interest has been defined in a variety of ways throughout the literature (Bergin, 1999) but Prenzel (1992) described it as a "preference for objects" (p.73) where objects is used broadly implying an interest in an activity. However, as Palmer (2009) explains, the two terms are connected given that interest is generally an effective motivator due to the benefits it has on the learning process. Indeed, Hidi (1990) argues that interest plays a main role in determining the process and product of one's mental activities. It can be seen that interest and intrinsic motivation are rather similar in meaning but the key difference separating them is that interest refers to "a person's interaction with a specific class of tasks, objects, events, or ideas" (Krapp, Hidi & Renninger, 1992, p.8). As Bandura (1986) explains, interest is a "fascination in something" (p.243) compared to motivation which requires an internal drive, and therefore argues that the two should not be confused.

Interest is both an affective and a cognitive motivational variable that develops from experience but is not necessarily related to age, merely the difference is *what* the interest is to the individual (Renninger, 2009). Interest also, as with motivation, involves two distinct areas of interest. The two areas are ‘personal interest’ (also referred to as individual interest) and ‘situational interest’ (Bergin, 1999; Krapp et al., 1992). Individual interest relates to the individual’s preference and “asks what dispositional preferences people hold, or what enduring preferences they have for certain activities or domains of knowledge” (Bergin, 1999, p.87). Individual interest is stable and gradually develops within the individual (Krapp et al., 1992). Moreover, Krapp et al., (1992) explained from research, that individuals who have a personal interest in an activity or topic are more inclined to pay more attention and for longer periods of time as well as acquire more knowledge than those who do not hold such an interest. It should also be acknowledged that one main feature of intrinsic motivation is a high personal interest in the activity (Linnenbrink & Pintrich, 2002).

Conversely, situational interest involves the “content, activities, stimuli, or environmental conditions that tend to generate interest” in individuals (Bergin 1999, p. 87). Though situational interest is rather unstable and temporary in occurrence, it does have the potential to be important because research has suggested that multiple experiences of this form of interest can lead to a long-term interest (Palmer 2009). Similarly with personal interest, situational interest has been reported to show a positive influence on cognitive performance, such as examinations (Hidi, 1990), focus attention (McDaniel, Waddill, Finstad & Bourg, 2000), and enhance learning (Wade, 1992).

Even though situational interest and individual interest are two separate concepts, they can also influence the other’s development (Hidi & Anderson, 1992). Recent research

(Renninger, 2009) has suggested that interest is “initially triggered and supported to develop based on the physical, social, psychological, and biological characteristics of the learner and develops through four phases” (pp.106-107). From these four phases, which include: “triggered situational interest, maintained situational interest, emerging (less-developed) individual interest, and well-developed individual interest” (Hidi & Renninger, 2006, p.111); situational interest supports the development of individual interest (Alexander, 2004; Schraw & Lehman, 2001; Silvia, 2001). Each phases is defined by Hidi and Renninger (2006): Phase one, triggered situational interest refers to a psychological state as a consequence of temporary differences in affective and cognitive processing; Phase two, maintained situational interest is “subsequent to a triggered state, involves focused attention and persistence over an extended episode in time” (p.114) with possible reoccurrences; Phase three, emerging individual interest is the starting phases of a somewhat ongoing predisposition focussing on maintaining engagement over time; Phase four, well-developed individual interest refers to an enduring predisposition to reengage over time. In order to progress through each phase a “trigger” from an interaction or circumstance which causes the learner to re-think their original requisites, generate the new interest, thus, a progression through the phases, regression is also possible if interest is not supported or developed (Renninger, 2009, p.107). The phases all contribute to one another and are not in isolation, a student’s interest will progress or regress through each phase and this has the potential to have implications on the learning process (Hidi & Renninger, 2006).

3.3: The cognitive, affective and behavioural domains

Throughout the literature in addressing the definition of attitudes, it appears that there are three recurring components which are the intervening variables for the overarching attitude the student possess, these are known as the tripartite model consisting of; the affective domain, the cognitive domain and the behavioural domain (for example, Bagozzi & Burnkrant, 1979; Bohner & Wänke, 2002; Maio & Haddock, 2010; Olson & Kendrick, 2008; Rajecki, 1990; Zain, Rohandi & Jusoh, 2010). This model has been used as a framework for educational research and a means of understanding attitudes into the way they are observed or perceived (Manstead, 1996). Indeed, within science education, a student's overall attitude towards science has been explained as an amalgamation of a variety of sub-constructs rather than a single construct Osborne et al., (2003), where constructs mean any variable that can influence an attitude. There have been studies (Kim & Song, 2009; Koballa & Glynn, 2007; Ormerod & Duckworth, 1975) that have researched a large variety of sub-constructs (such as motivation, achievement, and the school environment, among others); the variety is primarily due to the array of definitions given to an attitude. As a consequence of the variety of sub-constructs, Osborne, Simon, and Collins, (2003) also discuss the problem with measuring the significance of an attitude due to the exclusivity towards a particular object. In view of this, the student's behaviour towards, and their performance on the object becomes the focus of the research rather than the attitude (Ajzen, 2005; Osborne et al., 2003). Indeed as Krogh and Thomsen (2005) suggests, the focus on acquiring numerical data along with the separation and discussion in isolation of variables (or constructs) tends to "suppress the formation of attitudes through *the interplay* between some of these factors" (p.282) relating to an apparent inconclusive result from the data. Therefore, rather than dealing with variables of the whole attitude, it has been noted by Ajzen (2005) that separating an attitude into the tripartite model (affective, behavioural and cognitive) simplifies the problem of the kinds of responses, aiding analysis, and is a popular classification dating back to Plato. Ajzen (2005) also suggests that it is useful to separate the nonverbal and verbal responses within each domain. From the responses provided by each of the three domains, it enables inference to the overall attitude, "if cognitive, affective and behavioural measures of evaluative responses to an object are all indices of the same underlying construct, attitude, then there should be some consistency between them" (Manstead, 1996, p.5). Manstead (1996) continues to explain that if there was no consistency then the tripartite theory would have to be questioned.

In addition to the tripartite model, Cheung (2009) discusses two other major theoretical frameworks used within the area of social psychology: the separate entities viewpoint and the latent process viewpoint. According to Oskamp and Schultz (2005) the newer separate entities viewpoint, entails the three components as "distinct, **separate entities,** which may or may not be related, depending on the particular situation" (pp.10-11, *bold in original*). Attitude as a term is only referred to as the affective component with cognition and behaviour as determinants of an attitude rather than being a constituting factor of it (Cheung, 2009). The cognitive domain in this viewpoint is referred to as beliefs, specific to the individual about how an object has a particular characteristic and the behavioural domain here is referred to as behavioural intentions where the individual's particular behaviour is carried out towards object (Oskamp & Schultz, 2005). The difference between the separate entities viewpoint and the tripartite model is that the separate entities viewpoint does not imply congruence between beliefs, attitudes and behavioural intentions. However, some researchers (Cheung, 2009; Oskamp & Schultz, 2005) hold reservations over the simple nature of this theoretical conceptualisation of attitudes and comparisons on any sort of attitudinal scale may not always be possible. In a study by Breckler (1984), five conditions are explained as being important when making a strong test of validation of the model. These five conditions include:

1. Verbal and nonverbal measure of affect and behaviour such as through physiological response of affect and recording of observable behaviour
2. Dependent measures of affect, behaviour, and cognition or the individuals response to an attitude object
3. A multiple, independent measurements of affect, behaviour and cognition
4. A confirming approach to validation for example by covariance structure analysis
5. All dependent measures to be scaled on an evaluative response towards the attitude object.

(Taken from Breckler, 1984, pp. 1193-1194)

The third theoretical model is the latent process viewpoint which DeFleur and Westie (1963) explain "begins with the fact of response consistency, but goes a step beyond this and postulates the operation of some hidden or hypothetical variable, functioning within the behaving individual, which shapes, acts upon, or "mediates" the observable behavior" (p.21). In this model, an attitude takes the role of an intervening variable which is where the construct is not observed itself but aides in the explanation of the relationship between certain observed stimuli and certain behavioural responses (Oskamp & Schultz, 2005). The stimulus triggers a latent cognitive, affective and/or behavioural process in the individual, either acting together or separately, which the individual then derives an overall evaluative summary of the information producing the attitude (Cheung, 2009). DeFleur and Westie (1963) explain that a problem with this model concerns the degree at which people behave in reality compared to their verbal attitudes that are measured; how they act and what they say can be seen as "covary" (p.25), that is vary together. However, it could be argued that comparing results from models dealing with an attitude with other research studies (Kind et al., 2007) or integrating findings with previous research (Francis & Greer, 1999) could be difficult, if not invalid, because of the lack of clarity over the definition of terms such as attitudes and science (Wang & Berlin, 2010). As well as this, there are a variety of different instruments that can be used to measure the three components of (albeit with regards to) an attitude - the affective, cognitive or behavioural domain (Haddock & Zanna, 1999;

Zimbardo, Ebbesen & Maslach, 1977). A possible reason for the variety of instruments is due to the nature of attitudes, few can be described as purely affective, behavioural or cognitive (Olson & Kendrick, 2008) as indeed all are “hypothetical, unobservable classes of response” (Breckler, 1984, p.1191) to a stimulus. Breckler (1984) also suggested that whilst affect, behaviour and cognition are distinguishable parts of attitude, it is important that the researcher discriminates among them and measure either individually or specify the one that is of main focus rather than an ambiguous statement of investigation into attitudes. As Olson and Kendrick (2008) discuss, attitudes involve multiple sources and along with differing approaches in research suggesting that one way to attitude formation is better than another or such a concept should be avoided, has influenced the need for further research to advance the study of attitudes. Regardless of the status that the three domains have in relation to attitudes, it is still often viewed in these terms with the difficulty only in how they are connected and the extent to they are expected to be in agreement (Garrett, 2010). Therefore it is necessary to acknowledge the three domains and investigate them in greater detail. So, it is to these three domains – cognitive, affective and behavioural - that are now explored with a specific focus on the educational side of these domains.

3.3.1: The cognitive domain

The cognitive component of attitudes refers to a wide variety of issues but is primarily focused on the factual information or concrete knowledge relevant to the attitudinal object (Rajecki, 1990). The beliefs or judgements are generally rational, drawn from information where each attribute is associated to a value and expectancy in order to determine an overall attitude, which is then applied during evaluations of the attitudinal object (Olson & Kendrick, 2008).This component is verbalised through expressions of beliefs with regards to objects that the person has an attitude towards; unlike the nonverbal response for cognition which is a perceptual response (Ajzen, 2005). According to Reigeluth and Moore (1999) cognitive education is a set of instructional methods that aid students' learning, knowledge and develop their understanding, intelligence and skills and falls within the cognitive domain. The cognitive domain has often received attention within education dating back to the 1960s, where a popular belief was that cognition was an, if not *the,* important part of the education that a school provided (Gable & Wolf, 1993). Within education, as Zeyer and Wolf (2010) explain, cognitive styles surrounding the domain are generally seen as easily influenced so education has a decisive impact on them and students are able to adapt to teaching styles. Furthermore, Witkin and Goodenough (1981) assert that cognitive styles are influenced according to how children are socialised within education.

Measuring the cognitive domain is generally conducted within education using standard tests, such as intelligence quotient (IQ tests) or General Certificate of Secondary Education (GCSE), and students' results are used as a measure of their cognitive ability (Rovai, Wighting, Baker & Grooms, 2009). However, as Bernstein and Nash (2006) explain, tests are far from perfect in measuring the cognitive domain because firstly, the tests are not able to measure every aspect of a student's cognitive ability and secondly, there is a variety of outside factors which have a direct influence on the results, take for example the behaviour or the emotional state of the student on the day of the test. White (1988) discusses how cognitive strategies for completing tests to measure the student's cognition, take time for students to acquire them and in some cases the inhibitor is beyond the student or teacher's control: the reason can be either related to the lack of understanding between what is being taught and what the student takes in or the actually meeting the needs of the tests (Pokay & Blumenfeld, 1990; Pintrich, Marx & Boyle, 1993). Certainly, Pintrich et al. (1993) continue to say with regards to how the cognitive and affective domains relate that the students' "perceptions of the value of a task do not have a direct influence on academic performance but they do relate to students' choice of becoming cognitively engaged in a task or course and to their willingness to persist" (p. 184). A positive cognitive strategy has also been reported to correlate with positive self-efficacy judgements (Pintrich, Marx & Boyle, 2006). Within science education, according to Tobin (1998) and Baird (1998), cognitive outcomes can be optimised in science lessons, through the use of evaluative questioning such as reasons for why they are conducting tasks or what needs to be completed. Baird (1998) continues to explain how in doing so, students' become more aware of their learning through holding responsibility and acting accordingly as well as through the association to having a more meaningful learning experience.

3.3.2: The affective domain

The affective domain relates primarily to the emotional formation of attitudes, it is essentially the evaluative aspect of an attitude (Rajecki, 1990). White (1988) discusses the affect in more detail with regards to the instinctive physical reactions like a rise in blood pressure, crying or laughing. This domain can be verbally measured through the statements of affect, the feelings that the person holds and is also nonverbally observed from the sympathetic, physiological responses made by the person (Ajzen, 2005). The characteristics of affect have been described (Anderson & Bourke, 2000) as involving three attributes within its character: intensity - the strength of the feeling, direction – either positive, neutral or negative feeling, and target – the object, behaviour or idea for which the feeling is directed at. Anderson and Bourke (2000) explain that by having a clear definition of the characteristics provides a good foundation for selection or designing of an instrument to assess and interpret results positively.

Within the education system, the affective domain only became part of the learning goals and objectives during the 1970s (Gable & Wolf, 1993). The reasons for the late integration were provided by Tyler (1973) who suggested firstly, that educators thought this area was not the business of schools but churches and home life and secondly, that affect was learnt through natural progression as an end product rather than a means to the learning progress. Indeed, Griffith and Nguyen (2005-2006) comment how those individuals who intend to enter the teaching profession often refer to the "desire to positively affect children" (p.2) and yet in reality they explain how within the everyday classroom, this intended focus has altered to what most educators find is an increased focus on how to increase acquisition of skills. This focus away from affective influence on students has shifted more towards the cognitive domain. Indeed, Griffith and Nguyen (2005-2006) found that in the real life situation of teacher practice, the accountability issues raised the risk of minimising, or in worse cases ignoring, the affective domain. The analogy of how a greater focus on the cognitive domain is like "a skeleton without the skin" (Griffith and Nguyen, 2005-2006, p.2) if the affective domain is not nourished highlights some research studies expressing the importance of the domain in creating a healthy learning environment in education (Russell, 2004; Thompson & Mintzes, 2002; Watts & Alsop, 1997). In improving the affective domain in students, research has shown (Tuan, Chin & Shieh, 2005) that motivation is an important part in linking a student's desire to improve their concept learning and cognition. Furthermore, according to Ainley (2006), as has been reported by students who have been on task in their learning, interest is seen to be a component of wider progressions of motivation and activity showing engagement with learning tasks. Although, the more highly motivated a student is, the greater tendency they have to be of a higher academic ability and therefore they are more inclined to hold a greater affection towards the attitude stimulus (Hidi & Harackiewicz, 2000;Watts & Alsop, 1997).

An issue with the affective domain is how best to measure it. One example of the instruments used in measuring affective domain can be seen in a study by Breckler (1984) that looked into individuals' attitudes towards snakes. The study measured the affective domain in four different ways, these included: measurement of the heart rate; "an adjective checklist measure of positive mood (MACL+); an adjective checklist measure of negative mood (MACL-); and a Thurstone equal-appearing interval measure of affect" (p. 1196). The heart rate was measured throughout the study and analysed using the standard score z-values. The study took the median from the Thurstone affect which included sixteen statements of feelings and the MACL+ and MACL- were derived from the Mood Adjective Check-List (Nowlis, 1965) where the positive and negative affects were calculated from adding the responses to nine positive and nine negative adjectives. This in comparison to a study by Rennie (1994) shows the diversity in measuring attitudes. The study by Rennie (1994) used a mixture of observations, formal and informal interviews and informal conversations during the pilot with the final instrument involving a post-visit questionnaire focussing on three variables: "the students' perceived success in working with the activities, their enjoyment and their perceptions of the [activity's] helpfulness" (p.264). Rennie (1994) commented on the problem with measuring affective outcomes of students with diverse experiences whilst visiting a science educational centre. The study concluded that whilst the affective domain is measurable in relation to visiting science centres, consideration of students' differences in experience and how such an instrument could be used easily by teachers to inform practice. Indeed, the context of the studies would have influenced the format of the instruments used but it still highlights the problem of finding a widely applicable approach to assessing the affective domain of students' attitudes (Wang & Berlin, 2010). However, the benefit of assessing the affective component provides information that is unavailable from purely measuring the cognitive domain or behavioural domain alone (Haddock & Zanna, 1999).

Within science education, according to Liu, Hu, Jiannong, and Adey, (2010) attitudes towards science deteriorates with age, with significant gender differences as the students develop and progress through school. They conclude that affective attitude is closely related to the differences in gender experience in learning science. The study by Rennie (1994) found that students visiting science education centres did benefit and enjoy the experience and that through instruction linked to the visit (rather than how long ago the visit occurred) was more influential to their enjoyment. Rennie (1994) concluded that the affective domain is positively influenced by visits providing instruction after the visit is associated to it; although the cognitive outcomes did decrease, the affective outcomes seemed to be more resilient over time. Similar findings on students' affective attitude were commented on by Abrahams (2009) where students enjoyed conducting practical work but it is argued that this is because they *preferred* it to other learning activities, just as they would a visit to a science education centre. Practical work and science educational visits can create enjoyment and/or have a positive impact on students' learning of science as seen through some research (Braund & Reiss, 2006; Cerini et al., 2003; SCORE, 2008) but research suggests (Chen & Howard, 2010; Osborne & Collins, 2001) the need for continued re-stimulation because the engagement and enjoyment created is more likely to be short-term. Moreover, there needs to be support with science content for this to influence the affective domain as a long-term feature in a student (Rennie, 1994).

3.3.3: The behavioural domain

The behavioural component of attitudes refers to actions or overt behaviour of the person regarding on the attitude object. It demonstrates an intentional aspect of an attitude otherwise referred to as a conative and is not exactly like ‘behaviour’ per se because it intervenes between the obvious ‘behaviour’ of that person (Bagozzi & Burnkrant, 1979; Rajecki, 1990). This component is verbalised by statements concerning behaviour with nonverbal responses including overt behaviours with which this component of attitude can be inferred (Ajzen, 2005). Indeed, according to Heimlich and Ardoin (2008), a key aspect of education is to influence an affect in individual’s behaviour.

The behavioural domain in principle is measured by four basic types. According to Martin and Bateson (1993) the first type is latency, which is the time taken from an event to the first signs of the individual’s behaviour, observations are generally under time constraints and so the essence of the behaviour is not always seen. The second they suggest, is frequency, which is the measurement of the number of occurrences of that behaviour was observed during a specific amount of time and the third is the duration, relating to the length of time that a single occurrence of that observed behaviour lasts. Finally, they explain the fourth as intensity; this has no single definition but judgements about the observed behaviour and can be in the form of verbal descriptions. These four types could be supplemented by the inclusion of the individual’s verbal response to their reasoning for such behaviour as this can increase validity of the results as well as improving the overall understanding of the behaviour (Breckler, 1984). It appears from this that, observations into how they act towards the attitude object or after specific stimuli, and verbalised responses are the common forms of measuring the behavioural domain (Ajzen & Fishbein, 2005). Yet these approaches do raise concern regarding the validity and reliability for researchers. Indeed, Schwarz (2008) discusses a problem with observation is that the reliability of the results can be tainted due to the external variables that influence the students to behave they way they do and hence is a poor indicator of the behavioural domain and rather unreliable as a measurement strategy. As behaviour is generally an intrinsic component within the individual (Olson and Kendrick, 2008), and is conceptually different from affective and cognitive domains (Eiser, 1986), measuring verbal responses of an attitude to predict the behaviour has been reported as failing by some (Ajzen & Fishbein, 2005), or conversely, stating that there is an abundance of evidence by others (Oskamp & Schultz, 2005). However, the general consensus, according to Ajzen and Fishbein (2005), is that the problems with linking verbal responses and predicting behaviour comes from the methodologies of each specific study and that the amalgamation of the two means of measuring the behavioural domain, observation of action and the verbalisation, can show inconsistencies. The main reasons for the inconsistency is mainly due to response bias where students' responses do not seem to match behaviour or the multi-dimensionality of attitudes which relates to the concern that the approach in measuring an individual's response using a single, evaluative technique does not do justice to the complicated nature of attitudes (Ajzen & Fishbein, 2005).

3.4: Students' attitudes to science and practical work

Many studies in the last two decades have examined students' attitudes towards science in science education (Barmby et al., 2008; Kim & Song, 2009; Nieswandt, 2005; Osborne et al., 2003). The importance of researching students' attitudes towards science has been highlighted by the Organisation for Economic Co-operation and Development (OECD, 2010) who believe that a student's 'scientific literacy' should include certain attitudes, beliefs which by possessing and utilising effectively, it is believed this will benefit the individual, the society and worldwide. Yet the importance of attitudinal research, primarily attitudes towards science, is not a recent area in science education. Work by Dewey (1916 and 1934) highlighted the importance of scientific attitudes whilst work on attitude measurement instruments such as the Likert (1932) and Thurstone (1928) along with theoretical ideas (Sherif, Sherif & Nebergall, 1965) influenced the research into attitudes towards science which by the 1960s had become something of a regularity (Koballa & Glynn, 2007). Indeed, The Dainton Report in 1968 (2006) highlighted the issue regarding scientific attitudes moving away from science and by the mid-1970s Ormerod and Duckworth (1975) began researching into students attitudes to science.

During the 1990s, some science educators (Freedman, 1997; Thompson & Soyibo, 2002) reported in studies that practical work was important means for enhancing attitudes, stimulating interest and enjoyment, and motivating students to learn science. Moreover, it has been argued by Hofstein and Lunetta (1982; 2004) and Korwin and Jones (1990) that hands-on activities have the potential to enhance positive attitudes and cognitive growth. However, as highlighted by Abrahams (2009), the majority of studies (Beatty & Woolnough, 1982; Kerr, 1963) that have expressed such positive perspectives of practical work, have focussed more on the rhetoric through questionnaires on students views, than the actual reality of practice and behaviour of students. However, White (1988) assumes the stance that an attitude relating to science must be the amalgamation of the individuals beliefs, behaviour and emotions relating to the stimuli and therefore, as Bagozzi and Burnkrant (1979) consider the view that an attitude is the interplay of the affective, cognitive and behaviour domains, an attitude to science is acknowledged by White (1988) as this combination, the tripartite model.

In a recent study by Kim and Song (2009), they separated conventional instruments of an attitude towards science into either, intrinsic (related directly to students) and extrinsic (related to social viewpoint). They found intrinsic attitudes towards science, like ‘school science is easy’, influenced students’ interest and conceptual understanding. Conversely, finding students’ extrinsic attitudes towards science, like ‘science offers better job opportunities for the future’ failing to influence in the same way. Certainly, the House of Commons (2002a) report suggests that career aspirations are rather influential. Furthermore, Baker (1998) found that students having a negative attitude towards science may have more to do with the student not finding themselves suiting the image of science (Cleaves, 2005; Jenkins & Nelson, 2005) or lacking cognition in science (Malone & Cavanagh, 1997).

There has been research (Koballa & Glynn, 2007) suggesting that students’ affective factors consist of two theoretical areas: their attitudes towards science and their interest in science topics, where interest here means a direct causal factor influencing students’ learning behaviour. Indeed, as Mamlok-Naaman, Ben-Zvi, Hofstein, Menis, and Erduran (2005) showed, pure acquisition of knowledge has little effect on students’ attitudes, especially within western society where student voice is prominent. Mamlock-Naaman et al., (2005) explain that ‘if students are not interested in science, they tend not to make an effort to learn and understand the meaning of concepts that are being taught to them” (p.488). This could mean that students who are interested in science and understand the scientific concepts may hold more positive attitudes towards science and science studies than those who struggle with learning in science. Also, what can be seen here is the effect that the affective and cognitive domain can have on the behavioural domain, students not interested and lacking knowledge are more likely to disconnect with studies and become unmotivated to science (Hidi & Harackiewicz, 2000).

According to Lunetta, Hofstein, and Clough, (2007) a valid and reliable measure of assessing students' perceptions of a learning environment using practical work was a "Science Laboratory Environment Inventory". The Science Laboratory Environment Inventory (SLEI) examines the learning environment in laboratories by questioning students' perspectives of their realities environment and desired one using a Likert type scale (McRobbie, Fraser & Giddings, 1991). The main usage of the Science Laboratory Environment Inventory was to examine "Student Cohesiveness, Open-Endedness, Integration, Rule Clarity, and Material Environments in the laboratory class" (Fraser, 2007, p.110).

Alternative measures of attitudes towards science have more recently been researched and commented on. A recent study by Kind, Jones, and Barmby (2007) commented on five main methods which have been reviewed by Osborne, Simon, and Collins, (2003) and Gardner (1975), these include: preference ranking, attitude scales, interest inventories, subject enrolment, qualitative methods. Despite the variety of measures and the difficulty in measuring attitudes effectively, Kind, Jones, and Barmby (2007) used attitude scales to measure their subjects' attitudes towards science because of the increased reliability and simplicity of usage. They go on to discuss how any attitude measure needs to be "statistically *internally consistent* and *unidimensional*" (p.875, italics in original) due to the fact that many studies (Bennett, 2005; Gardner, 1975; Osborne et al., 2003; Schibeci, 1984) comment on them being of a poor psychometric quality. It could be concluded, Wang and Berlin (2010) comment, "science attitude instruments developed to date have been critiqued closely, and a number of problems and weaknesses in them have been reported. Central to these critiques is the lack of clarity and definition of the underlying attitude constructs being measured…" (p. 3). Whilst the literature stresses the need to clarify explicitly the meanings of the attitude constructs, it is possible to effectively measure students' attitudes towards science. Indeed, work by Reid (2006), discusses how effective attitudinal measures can be used in methodologies which can give a better, more useful, detailed analysis. The key areas that are applicable to this study and reported by Reid (2006) include:

> The measurement of attitudes is, therefore, extremely important and there is a need for valid approaches which are accurate and offer rich insights…. *Absolute* measures of attitudes are impossible. Only comparisons can be made….There are numerous paper-and-pencil approaches: based on Likert, Osgood as well as rating questions and situational set questions, interviews can offer useful insights.
>
> (p. 20, italics in original)

The key messages from this is that whatever method is to be adopted for the collection of data for this study, it needs to be a valid approach which not only uses pencil and paper questionnaires but also interviews to better enrich the quality of the data collected. Indeed, Reid (2006) stresses that the approach of an attitude scale is best avoid because whilst a simple number is gained, the specific detail and precision is lost because of the reliance on purely categorical data: a slight concern when an attitude - that which is being researched is far from an absolute or explicit concept.

However, whilst the instrument would strive from a more descriptive and empirically driven approach, such as the VOSTS approach by Aikenhead and Ryan (1989) and is discussed further in Chapter 4, an attitude can be described and analysed in terms of the three component parts. Therefore, with understanding an attitude as being the result of the tripartite model – involving affective, cognitive and behavioural domains- Reid (2006) defines how these three domains can be defined in terms of application to research:

(1) knowledge about the object, the beliefs, ideas component (Cognitive);

> (2) a feeling about the object, like or dislike component (Affective); and
> (3) a tendency-towards-action, the objective component (Behavioural).
> (p. 4)

Using the three definitions for affective, cognitive and behavioural a students' attitude can be better explained and analysed. For example, a student who is giving their attitude towards studying chemistry would need to know (Reid, 2006): some *knowledge* of what chemistry is and involves; what their *feelings* are towards chemistry – which could be determined from what they *know* about chemistry; and whether they feel a tendency, or a *committed* to studying chemistry beyond compulsion. However, whilst this appears to suggest that a student would need all three components to involve a positive attribute in order to form a positive attitude, the balance between the three can vary (Reid, 2006) and Wilson, Lindsey and Schooler (2000) do suggest that these three components can, and do, exist with some inconsistencies. So this suggest that for students claiming they enjoy practical work (affective domain), they can say or indeed show that they struggle to understand, and often avoid to see, the required learning outcomes – which follows the work by Abrahams and Millar (2008) (cognitive domain) and whilst these two domains are inconsistent, they may still not continue with science (behavioural domain). Reid (2006) claims that the behavioural domain in science education is often dubbed in terms of science uptake post compulsion. Although if within the behavioural domain of a students' attitude to practical work, it is seen as a motivating factor for doing science, it might be expected that the numbers continuing with science post compulsion because of practical work. However, as Hodson, (1990) discussed this was not the case for the Nuffield inspired courses which were practically focussed. More recently as Toplis (2012) discusses the fact that practical work itself appears to have little impact on motivation influencing continued uptake in science. Therefore, whilst students may show that positive attributes within the affective domain, they need not hold positive attributes within either of the other two domains. Indeed, as Wilson et al., (2000) discuss, there may be conflict between the three domains but Rosenberg (1960a) argues that at this time people are more inclined to change their attitude to ensure there is consistency between the three domains. When a student claims they enjoy practical work it may be therefore that the strength of the affective domain overrides the other two domains and whilst causing a conflict here, for the younger students this may be the main objective, to just enjoy doing practical work in science as opposed to the cognitive domain or retention post compulsion (behavioural domain). It seems understandable that for students who provide descriptive accounts of practical work that were memorable in some way other than be able to recall what they learnt from it (Abrahams & Millar, 2008) would be referring to the affective domain when giving an answer to why they like or do not like practical work. Indeed, for most students at the start of secondary school science their attitudes within science at least are very positive and they then start to decline by the end of secondary around aged 16 (Woolnough, 1996).

One conclusion that can be made is that whilst there have been comments by students about their claims of enjoyment in and for practical work as part of a wider study into students attitudes (Barmby et al., 2008; Cerini et al., 2003; Toplis, 2012), there needs to be more in depth research into the explanations for why students feel the way they do. Furthermore, as attitudes can only be inferred (Reid, 2006), any means of using multiple approaches to the method of data collection can therefore benefit and enrich the results. Indeed, questionnaire data can gauge the cognitive and affective domains of students but it may well be worthwhile to see the behavioural domain by observation.

3.5: Summary of the chapter on attitudes

Within this chapter on attitudes, it has explored the concept of an attitude and defined the tripartite model which involves the cognitive, affective and behavioural domains. It has discussed the terms interest and motivation and how these are inferred in a student's attitude to practical work. This chapter has also built on the section from Chapter 2 regarding students' attitudes to the nature and value of practical work by going further as to how their attitudes to practical work can be explored in relation to the tripartite model of an attitude.

What this chapter seems to emphasise is how the use of critically examining an attitude in terms of the cognitive, affective and behavioural domains as well as the terms motivation and interest, students' attitudes can be probed and deeper explored with regards to any particular subject or stimuli, which in terms of this study is practical work. Also, there is a need to ensure that the method of data collection allows for richness by means of not restricting a student's attitude to a mere number. Instead, it may be possible to obtain data from different methods such as observing, interview or questioning. Each form of methodology may then be able to triangulate the findings to show the affective, cognitive and behavioural domains. For example, data could be obtained by observing a student's behaviour in a practical lesson or interview or implementing a questionnaire to measure their feelings and thoughts to practical work. This chapter has also highlighted how data can be analysed using the cognitive, affective and behavioural domains to explain why students' attitudes may not be consistent and/ or change over time.

3.6: Implications of the literature

The implications of the literature from the research explored and investigated in Chapter 2 on practical work and Chapter 3 on attitudes highlights some important considerations for how to proceed with this study. Certainly, there is an underlying theme running through the literature on attitudes to practical work, that there is a need for greater and deeper exploration into *students'* attitudes to practical work, separate to their attitudes to science. Indeed, many researchers, including Reid (2006), Toplis (2012), Osborne et al., (2003), have discussed the need to further explore students' attitudes to benefit areas within science. The research has highlighted some important areas for how to effectively measure attitudes in science education and how the use of defining attitudes with its three components – cognitive, affective and behavioural – can all contribute to the student's overall attitude (Reid, 2006). What appears reflected in the research, is that if students' attitudes are better understood in terms of the attributes of an attitude – the tripartite model of cognitive, affective and behavioural domains – there is the opportunity to probe deeper into what students really mean when they claim to *like* practical work. The use of the tripartite model appears to be a helpful tool in critically analysing and exploring students' attitudes.

The literature in the two chapters has also highlighted some interesting areas for consideration with regards to data collection. From the research literature it appears that as Reid (2006) describes there is a need to avoid attitude scaling in order that the results obtained are as rich and accurate as is possible. It could be argued that multiple methods approach to collecting data (triangulation) would benefit a study looking into attitudes because for example, then the *claims* students make about what they think, or what they know can be compared with what they actually do. Indeed according to Cohen, Manion and Morrison (2007), a mixed methods approach to the methodology can prevent bias and instead can provide a fuller, more detailed picture to the researcher and this in turn gives a more holistic view of that being researched.

The implications of the literature reviews into practical work and attitudes have highlighted areas that this study will now focus on. Chapter 4 will now discuss the methodology which draws on the literature discussed in Chapter 3 and Chapter 2. The next chapter will discuss how the data will be collected, the method implemented and how the pilot study informed the main study. Also, Chapter 4 will discuss the definition of an attitude in terms of the tripartite model in how this can be used as an analytical framework for analysis.

Chapter 4

Research methodology

4.1: Introduction

This study is a critical investigation into the affective value of practical work within biology, chemistry and physics, on students in English secondary schools. It involves the design, development, distribution and analysis of a new instrument that uses a phenomenological methodology as its theoretical framework. The methodology is one where the instrument is developed from the participants, in this case the students, and the method is based on "Views on Science-Technology-Society (VOSTS)" by Aikenhead and Ryan (1989) which has since been used in a number of studies including; Bennett and Hogarth (2005), Bennett, Rollnick, Green, and White (2001) and Röhm and Rollnick (2010). The three instruments are referred to as the biology questionnaire, chemistry questionnaire and physics questionnaire.

The three questionnaires investigate students' attitudes to school science practical work whilst drawing on observations with semi-structured interviews of a biology, chemistry and physics practical work lesson followed by focus groups with students to further discuss their views on practical work.

4.2: Background and research focus

Even though the constant, wide spread claims regarding the affective value of practical work on students expressed by teachers (Wellington, 2005) and policy makers (House of Commons Science and Technology Committee, 2011), research on students' attitudes to practical work has generally been part of much wider studies into students' attitudes to science (such as, Barmby et al., 2008; Kind et al., 2007; Osborne & Collins, 2001;

Reiss, 2004). Indeed, there is evidence that the reasons why students enjoy practical work is that they *prefer* it to other teaching methods (Abrahams, 2009; Cerini et al., 2003) or alternatively that it provides them with positive reasons to continue studying science (House of Commons Science and Technology Committee, 2011). However, it has been noted how there is a greater need to probe further into students' attitudes to science and, more importantly, try to understand how the practical work activities might be used in engaging students (Osborne et al., 2003). A report on a seminar held at the ASE Annual Conference, Nottingham, on 6 January 2010 found participants commenting on how some students (Dillon, 2010):

> ...*'love it - it breaks up the day'* and they value the fact that it is hands-on. Other students '*see practical work as a way of relaxing, considering it as "down time" and time to chat to their mates'.* At worst, students think practical work is a '*necessary evil that follows learning the theory'.* It was felt that some students are '*not keen on evaluation or interpretation of results or cleaning up!*'
>
> (p. 38-39 italics in original)

What is interesting here is how the comments are typical comments that one might hear when visiting students in their science classes, have been seen in a few studies such as Cerini et al. (2003), Hart et al. (2000) and Toplis (2012). Yet such studies tend to involve student comments about practical work in response to students' attitudes to science; this is rather than researching students' attitudes to practical work alone. One reason for this may be due to the issues regarding the validity and reliability of data from attitudinal instruments which can be difficult when measuring students' attitudes (Cheung, 2009).

Whilst there have been previous large scale studies into attitudes of *teachers* on practical work (Abrahams & Saglam, 2010; Beatty & Woolnough 1982; Kerr 1963), these have primarily focussed on what teachers *believe* students gain from practical work and what they *think* occurs in the school laboratory, the findings showed, as Beatty and Woolnough (1982) note what teachers *thought* but not the actual reality. Despite this, there has been no similar research directly questioning students on their attitudes to practical work and little is known in the area (Toplis, 2012). Over the years, the actual ‘voices of students’ (Collins, 2011, p. 14) have been deficient in the contribution to the research into students attitudes. One possible reason for this is “perhaps reflecting an assumption that they had little to contribute to issues of such import as the teaching and learning of science, which needed to be decided by scientists and science educators” (ibid, p. 14).

It has been noted by Osborne et al. (2003) that more research should be done into the area of students’ attitudes within science, because it is these attitudes that have the potential to either alienate or engage students, “for lest it be forgotten, attitudes are enduring whilst knowledge often has an ephemeral quality” (p. 1074). Along side this, the ever pressing strains on science departments regarding financial issues (House of Commons Science and Technology Committee, 2011; SCORE, 2008), places a greater importance on research into students’ attitudes to practical work, to both justify the expenses and to understand fully the role it plays in teaching and learning of science.

This study aims to provide a deeper investigation into students’ attitudes to practical work within the three sciences; biology, chemistry and physics. The study employs a questionnaire supported by observations and focus groups to triangulate the data with the aim of improving the validity of the research (Mathison, 1988). By using this strategy for the methodology, students’ attitudes to practical work may be better understood. This understanding has the potential to benefit educational policy makers in helping to encourage the teaching and learning of science to better suit the needs of the students. Indeed, Cook-Sather (2002) writes, “there is something fundamentally amiss about building and rebuilding an entire system without consulting at any point those it is ostensibly designed to serve” (p. 5). Thus, by beginning to understanding the attitudes of those students that science practical work concerns, science lessons and science uptake may be better comprehended.

The literature on attitudes to practical work, and science for that matter, (Kind et al., 2007; Osborne et al., 2003) draws on the methodological problems with instruments that aim to effectively measure an attitude, whilst attempting to address the issues of validity and reliability as well as the array of instruments that are restricted to particular studies or that ignore the psychological issues. As this study aims to examine students’ attitudes to practical work in biology, chemistry and physics, it was decided that the attitudinal instrument to be used would follow the design and development of the work by Bennett and Hogarth (2009) on the *AS*^{3} *instrument* and Aikenhead and Ryan (1989) on the *VOSTS* instrument, rather than develop a completely new instrument. The attraction of this approach was that it involves the instrument using students’ *own* words to directly influence and guide the development of the questionnaire and enables the researcher to probe further into the explanations for *why* students respond to a set disposition statement (Lederman, Wade & Bell, 1998).

What emerged from the literature review was a need for research to focus primarily on students’ attitudes to school science practical work. Whilst there have been many research studies and reviews into students’ attitudes to science (for example Cerini et al., 2003; Jenkins & Nelson, 2005; Ormerod & Duckworth, 1975; Osborne et al., 2003), it appears that these studies did not probe specifically into students’ attitudes to practical work in any depth. Whilst research has reported students’ attitudes being positive to practical work (Barmby et al, 2008; Cerini et al. 2003), this has been reported on as part of larger studies into students' attitudes to science. This has led to claims that students enjoy practical work and find it fun (House of Commons Science and Technology Committee, 2011). However, this is often evidence based on very little in-depth research which has not questioned or probed further into why students hold such views or what they actually mean by *fun*. The evidence of students' claiming to be motivated by practical work has been reported by Abrahams (2009) and Hodson (1990) as being more about the avoidance of writing than enjoyment of studying science as an "intellectually fascinating subject" (Abrahams, 2007, p. 122). Claims that students are motivated or interested by practical work have led to some disparity relating to the terminology that teachers use to express students' attitudes to practical work. When teachers claim practical work motivates their students, this has been reported (Abrahams & Sharpe 2010) as being reflecting students' short-term interest for practical work that does not continue beyond the lesson rather than a personal interest for practical work in science.

The importance of researching into the affective outcomes from the approaches to science teaching has become as important as researching into cognition and learning in science (Hofstein & Mamlok-Naaman 2011; Shulman & Tamir 1973): indeed it could be argued that understanding how to engage students in science and ensure enjoyment in science has never been as important for teachers as it is today (House of Commons Science and Technology Committee, 2011; Osborne et al. 2003) especially with the concerns over student uptake of science, in particular physics and chemistry, post compulsion (Gorard & See, 2008). If the common view held by teachers, that practical work motivates students (Wellington, 2005), then any GCSE course that increases the amount of practical work should spark students to continue studying science post compulsion when understanding motivation to be “an inner drive to action” (Bandura 1986, p. 243). However, the Nuffield-inspired courses which focused on practical work during the 1960s failed to increase student uptake but instead had the opposite effect at A-level (Hodson, 1990). According to SCORE (2008), a similar frequently claims by teachers is how practical work can “arouse and maintain interest” (p. 5). However for some students the use of practical work can disinterest them (Wellington, 2005), indeed Holstermann et al., (2009) found that there is a need to investigate further the types of practical work activities, in order to differentiate the most effect practical work activities that effectively interest students. Yet as Abrahams (2009) explains this motivation and interest that practical work promotes for students is more down to students holding a situational interest within the confines of the individual science lesson, thus explaining the need for students to be continuously re-stimulated from lesson to lesson for the interest to be sustained.

The research literature suggested that the main area that was yet to be adequately explored related to:

- What are students’ attitudes to school science practical work?

It was also felt that whilst this was likely to be the main area of research within this study it was also envisaged that additional areas of research would focus on issues relating to:

- The effects of schools science practical work on students’ motivation and interest?
- The extent to which students’ attitudes to school science practical work indicative of their attitudes to school science?

From these questions, it then became necessary to develop an appropriate research methodology in order to address them effectively. In finding the appropriate method to explore students' attitudes to practical work it was decided to design, develop and validate a questionnaire to measure these attitudes. Therefore, a methodological framework was required to explain how to effectively measure an attitude and, specifically for this study, students' attitudes to practical work in science.

4.3: Methodological framework

The main issue with researching students' attitudes is how to effectively measure an attitude held by a student. The notion of an attitude is an abstract and created construct serving as a means to understand behaviours and actions in order to predict future events. For this reason it is not as easily measurable, "*we can only infer that a person has attitudes by her words and actions"* (Henerson, Morris & Fitz-Gibbon, 1987, p. 12, italics in original.).

The most common approaches to measuring attitudes involve summated rating scales with Likert-type scales, differential scales such as Thurstone-type scale and semantic differential scales (Kind et al. 2007). However, the problems with these attitude scales discussing the issues surrounding the validity and reliability of the instruments as well as the lack of careful theoretical and constructional approaches to the instruments, have been well noted in many studies such as Blalock et al. (2008); Cheung (2009); Kind et al. (2007); Osborne et al. (2003). As Reid (2006) advises that "scaling methods be rejected on grounds of logical and statistical weaknesses. Rich detail is lost in such methods" (p. 21). As this study aims to probe deeper into students' attitudes to practical work the theoretical framework follows an approach that is more "naturalistic" (Aikenhead & Ryan, 1992, p. 487) whereby the instrument is derived by the participants, the students. The framework is provided by the approach that Aikenhead and Ryan (1989) developed in researching views on science, technology and society and was later designed and developed to be used in a study by Bennett and Hogarth (2005). The work by Aikenhead and Ryan (1989) involved the development of an instrument to look at high school students' views on science, technology and society (VOSTS). The theory behind the VOSTS instrument involved an empirical approach underlying the framework. The approach dislodges the idea of science educators assuming how students might respond to a given statement, instead they "must gather empirical data about how students *actually* respond to an item" (Aikenhead & Ryan, 1992, p. 488, italics added). The work by Bennett and Hogarth (2005), which drew on the initial framework of the VOSTS instrument, developed the *Attitudes to School Science and Science (AS^3)* instrument used with students aged eleven, fourteen and sixteen years. The essence of both the VOSTS and AS^3 instruments is how they draw on both descriptive (Level 1 responses) and explanatory data (Level 2 responses). The two levelled structure to the data means that students' attitudes can be probed for explanations as to why they think and feel the way they do with regards to a given statement.

The development of an instrument like the VOSTS and AS^3 follows a similar number of steps which are summarised and compared in table 4.1. The fundamental key to the development of the instrument in this way is how it is derived empirically through students' words during written responses and interviews (Aikenhead & Ryan, 1989; Lederman et al., 1998).

Table 4.1: Stages involved in the development of the VOSTS and AS^3 instrument (Taken from Bennett & Hogarth, 2009 and Aikenhead & Ryan, 1989)

Stage	VOSTS approach (Aikenhead & Ryan, 1989)	AS^3 approach (Bennett & Hogarth, 2009, p. 5)
1	The evaluator composes one statement which addresses an STS topic and a second statement which expresses the opposite viewpoint on that topic. Students check off a three-point Likert scale and then write a paragraph in reaction to one of those two statements, explaining why they agree, disagree, or neither agree nor disagree with the statement.	Literature search plus interviews with 36 students aged 11, 14, and 16 years (12 of each age)
2	The evaluator analyzes 50 to 70 paragraphs written in response to <u>both</u> statements. The evaluator attempts to find common arguments or viewpoints expressed by the students. These common arguments, called “student positions,” are written in the students’ language as much as possible….One of the two statements is chosen to become the item’s statement.	Initial development by team of three researchers plus two teachers; validation by approximately 25 science educators and teachers
3	About ten students who did not participate in step 2 then respond to the revised VOSTS statement in two ways: first by writing a paragraph response and the secondly by choosing one of the students positions…This is followed by an interview to determine how well the wording of the multiple choice captured student’s viewpoint.	Approximately 40 responses per item, 10-15 per age range in two all-ability comprehensive schools
4	Yet another group of ten students, individually in the company of an evaluator, works through the revised multiple-choice VOSTS item talking aloud about the choices made. This allows the evaluator to polish the item’s wording for greater precision.	Categorisation and validation of responses
5	A large sample of students (n>500) responds to the VOSTS item.	Trial with 91 students in four classes, two aged 11 years and two aged 16 years

The development is routed in a naturalistic, grounded theory approach whereby collection and analysis of data interact in order that the theory better reflects the understanding of the area (Bowen, 2008; Yu & Mensah 2011). Initially in step one a literature search is completed to identify areas within the topic for investigation assisted by student interviews as Bennett and Hogarth (2009) or student paragraph responses to two bipolar statements as Aikenhead and Ryan (1989). This step one is primarily focused on understanding and exposing the areas of concern.

Once the areas have been highlighted, step two involves the composition of the disposition statements for the instrument and after peer validated by science educators. This approach of obtaining the statements for the attitudinal instrument from the students as opposed to the science educators happens due to an underlying assumption. This assumption is that "students and researchers do not necessarily perceive the meanings of a particular concept in the same way" (Lederman et al., 1998, p. 605). So rather statements being produced by educationalists, students develop the statements from within the context of that which is being investigated. Step three for the AS^3 instrument involves students responding to the statements from step two on a Likert-scale from strongly agree to strongly disagree, and then asked to provide reasons to their view to the given statement. The layout of this questionnaire approach can be seen in table 4.2.

Table 4.2: Example of the free-response item (taken from table 2.4 in Bennett & Hogarth, 2005, p. 16)

B06 I would like a job involving science

Tick the box which best fits your view.

Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
☐	☐	☐	☐	☐

Why did you tick this box? Please explain in the space below.

In step four these "free responses" from step three are categorised and validated by the researchers to become the fixed responses in the instrument for the agree, neither agree nor disagree, and disagree options with between eight and ten reasons per disposition statement. This stage four layout can be seen in table 4.3.

Table 4.3: Example of the trial of fixed responses to a disposition statement (taken from table 2.5 in Bennett & Hogarth (2005, p. 17)

B06 I would like a job involving science

Circle the response which best fits your view.

A I AGREE because I enjoy science at school.

B I AGREE because scientists are generally well-paid.

C I AGREE because science makes the world a better place to live in.

D I AGREE because there are good jobs you can do with science.

E I NEITHER AGREE NOR DISAGREE because it depends on the sort of science involved in the job.

F I DISAGREE I find science boring.

G I DISAGREE because science causes too many problems for the world.

H I DISAGREE because scientists don't get very well-paid.

I I DISAGREE because science is a job for a man.

X None of the above statements reflects my view which is:

Validation of the instrument at stage four involved students from step three to trial the fixed responses by selecting as many as they thought fitted their view and then comparing these responses with those given in stage three. Also, prior to the final stage, an additional option of "another reason –please say what" (Bennett & Hogarth, 2009, p. 5) was added to each agree, neither agree nor disagree and disagree option for all disposition statements. By the addition of the 'another reason' option meant that students were not being pressured into an answer that many other instruments such as Likert-type responses can incur (Lederman et al, 1998).

For the VOSTS instrument, by step two composition of the VOSTS statements had been developed and analyse of fifty to seventy paragraph responses per pair of bipolar statements by students had been carried out; this number ensured theoretical saturation where “the data categories are well established and validated” (Bowen 2008, p. 140). Step two also involved the production of the VOSTS multiple choice layout devised from students, three researchers agreed on the fixed responses categories to be used as reasons for students’ views, with between five and thirteen reasons per statement; and one of the two bipolar statements was chosen. Step three and four for the VOSTS instrument is primarily related to revising the multiple choices to fit the students’ words and ensure clarity through the use of semi-structured interviews with students.

Finally, for step five of both VOSTS and AS^3 involved a trial of the instruments to students within the age range to be involved: 16 to 17 year olds for VOSTS and aged 11 and 16 for AS^3. At this stage certain responses could be changed, ignored or added to as required to the research. Bennett and Hogarth (2009) also assessed content validity at this stage using teacher rankings of each student’s attitude, and compared scores with the student’s actual response in the instrument. An example from the final format for the AS^3 instrument can be seen in table 4.4.

Table 4.4: An example of a disposition statement in the final AS^3 instrument (taken from table 2.6 in Bennett & Hogarth, 2005, p. 20)

B06 I would like a job involving science.					
I agree because…		I neither agree nor disagree because…		I disagree because…	
a	…I enjoy science at school	k	…it depends on what science you would be doing	p	…I find science boring
b	…they are generally well paid			q	…science causes too many problems for the world
c	…science makes the world a better place to live in			r	…they don’t get well paid
d	…there are good jobs you can do with science				
x	… another reason – please say what	y	… another reason – please say what	z	… another reason – please say what

The benefit of the VOSTs and AS^2 approach is how the instrument encapsulates students' attitudes clearer than paragraph responses and Likert scales (Aikenhead & Ryan, 1992; Aikenhead, 1988). The VOSTS approach focuses more attention on the possible explanations rather than just describing, the views of the students' are valued and probed deeper (Lederman et al., 1998). As this theoretical approach is derived from and by the responses by the students themselves, there is a greater degree of validity of the instrument in comparison to other instrument approaches to measuring attitudes (Osborne et al. 2003).

The initial strategy began with extrapolating students' attitudes to practical work, their likes and dislikes before applying the VOSTS and AS^3 instruments theoretical framework to further explore students' attitudes. The initial strategy will now be discussed.

4.4: Initial strategy

The instrument development involved three phases followed by a pilot stage. This initial strategy was seen as a means of progressing from what students thought about practical work, to producing a final questionnaire that could be used in more than one school to further investigate students' attitudes to practical work in biology, chemistry and physics. The research strategy including the pilot stage is summarised in table 4.5.

Table 4.5: Initial strategy to the end of the pilot stage

		Method	**Data**
Instrument Development Stage	Phase One	Questionnaire asking students about their likes and dislikes regarding practical work	60 students: 27 in Year 8 and 33 in Year 9 at School A.
	Phase Two	Open response phase, students respond to 14 statements and provide their reasons	90 students in Year 9 at School L.
	Phase Three	Group interviews to validate results from phase two and probe areas further	Year 9 students from phase two. Six group interviews each with 15 students in School L.
Pilot Stage	Phase One	Trial of the 3 questionnaires. 10 biology, 10 chemistry and 10 physics were completed	30 Students from Year 9, Year 10 and Year 11 in School W.
	Phase Two	Individual interviews followed by two focus groups to validate the findings in phase one and provide feedback on questionnaires	6 students from phase one: 3 from Year 9 and 3 from 10 (Year 11 on study leave), in School W.
	Phase Three	Observation with semi-structured interviews of Year 9 biology practical lesson	22 students from Year 9 at School L.
	Phase Four	Focus Group with Year 9 students after observation in Phase Three	3 boys and 2 girls from Year 9 that had been observed in Phase Three at School L.

Phase one of the instrument development involved asking students in the form of an open response questionnaire into their reasons for liking and disliking practical work in science. It was conducted with Year 9 students in a School A, a selective academy with business and enterprise status in a rural county. From this, along with further literature research and discussions, fourteen statements were decided upon and in phase two of the pre-pilot study Year 9 students from a new school, School L a secondary modern school with specialist science college status within a selective county, were asked to respond to them in an open phase questionnaire. Finally, in phase three of the instrument development, group interviews were conducted with the same Year 9 students used in phase two. This was to collaborate and probe findings further in preparations for the development of the questionnaires.

The pilot study involved the design, development and validation of the final three questionnaires for use in the main study. Phase one of the pilot study involved distribution of the three trial questionnaires (biology, chemistry and physics) in School W, a comprehensive academy with specialist science and technology college status. Phase two involved validating the findings from the questionnaires by conducting interviews with nine students that had completed the questionnaires in phase one. Phase three involves an observation with semi-structured interviews of a Year 9 biology practical lesson in School L and phase four is a focus group with five Year 9 students that were involved in phase three. The instrument development and theoretical framework will now be discussed.

4.5: Instrument development and theoretical framework

The instrument development followed a phenomenological approach in order to best address the research questions. The development of the instrument is led primarily by the voices of the students: the students' comments and opinions.

It was therefore decided the researcher would conduct some pre-pilot investigations into what students liked and dislike about practical work to begin to understand students' current attitudes to it. This phase was similar in the approach taken by Bennett and Hogarth (2009) where they interviewed students as a means of "identification of areas to be explored" (p. 5). From this, the researcher was able to begin to unearth the key areas that were emerging from students regarding their likes and dislikes to practical work. This phase of the procedure correlated to the "composition and peer validation of disposition statements" (Ibid, p. 5) where the areas facilitated the development of disposition statements. In this study fourteen disposition statements were developed and peer validated by Supervisors and three members of the Science Department in School

A. These fourteen disposition statements were then used in phase two of the pre-pilot study. Phase two involved the validation of the disposition statements and the “gathering of free responses to disposition statements” (ibid, p. 5) in this case the fourteen disposition statements that had been peer validated in phase one. Students were invited to respond to the disposition statement with their position (agree, neither agree nor disagree, disagree) and then provide their reason as an open response, for why they held this view. Phase three of the pre-pilot study was added for the researcher to validate the findings from phase two as well as investigate further students’ responses to the disposition statements. From this phase, the questionnaires and the fourteen disposition statements were able to be designed and developed for use in the pilot stage of the study. The pre-pilot stages will now be discussed in more detail.

4.5.1: Phase one

In order to begin to understand students’ attitudes to practical work in school science, it was decided that the researcher would ask students to respond to two questions: firstly, to write three things they like about practical work in science and secondly, to write three things they do not like about practical work in science. The word ‘things’ was used to help responses be as open as possible and keep the format as simple as possible for respondents completing the questionnaire: simplicity in questionnaires that applies to the audience, students in this case, ensures responses are applicable and useable (Cohen et al., 2007).

It was necessary that the researcher conducted this investigation promptly because it would form the basis of the method of data collection later. Therefore, an opportunistic approach was taken for requesting permission from a secondary school. This consequently led to permission being obtained from School A, a selective academy with business and enterprise status, where the science department and more importantly, the head teacher had worked with the researcher previously, thus they allowed access to two science classes involving twenty-seven Year 8 students and thirty-three Year 9 students. At this stage, the researcher was keen to use students to the middle and end of Key stage 3, as findings show that students' attitudes decline slowly from Year 7 to Year 9 (Barmby et al., 2008; George, 2006; Osborne et al., 2003) and thus it was important to obtain responses from students that provided an holistic coverage of their attitudes. Although the school was a selective academy in a rural county it was decided at this stage the need for the data was greater than awaiting permission from a comprehensive school. The researcher distributed the sixty questionnaires to the students, firstly the Year 8 students during their chemistry lesson and then the Year 9 students during their physics lesson. The students were informed on how the information they gave was anonymous and that they were not to write their name on the paper. The importance of the questionnaires as part of the main study into students' attitudes to practical work was also discussed with them.

The common areas that emerged from phase one showed students referring to the 'doing', the 'learning' and the 'preference' domains of practical work. What appeared interesting was how students were able to provide negative responses to practical work and these seemed more. There were a few students that commented with words such as 'fun', 'interesting', 'hands on experience', 'boring', 'dangerous chemicals' and 'wearing safety goggles'. Positive comments veered to practical work as something different in the lesson, a time to visualise what was explained by the teacher and have a go themselves at science whereas, negative comments tended to side on the health and safety issues, such as not liking to wear safety goggles or worrying about using dangerous chemicals in lessons. Although it is important to note that most comments were not restricted to being given as a reason for solely liking or disliking practical work.

The comments that formed the ‘doing’ domain related primarily to the action of the practical work in the lesson, the procedure, and the comments tended to be with regards to observing phenomena, to actual processes of setting up the equipment and obtaining results. Examples of students’ comments that formed the ‘doing’ domain related to the actual process of the practical work in the science lessons, positive comments included; a Year 8 stating ‘you get to see what happens when you mix stuff together’ and a Year 9 explaining ‘we can chat while we are doing the practical’: while negative comments included; a Year 9 explaining ‘If your[sic.] with a boy (or someone you don’t like) they take over and don’t let you do anything’ and a Year 8 explained how it was not enjoyable ‘when you don’t have enough time in the lesson to complete the experiments’.

Comments that formed the ‘learning’ domain were mainly about the visual aid to learning, positive comments included; a Year 8 explained that practical work ‘improves understanding of the subject to show you step by step’ and a Year 9 further explains that ‘it tests what you already know and what you need to learn/work on’: whilst negative comments included; a Year 9 explained how ‘it’s pointless because people have already discovered the things we’re learning and using them in the world now, so why would we need to learn them?’ and this was comparable with a Year 8 who explained ‘I don’t like that sometimes you know what is going to happen so it feels a bit pointless.’

The ‘preference’ domain related to any comments that showed students’ preference for or against practical work and there was clear similarities here to that of Abrahams

(2009) which found students claiming to prefer practical work to other activities in science lessons. Positive examples included; a Year 9 explained ‘I find it easier to learn by visualising something rather than just reading it out of a book or being told something by the teacher’ and a Year 8 encapsulates the point simply saying ‘practical work takes up the whole lesson and you don’t have to do as much listening or writing!’ Whereas, negative examples included; a Year 9 explains how ‘we have to write up the results [from the practical], which is more writing than normal’ and a Year 8 explained simply ‘I dislike practical lessons because I like writing.’

The responses in phase one of the pre-pilot study, when categorised as above, were then used along with discussions with supervisors, peers and three members of the science department at School A to produce fourteen disposition statements that would then be used in the open response questionnaires in phase two of the pre-pilot study. This method showed similarity with stage two of Bennett and Hogarth (2009) where their statements were categorised, developed and validated with teachers and researchers. These fourteen statements are explained further in phase two of the pre-pilot study.

4.5.2: Phase two

In phase two of the pre-pilot study, the aim was to collect open responses to the fourteen disposition statements that would then be validated and used to develop the questionnaires for the pilot study. This approach was similar to stage three of the procedure by Bennett and Hogarth (2005) involving students responding to the statements on a Likert–type scale and then explaining their view. The open responses in phase two formed the level 2 fixed responses in the questionnaires that would, eventually, be the options for selection by students in the pilot study as best suiting their reason for responding to the disposition statement with their level 1 response of either agree, neither agree nor disagree or disagree. The fourteen statements used for the open response in phase two are shown in table 4.6.

Table 4.6: Fourteen disposition statements used in phase two of the pre-pilot stage

Item Number	Disposition Statement
1	I enjoy doing practical work in *biology/chemistry/physics* lessons
2	I am able to learn from practical work in *biology/chemistry/physics* lessons
3	I prefer practical work to non-practical work in *biology/chemistry/physics* lessons
4	Doing practical work is my favourite part of *biology/chemistry/physics* lessons
5	Practical work helps me understand *biology/chemistry/physics*
6	I find practical work in *biology/chemistry/physics* easy
7	What I do in *biology/chemistry/physics* practical work will be useful when I leave school
8	What I learn from *biology/chemistry/physics* practical work is always useful for when I leave school
9	I find practical work a way of seeing how *biologists/chemists/physicists* work in the real world
10	I think we should do more practical work in *biology/chemistry/physics* lessons
11	For me to learn in *biology/chemistry/physics* lessons, I need to do practical work
12	I prefer the freedom I have during practical work in *biology/chemistry/physics* lessons
13	My school science environment makes doing practical work difficult in my *biology/chemistry/physics* lessons
14	I do not find practical work helps my learning in *biology/chemistry/physics*

As can be seen in table 4.6 the disposition statements included biology, chemistry and physics separately rather than using the generic term science. It was decided that in order for the responses given by the students to be specific, the disposition statements would be best formatted to keep the sciences separate from one another. Indeed, in phase one of the pre-pilot stage there had been a number of comments for example, referring to the use of chemicals in chemistry. Therefore, from this phase onwards the disposition statements were the same but specific to biology, chemistry and physics. This in effect replicated the fourteen disposition statements; fourteen for biology, the same fourteen but with regards to chemistry and fourteen in regards to physics. The layout of the open response questionnaire was the same for biology, chemistry and physics with the exception of two format changes. Firstly the change of science subject for each questionnaire and secondly the colour of paper the questionnaires were printed. It was decided for this phase coloured paper would be used to keep the science separate and to observe the change this may have on the students when completing them: chemistry was printed on green paper, physics on purple and biology on pink. An example of disposition statement one as laid out in the biology questionnaire can be seen in table 4.7.

Table 4.7: Biology questionnaire used in the open response phase two of the pre-pilot stage

1. I enjoy doing practical work in Biology lessons

Please tick one choice from below:

	I agree
	I neither agree nor disagree
	I disagree

Please explain your answer:

It was decided that 30 students would complete seven of the fourteen statements for biology, for chemistry and for physics. Therefore 15 students would respond to disposition statements one to seven and another 15 students would respond to disposition statements eight to fourteen; this was seen as a sufficient number or responses to obtain theoretical saturation for the any appearing categories (Aikenhead & Ryan, 1989; Bowen, 2008). It was decided that the students should be in Year 9 or Year 10 because this is towards the end of the important years when students are forming their attitudes and decisions primarily for General Certificate of Secondary Education (GCSE) (Barmby et al. 2008). Furthermore, where possible it was decided that the students would complete the appropriate questionnaire for the lesson which they were studying at the time of data collection; thus a student in a biology lesson would complete the biology open response questionnaire.

The approach taken for choosing the school was opportunistic although it was decided that the school used for this pre-pilot phase would be a school that was a typical secondary school. At the time of data collection, permission was granted from one school, School L, a secondary modern school with specialist science college status within a selective rural county. School L allowed for the researcher to have access to ninety Year 9 students during one period where all Year 9 students were in science lessons: thirty students were in a biology lesson, thirty in a chemistry lesson and thirty in a physics lesson. A stratified random sample was used when distributing the open response phase questionnaires; this meant within the categories of biology, chemistry and physics there was a mix of randomly selecting any Year 9 student (Cohen et al. 2007). The open response phase questionnaires were distributed by the researcher and the students were informed of how important it was that they gave their own opinion in response to the statement and the role of the questionnaires as part of the main study, and the development of an attitude questionnaire into students' attitudes to practical work. All students were informed that the information they gave was anonymous and thus they were not to indicate their name anywhere on the paper.

Once all open response questionnaires were completed, the researcher avoiding censoring the responses at this pre-pilot stage; instead the responses were grouped according to which responses were similar or different between biology, chemistry and physics in respect to each disposition statement. These responses given in this open phase would become the fixed responses to be used in the pilot study. From looking for common responses to each of the fourteen disposition statements, it became possible to group between two and seven possible responses for each agree, neither agree nor disagree and disagree option for each disposition statement. An important point here is that the responses were kept as close as possible to students' words in order to ensure that the final questionnaires were drawing on students' words directly as seen the VOSTS approach (Lederman et al., 1998).

From analysis of the responses at the phase two, it appeared that there were a number of disposition statements that required further investigation because there were limited options for the 'agree' or 'disagree' for some of the statements. Table 4.8 shows the disposition statements for each science subject that requires further probing of students to ask why there were limited responses. All disposition statements have been included to show which statements were completed by this phase of the pre-pilot study.

Table 4.8: Disposition statements and required sections that are lacking and thus need further investigation

Disposition Statements	Biology:	Chemistry:	Physics:
1. I enjoy doing practical work in *biology/chemistry/physics* lessons	*Complete*	Disagree	Disagree
2. I am able to learn from practical work in *biology/chemistry/physics* lessons	Disagree lacking across all three		
3. I prefer practical work to non-practical work in *biology/chemistry/physics* lessons	Disagree lacking across all three		
4. Doing practical work is my favourite part of *biology/chemistry/physics* lessons	Disagree lacking across all three		
5. Practical work helps me understand *biology/chemistry/physics*	Disagree lacking across all three		
6. I find practical work in *biology/chemistry/physics* easy	Disagree	Disagree	Agree and Disagree
7. What I do in *biology/chemistry/physics* practical work will be useful when I leave school	*Complete*	*Complete*	Disagree
8. What I learn from *biology/chemistry/physics* practical work is always useful for when I leave school	*Complete*	*Complete*	*Complete*
9. I find practical work a way of seeing how *biologists/chemists/physicists* work in the real world	Disagree	Disagree	*Complete*
10. I think we should do more practical work in *biology/chemistry/physics* lessons	Disagree	Disagree	*Complete*
11. For me to learn in *biology/chemistry /physics* lessons, I need to do practical work	Disagree	*Complete*	*Complete*
12. I prefer the freedom I have during practical work in *biology/chemistry/physics* lessons	Disagree	Disagree	*Complete*
13. My school science environment makes doing practical work difficult in my *biology/chemistry/physics* lessons	*Complete*	*Complete*	*Complete*
14. I do not find practical work helps my learning in *biology/chemistry/physics*	*Complete*	*Complete*	Agree

What table 4.8 shows is how students seemed to agree with the statements although, it is interesting to note how disposition statement 6 in physics, I find practical work in *physics* easy, lacked any agree responses unlike biology and chemistry. However, it was decided that the understanding of the disposition statement here was quite misleading, as it was unclear as to whether the students were accepting the disposition statement because they felt that in terms of *doing* practical work it was *easy* in physics or that the *understanding* of practical work in physics was *easy*. This issue along, with a lack of disagree responses to the other disposition statements, was addressed in phase three of the pre-pilot stage. It was decided that the researcher needed to probe the students' attitudes further into those disposition statements in order to validate that these options were not rejected for null reasons. In order to accommodate for this, phase three of the pre-pilot was required before completion of the pilot study questionnaires. This involved interviews with the same ninety students but in six groups of fifteen Year 9 students, this is now discussed.

4.5.3: Phase three

In phase three of the pre-pilot study, the researcher conducted six grouped interviews each involving fifteen Year 9 students; all ninety Year 9 students had been involved in phase two of the pre-pilot study. The interviews were semi-structured as the researcher needed to probe into the students' responses in the open phase and ask why certain disposition statements had not been responded accordingly, as seen in table 4.8. The interviews were not recorded for one main reason; there was not enough time to collect permission to allow for the recording. The turnaround time between conducting the open responses in phase two and further probing the students in phase three needed to be brief as students in Year 9 were at the stage where they were exposed to many influences beyond the scope of the study that could alter their attitudes (Osborne et al., 2003); thus the more time left between phases, the likelihood that their attitudes and hence responses would differ greatly between the two phases (Oppenheim, 2000). The researcher recorded their comments and offered groups of students to write their own responses to the disposition statements that had shown a lack of responses. Students were informed that all responses were anonymous and how their responses were being used in regards to the main study.

From the group interviews and further discussions with supervisors, a number of changes were made to the statements and responses for the questionnaires. The overall responses provided during the group interviews showed there was clear agreement with how the students had previously responded during phase two. Also, at this phase there was ample evidence to suggest that how students responded to biology, chemistry or physics differed enough to warrant that there should be three questionnaires used for the pilot stage – biology, chemistry and physics questionnaire. The wording of the disposition statements was another key area that required clarification before progression to the pilot stage. This was apparent with disposition statement 6, *I find practical work in biology/chemistry/physics easy,* which had been highlighted as an issue in phase two of the pre-pilot study. It was decided that this statement would be changed to *I find practical work in biology/chemistry/physics easy to do.* This change tried to address any future confusions arising from what the disposition statement was referring to, the doing of the practical work and not the understanding of the practical work. The responses given for why a student may agree, neither agree nor disagree or disagree with the new disposition statement were also discussed in the group interviews and thus changed accordingly to fit.

Through the group interviews with the students it became clear that disposition statement 13, *my school science environment makes doing practical work difficult in my biology/chemistry/physics lessons* and disposition statement 14, *I do not find practical work helps my learning in biology/chemistry/physics* , needed revising. Firstly, because they were currently both negative statements, some students became confused with how to respond to them confidently and secondly, as the other statements were all positive, it was decided to change the disposition statements to the positive type. This turned disposition statement 13 to *my school science environment makes doing practical work easy in my biology/chemistry/physics lessons* and disposition statement 14 changed to *I do find practical work helps my learning in biology/chemistry/physics. C*hanging the statements meant that that reasons provided for agree, neither agree nor disagree and disagree needed validation with students and were correct to meet the new disposition statements accordingly.

Once the disposition statements with their responses were validated and developed, the final three questionnaires were designed for the pilot study. The open responses that had been provided as reasons for agree, neither agree nor disagree and disagree, then became the fixed responses for the pilot study questionnaires. The fixed responses for each questionnaire involved two to six options that were common to all three questionnaires. It is important to note here that the common responses were found from the open response phase and, in order to accommodate for the few responses that were subject specific, they were included individually on those specific subject instruments. Additional responses that were added to the questionnaires can be seen in table 4.9.

Table 4.9: Additional subject specific responses for each questionnaire

	Disposition Statement	Additional Level 2 responses
Biology	9. I find practical work a way of seeing how Biologists work in the real world	**Agree:** I get the understanding of the animal and the human body
Chemistry	1. I enjoy doing practical work in Chemistry lessons	**Disagree:** I am always scared of the safety aspects when using chemicals
	5. Practical work helps me understand Chemistry	**Disagree:** I do not understand chemistry practicals because the results do not always appear
	6. I find practical work in Chemistry easy	**Neither agree nor disagree:** I am good at Bunsen Burners but I am not good at pouring chemicals as I often spill them
	8. What I learn from Chemistry practical work is always useful for when I leave school	**Neither agree nor disagree:** I think it depends what I want to do with my life, if I want to be a doctor then it would help but I am not sure what else it would help **Disagree:** There are not many jobs that involve burning stuff or mixing hazardous chemicals
	11. For me to learn in Chemistry lessons, I need to do practical work	**Neither agree nor disagree:** I learn a lot from my written work but remember specific things, e.g. names of elements, when doing practical work
	12. I prefer the freedom I have during practical work in Chemistry lessons	**Disagree:** Practicals in chemistry are too dangerous for me to be given freedom
	13. My school science environment makes doing practical work difficult in my Chemistry lessons	**Neither agree nor disagree:** There is enough space but sometimes there are too many people in one area to get an ingredient and end up knocking each other
	14. I do find practical work helps my learning in Chemistry	**Agree:** It helps a lot to discover and make new substances **Agree:** Practical work and written work for me are best ways to learn as I can remember facts and look back in my book, but in practicals I can remember the chemicals and elements and what they make **Disagree:** I need the theory to learn chemistry, like balancing chemical equations
Physics	7. What I do in Physics practical work will be useful when I leave school	**Disagree:** Most jobs do not involve physics
	8. What I learn from Physics practical work is always useful for when I leave school	**Disagree:** In life people do not come across that many everyday situation where physics practical is needed

These additional responses were added to the respective main questionnaire that incorporated the responses that were common to all three questionnaires. The pilot study involved the final designing, trial and validation of the three questionnaires.

4.6: The pilot study

Once the pre-pilot stage was completed the draft of the three questionnaires for biology, chemistry and physics, could be trialled in a secondary school. It was decided that the questionnaires would continue to separate the three science subjects since there had shown some responses in the open-phase stage of the pre-pilot study that were subject specific and the pilot study would serve to confirm this further prior to the main study.

It was decided that the pilot study of the questionnaires would be within one comprehensive secondary school, this was School W. This school had *not* been previously used for the any of the study until now for the pilot study. There were three key reasons for this: firstly it tested the accessibility of the overall design of the questionnaires with a different group of students in another school; secondly to gauge the length of time required for students to complete the questionnaires; and thirdly to validate the responses to ensure they met with all possible reasons in reference to the fourteen disposition statements that were developed by students in School L. Additionally, the pilot study enabled validation of the questionnaires as a means of collecting students' attitudes to practical work in all three sciences, this became phase two of the pilot stage and involved a focus group with students.

4.6.1: Phase one: Trial of the questionnaires

Phase one of the pilot study was conducted in School W. School W is an urban comprehensive academy with a specialist science and technology college status and around 1400 students from age eleven to eighteen on roll: it is in the same Education Authority as School A and School L used previously. The science department at School W were willing to assist in the study and the Head teacher allowed student involvement providing those students, who were to be involved, had parental consent in the form of a letter that was to be returned to, and kept by, the school. The researcher decided that 30 students would be sufficient to meet the aims of the pilot study and would enable ten questionnaires of each science subject to be completed. Therefore, once 30 students had consent the researcher was invited to the school during one full day in April to collect the data from the students. The 30 students involved included: 6 students (4 male, 2 female) from Year 9, 12 students (8 male and 4 female) from Year 10 and 12 students (7 male and 5 female) from Year 11. Table 4.10 shows the distribution of the three questionnaires at School W.

Table 4.10: Distribution of the pilot study questionnaires by each science subject

		Biology Questionnaire	**Chemistry Questionnaire**	**Physics Questionnaire**
Year 9	**Male**	0	2	2
	Female	2	0	0
Year 10	**Male**	3	4	1
	Female	1	0	3
Year 11	**Male**	0	3	4
	Female	4	1	0
Total number:		**10**	**10**	**10**

The layout of the questionnaires involved two levels of responses from students to fourteen statements. The fourteen statements that were included in the pilot study are seen in table 4.11 and the statements were changed accordingly to fit the subject specific questionnaires: biology, chemistry and physics. The students were asked to read the disposition statement then select whether they agree, neither agree nor disagree or disagree with the statement; this became their level one response. The level two responses involved the students choosing as many of the fixed responses that matched their reasons for their choice of level one response, and to circle the appropriate letter preceding the response.

Table 4.11: Disposition statements used in the pilot questionnaires

1. I enjoy doing practical work in *biology/chemistry/physics* lessons
2. I am able to learn from practical work in *biology/chemistry/physics* lessons
3. I prefer practical work to non-practical work in *biology/chemistry/physics* lessons
4. Doing practical work is my favourite part of *biology/chemistry/physics* lessons
5. Practical work helps me understand *biology/chemistry/physics*
6. I find practical work in *biology/chemistry/physics* easy to do
7. What I do in *biology/chemistry/physics* practical work will be useful when I leave school
8. What I learn from *biology/chemistry/physics* practical work is always useful when I leave school
9. I find practical work a way of seeing how *biologists/chemists/physicists* work in the real world
10. I think we should do more practical work in *biology/chemistry/physics* lessons
11. For me to learn in *biology/chemistry/physics* lessons, I need to do practical work
12. I prefer the freedom I have during practical work in *biology/chemistry/physics* lessons
13. My school science environment makes doing practical work easy in my *biology/chemistry/physics* lessons
14. I do find practical work helps my learning in *biology/chemistry/physics*

Table 4.12 shows two examples, firstly the front instruction page and secondly, the layout of disposition statement 6 for the biology questionnaire as distributed to students in the pilot study. The layout of the entire pilot study for biology, chemistry and physics questionnaires can be seen in Appendix 1, 2 and 3 respectively.

Table 4.12: Front instruction page and layout of disposition statement 6 in biology questionnaire

Student questionnaire: Your views on practical work in biology

This questionnaire is looking into **your** views on practical work within **biology**.

Completing the questionnaire:

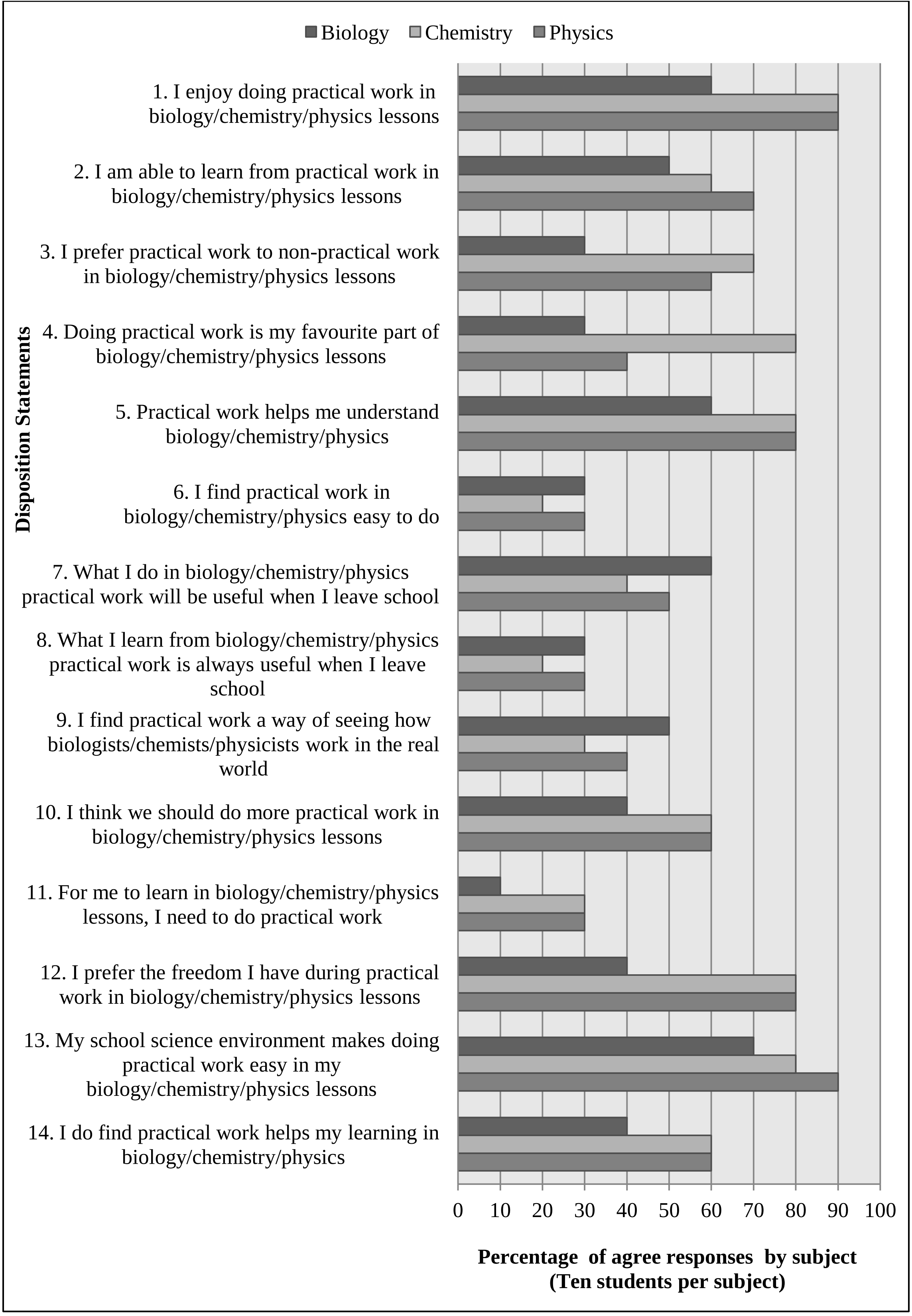
The questionnaire involves **fourteen** statements.
You need to read the statement and decide if you:
Agree with the statement
N**either agree nor disagree** with the statement
Disagree with the statement
Then circle the letter next to the reason, or reasons, which best fits **your own** view.
Do feel free to add **your own** reasons in response to the statements if you feel there is no reason that matches your own view.
Your responses are anonymous, so **do not** write your name anywhere on the questionnaire.
Firstly, please circle your gender and year group:
I am: **Male** **Female**
I am in: **Year 9** **Year 10** **Year 11**
Now continue to complete **the entire** questionnaire.

Thank you for all your help with this research

6. I find practical work in Biology easy to do					
I agree because		I neither agree nor disagree because		I disagree because	
a	It is always easier than copying out of a book	h	Some of the things I do in biology is easy but some of it can be hard	n	It always takes a long time to set the practical up and put away
b	The teacher tells me everything I need to do and I just do it	i	I still have to memorise what I am learning but I find it more fun	o	I struggle to understand what to do
c	I can work with a partner so I share the work	j	Most is easy but when I am learning a new skill it becomes difficult	p	It confuses my original thoughts
d	It does not matter if I do not see the results so I do not need to focus as much	k	The written and practical work is the same really	q	There are far too many safety issues to remember during the practical
				r	I do not do enough for it to be easy
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

The pilot of the three questionnaires proved to be a very useful tool for beginning to understand what the data for the main study might show. As Cargan (2007) explains a pilot study is a good means of ensuring that the questionnaires will provide data that is accurate and is standardised as well as guaranteeing successful administration in the main study. Indeed, from the data there was a forming trend towards more '*agree'* responses for disposition statements in physics than there were for biology, with chemistry fluctuating between the two; of the fourteen statements, physics responses were more positive than, or equal to, those responses for biology 85 percent of the time. The number of times a student agreed with each disposition statement in biology or chemistry or physics can be seen in table 4.13. There was evidence of a clear drop in *agree* responses (below 50 percent) for statement 6, *I find practical work in biology/chemistry/physics easy to do;* statement 8, *what I learn from biology/chemistry/physics practical work is always useful when I leave school;* and statement 11, *for me to learn in biology/chemistry/physics lessons, I need to do practical work.*

Table 4.13: Percentage of *agree* responses for biology, chemistry and physics questionnaires



With regard to the level two responses, the option of ‘another reason - please explain’ had been included to ensure that the fixed responses had encapsulated all the possible reasons in response to each given statement. In the pilot study, the results showed that during 94% of the time for biology the fixed responses were effective in explaining students’ reasons and this was also true of physics, and although chemistry was slightly lower, with 89% of the time fixed responses being used. However, it was agreed with supervisors that the three questionnaires had been effective in encompassing all the variety of possible reasons to the given statements. Thus the questionnaires were found to be a valid measure of their responses. Therefore, the use of the ‘another reason – please explain’ option was to be retained in the main study, in order to ensure that students’ responses were *true* of their attitudes in response to the given statements. These pilot findings began to show some interesting areas for the main study; two fundamental conclusions were drawn, firstly, that there was enough disparity between the responses for the disposition statements in the biology, chemistry and physics questionnaires. Secondly, that the questionnaires would continue to be kept separate for the main study and secondly, the option of ‘another reason – please explain’ would remain an option in all three questionnaires. Also, the findings from the pilot study influenced the direction of the research questions and this is discussed later.

The pilot of the questionnaires also showed that students were able to complete a questionnaire within ten to twenty minutes. So it was decided the length of all three questionnaires were sufficient for effective administration in the main study. Furthermore, for the main study it was essential in understanding students’ reasons that the option of choosing only one level two response should be implemented; rather than choosing all the level two responses the student may agree with as in the pilot study that was merely to endorse the options of fixed responses, they would instead in the main study choose the key reason for their level one response to the given statement. In order to validate that the responses given in the questionnaires were accurate, the pilot study required an additional phase, phase two, which will now be discussed.

4.6.2: Phase two: Validation of the questionnaires

By piloting the three questionnaires there were two key aims, firstly to ensure it suitably probed into students attitudes as seen in phase one and secondly to validate the questionnaires; this is phase two. In order to validate the questionnaires it was decided that individual interviews followed by focus groups would be the best way to proceed. This would ensure that the way students had responded in the questionnaires was a true likeness of their verbal responses; thus ensuring the validity of the questionnaires to probe their attitudes. Furthermore, the focus group would provide the opportunity for student feedback on the aesthetics and layout of the questionnaires.

School W allowed the researcher access to six students that had previously taken part in phase one of the pilot study. There were three Year 9 students and three Year 10 students, the Year 11s at the time were on study leave and the validation process took place one month after phase one of the pilot study. Individual interviews with all six students were conducted before the two focus groups each involving 3 students in the same year group. The students would be asked to respond to verbal questions that were derived from the disposition statements given in the three questionnaires and whichever questionnaire the student had previously answered, the interview would focus on that questionnaire; for example if a student had previously completed the biology questionnaire, the interview involved the disposition statements with regards to biology and not physics or chemistry. The responses were then compared with those that the students gave in their respective questionnaires.

Analysis of the verbal responses given in the interviews with the written responses in the questionnaires showed clear evidence that the responses provided matched in relation to the fourteen disposition statements for biology, chemistry and physics. Indeed, there were only 2% discrepancies for Year 10 and 7% for Year 9 where their responses were contradicting extremes (i.e. Gave agree response in the questionnaire and then disagree in individual interview). Through discussion during supervision meetings it was decided that the slight differences could be accounted for and that the percentage of concordance between the responses given in the questionnaires and the responses in the interviews was acceptable. Thus there was ample evidence to ensure validity of all three questionnaires (biology, chemistry and physics).

During the focus group discussions it was evident that the students felt there was some discrepancies with how to circle the level one response of agree, neither agree nor disagree and disagree effectively. The suggestion was made that a square tick box be placed at the side of each level one response (I agree, I neither agree nor disagree and I disagree) to enable clarity over the student's decision. Furthermore, the students thought an example on the instructions page would ensure simplicity in effectively completing any one of the three questionnaires. This approach of taking suggestions directly from the students about the layout of the questionnaires was similar to Aikenhead and Ryan (1992).

Further to the validation in School W, the researcher, having completed the changes suggested in the validation phase, decided that it would be necessary to obtain validation of the instructions and general layout of the final questionnaires prior to the main study. This took place on two separate occasions at the two schools that had previously participated in the pre-pilot study; School A and School L. Two members of the science staff and four Year 8 students from School A were asked to establish whether the instructions and layout of the questionnaires were understandable and fully comprehensible. They agreed that the layout worked effectively and that there was ease of completion. This was further endorsed by School L where two members of the science staff and four Year 9 students who had also previously been involved in the study, were able to confirm that the questionnaires were clear and straightforward to complete.

4.6.3: Phase three: Observation with semi-structured interviews

Alongside the questionnaires, a pilot observation with semi-structured interviews was conducted in School L during the summer term after distribution of the pilot questionnaires. The choice of school, School L, was decided due to convenience and thus the year group and science lesson observed was opportunistic according to what was accessible at the time in the school. Consequently, the observation involved a Year 9 class of 22 students of a biology lesson looking into the prevention and control of infection. Students had to design an experiment to test the effectiveness of hand wash and they worked in their chosen pairs. They had to divide an agar plate into four sections, labelled D1, D2, W1 and W2. One student in the pair placed three fingers un-washed into D1, the second student on D2. They then washed their hands with a hand wash and placed three fingers onto W1 and W2. The results would be discussed in a follow up lesson. During the observation of the practical lesson, students were asked what they were doing and what their thoughts were of it.

From the pilot observation with semi-structured interviews, it was decided that for the main study two areas would be addressed. Firstly, the observation would be audio-recorded to enable exact phrases said by the students to be used for analysis and permission would be granted from the schools to do this. Also, three key questions would be used in each of the three main study observations to ensure continuity of questions rather than just un-structured conversation which did lead to deviation away from the main focus of the study.

4.6.4: Phase four: Focus group with students

The focus group involved five students, two females and three males, selected by the teacher and it followed the observed practical work lesson in School L. The main aim of the focus group was to trial the method for use in the main study, where it would be used to probe deeper into students' comments about practical work. During the focus group, students were asked to openly talk about practical work. There were a number of issues with this, such as students deviating from the topic or not sure what to say. So, during the pilot a trial questions were asked to the students to initiate discussion by the students, such as tell me you thoughts on practical work.

From the pilot focus group, there were a few areas that would be adapted to further benefit the strategy in the main study. Firstly, there would be four students involved, two girls and two boys selected by the teacher and demonstrating a mixture of ability. This meant that the students involved would all have an equal opportunity to talk whilst still providing the opportunity for a group discussion. Secondly, due to the difficulties with students focussing on the discussion, five stimulus statements and three questions would be used to ensure continuity between the three schools as well as initiating discussion during the focus groups. Thirdly, in order to concentrate the focus groups on biology, chemistry or physics practical work, it was decided to ensure the focus group followed the respective observed lesson. So an observed biology practical would mean the focus group was also based on biology practical work. Finally, it was decided that the focus group would be audio-recorded and that permission would be granted from the three schools to do this. This would enable effective exact recording of what students said and the way they said it.

4.7: Emergent issues

The pre-pilot and pilot study process had an influential effect on the study's research questions and the intended research strategy that would be established for the main study.

The findings from the pilot study also highlighted areas where the questionnaires could be improved and modified to further benefit the main study. From the distribution and collection of the questionnaires, along with discussions during the focus group, a number of changes were decided. Firstly, the three questionnaires would remain so, whereby biology, chemistry and physics would remain separate rather than one questionnaire combining all three sciences; there was adequate evidence to suggest that students were able to differentiate between the sciences, and that there were differences emerging from the way they responded to each science questionnaire. Second, for each questionnaire a cover sheet with instructions, including a worked example, would be provided; this enabled collection of each student's gender and year group that were involved as well as attempting to reduce the number of questionnaires that would be rejected through incompleteness or errors in completion. This issue also followed the methodology on the work on VOSTS (Aikenhead & Ryan, 1989) and the AS^3 instrument (Bennett & Hogarth, 2005).

Furthermore, with regard to the contents of the questionnaires, it was clear from the validation process that a tick box would be added next to 'I agree', 'I neither agree nor disagree' and 'I disagree' for clarity over the chosen response by the student towards to each statement. Again, this would attempt to reduce the number of questionnaires that would be rejected for incoherent responses. In order to engage fully with a student's attitude, the number of level two responses from the list under the level one response (agree, neither agree nor disagree, or disagree) that students were able to select was decided to be limited to one for the main study. This was in contrast to that of the pilot study and the reason for this was to aid analysis by highlighting the main reason for students' disposition. Whilst students may wish to make more than one choice, it has been reported by Aikenhead and Ryan (1992) that requesting one choice did not "increase the ambiguity of a student's response" (p. 488), students were able to justify their level 1 response with just one level 2 response. An example of the cover instructions and disposition statement 1 as laid out in the chemistry questionnaire, is seen in table 4.14

Table 4.14: An example of the cover instructions and disposition statement 1 in the chemistry questionnaire.

Student questionnaire: Your views on practical work in chemistry

This questionnaire is looking into **your** views on practical work in **your** chemistry lessons.

The questionnaire involves **14 statements.**

Your responses are anonymous, so **do not write your name** anywhere on the questionnaire.

What you need to do to complete the questionnaire:

1. Read the statement.
2. Decide if you **agree** or **neither agree nor disagree** or **disagree** with the statement and **tick the one square box** which **you** agree with.
3. Then **circle ONE letter** underneath **your ticked square box** which shows your **MAIN** reason for your position towards the statement.
4. If you do not agree with any of the reasons given, do write your own reason in the 'another reason' box in that same section.

Example:

EXAMPLE: I love practical work in chemistry lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☑	
a	It is fun	h	I like practical and non-practical	[✓ n]	I hate it
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Firstly, please circle your gender and year group:

I am: **Male** **Female**

I am in: **Year 7** **Year 8** **Year 9** **Year 10**

Now continue to complete the entire questionnaire and thank you for your help with this research.

Table 4.14 cont'd: An example of the cover instructions and disposition statement 1 in the chemistry questionnaire.

1. I enjoy doing practical work in chemistry lessons					
I agree because		I neither agree nor disagree because		I disagree because	
a	I like working and talking with friends sharing answers, rather than writing	h	Some chemistry topics I like, some I do not	n	It takes times to pack away and carry on with the lesson
b	I learn from doing it, not just writing	i	I have not done a practical in a chemistry lesson	o	It can be difficult to do and understand the practical work
c	I get to investigate different things and explore with different experiments	j	I do not enjoy anything about chemistry because I have never been good at it	p	I have to complete follow up written work, like graphs of the results
d	It is a good time to take control of my learning	k	It is not something I look forward to unless I have not done one for a while	q	It is difficult to do the work in groups or with people I do not like as they mess around or distract me from the practical work
e	It is not something I do everyday	l	I prefer chemistry more to biology or physics but I do find it quite boring because some of it I do not understand	r	I get limited to the safe things I can do, so most of the practicals are the same
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

The final three questionnaires (biology, chemistry and physics) that were used for the main study can be seen in Appendix 4, 5 and 6 respectively.

4.8: The modified research questions

The initial questions that were taken in light of the review of the literature had been:

1. What are students' attitudes to school science practical work?
2. What are the effects of schools science practical work on students' motivation and interest?
3. To what extent are students' attitudes to school science practical work indicative of their attitudes to school science?

With regard to question 2, the pre-pilot and the pilot study had shown that this would be hard to measure or effectively observe. The question arose as to how the nature of these *effects* would best be observed; be that by the researcher, reported by the students or teachers of the students. Indeed, how effectively the measurement of a students' motivation could be researched using the questionnaires or focus groups was problematic.

The pre-pilot and pilot study had shown that question 3 did not seem to be feasible within the constraints of the study. The pilot study involved research of students' attitudes to *practical work* in the three sciences and *not* data collection of generic students' attitudes to school science. The pilot data had also shown clear evidence to suggest that students' attitude to practical work differs between the sciences and that these differences had started to show that further research could be substantiated. Indeed, the responses to the statements in the chemistry questionnaire were different to those given in the physics questionnaire and more specifically as seen in the pilot study the agree responses for the physics questionnaire had shown variations to those in the biology questionnaire. Also, as these questionnaires during the pilot study had separated the statements between biology, chemistry and physics, it was felt that the research questions would be refined to take account of these preliminary findings. This would then be beneficial in researching students' attitudes to practical work and in particular exploring the responses between biology, chemistry and physics. Therefore, it was decided to modify the second research question to better reflect the data and findings to date. Further to this, because the distribution involves four different year groups, an additional research question was added that reflected the findings as well as the potential findings that could be analysed.

By analysis of the findings from the pre-pilot and pilot stages the final research questions were developed and decided as:

1. What are secondary school students' attitudes to practical work in science lessons?
2. To what extent, if at all, do students' attitudes to practical work differ across the three sciences?
3. To what extent, if at all, do students' attitudes to practical work in the three sciences differ within each year group?

The table 4.15 shows how each research question will be addressed by the source of data.

Table 4.15: Research questions and data sources to help answer them

Research question	Source of data to help answer the research question
1. What are secondary school students' attitudes to practical work in science lessons?	1. *Questionnaires* – These would provide students' written responses to statements regarding their own attitudes. 2. *Observations with semi-structured interviews* – These would show the overt behaviour of students' attitudes towards practical work in a practical work lesson. 3. *Focus groups* – These would provide students' verbal statements of how they perceive their attitudes after being observed in a practical lesson. All three methods here would show how students respond to statements about practical work, what they seem to express and how they act in response to the practical work.
2. To what extent, if at all, do students' attitudes to practical work differ across the three sciences?	1. *Questionnaires* – How the responses given by the students differ in the biology, chemistry and physics across all year groups. 2. *Observations with semi-structured interviews* – How students react during the three practical work lessons in biology, chemistry and physics. 3. *Focus groups* – Direct responses to questions relating to each science.
3. To what extent, if at all, do students' attitudes to practical work in the three sciences differ within each year group?	1. *Questionnaires* – How the responses given by the students differ in a year group to biology, chemistry and physics. 2. *Observations with semi-structured interviews* – How students react during the three practical work lessons in biology, chemistry and physics. 3. *Focus groups* – Direct responses to questions relating to each science in the year group.

From the pre-pilot and pilot stage, the research strategy was developed and further improved to benefit answering the above research questions in the main study.

4.9: The modified research strategy for the main study

From the design of the three questionnaires at the pre-pilot stage to the development and validation at the pilot stage, it was decided that the questionnaires were at the position to be used and distributed for the main study.

For the main study, as with the pilot study, the questionnaires were distributed by the researcher during the related science subject: the biology questionnaire was administered to students during their biology lesson, the chemistry questionnaire during chemistry lessons and physics questionnaire during physics lessons. By administrating them in such a way meant that for all three schools, there were no further disruptions or complications to the students or the school as well as ensuring consistency of procedure. The students involved were informed about the purpose of the data collection and the procedure was explicitly explained. Also, students were especially warned that there were no correct answers and that they were to select the option that best reflected their own opinion not that of a friend or the expectations of their teachers. This was further enhanced from the knowledge that the questionnaires were all completely anonymous.

Furthermore, since triangulation is concerned with “the correctness of the insight and legitimacy of the interpretation” (Newby, 2010, p. 128) and using a variety of methodological approaches can increase the “credibility” of the study (Lichtman, 2010, p. 229), it was decided to conduct observations with semi-structured interviews and focus groups in conjunction with the distribution of questionnaires. The main study involved the researcher observing, with semi-structured interviews, one practical lesson in each of the three schools followed by a focus group with four students that were observed in the practical lesson. The use of the observations with semi-structured interviews and focus groups would then enable the researcher to meet two key aims; firstly to validate the findings presented in the questionnaires and secondly to probe deeper into areas that were highlighted from the questionnaire data with regards to students attitudes to practical work in biology, chemistry and physics.

4.10: School selection

An important consideration in deciding the schools to be selected for inclusion in the main study was, to ensure that they were ‘typical’ representatives of schools in England. What is meant here by ‘typical’ is best described in terms of the size, geographical location and nature of the school, that being comprehensive in nature. This meant schools that would not be classed as typical, such as selective schools – grammar schools, or independent schools, were to be avoided. Due to the majority of students in England being taught in comprehensive schools, it would be beneficial to the study to utilise them as far as possible in order to be able to make generalisations that could be applicable to the majority of students in comprehensive schools throughout England.

The majority of issues with selection of schools fell to access and the ever growing security within schools. However, as the researcher held a Criminal Records Bureau (CRB) Check, the issue became more to do with teacher availability and the organisation of times to visit students. A convenience or opportunistic sampling approach was undertaken whereby schools were chosen through acquaintance with Heads of Science departments at the schools. This led to a relatively open selection of schools across three different counties and educational authorities that were known to the researcher. It was then decided that the three schools to be chosen would be broadly representative of comprehensive schools in England in terms of their size and geographical setting where possible. Even though convenience sampling enables easier access to schools, in practice issues regarding external validity when interpreting the findings and making generalisations can mean very low population and ecological validity (Cohen et al. 2007), however the aim of school selection was more with reference to ensuring a “naturalistic coverage” (Ball, 1984, p. 75) of schools that represented the vast majority of schools in England than for meeting the statistical sampling approach in such methods. The schools were approached verbally over the telephone and then later confirmed via email including allowing permission of access into their schools. The three schools that allowed access and agreed to participate in the main study were School L, School Y and School N.

School L is a rural secondary modern school with specialist science college status within a selective county. The school has around 600 students on roll from age eleven to sixteen all of mixed ability. Even though School L had taken part in phase two and phase three of the pre-pilot stage, the students had not taken part in the stages involving the constructed questionnaires and therefore, they would not be replicated in the data collection. The science department follows the National Curriculum throughout Key Stage 3 and 4. The framework of lessons at the school is based on Collins Science, the CASE (cognitive acceleration through Science Education) for Key Stage 3. Key Stage 4 framework is based on the 360 Science Suite of specifications by Edexcel which is a GCSE examinations board from December of Year 9.

School Y is north of School L in another county and is a rural community comprehensive school with a specialist science college status. It has around 950 students on roll from eleven to nineteen of mixed ability. The science department follows the National Curriculum throughout Key Stage 3 and Key Stage 4. The framework at Key Stage 3 is by Collins Educational entitled Key Stage 3 Science. At Key Stage 4 students follow the framework by Oxford Cambridge and RSA Examinations entitled 21st Century Science for the GCSE course from December of Year 9.

School N is south of the previous two schools, in a separate county and is an urban comprehensive academy with specialist performing arts status. It has around 1400 students on roll from eleven to nineteen, all of mixed ability. The science department follows the National Curriculum throughout Key Stage 3 and 4. The framework followed at Key Stage 3 is by the Oxford University Press entitled Science Works. At Key Stage 4 students follow the framework by Oxford Cambridge and RSA

Examinations entitled 21st Century Science for the GCSE course, as School N this is from December of Year 9.

All three schools are under three separate Education Authorities they all follow the National Curriculum for science in England and whilst there are slight differences on the course frameworks for Key Stage 3 and Key Stage 4, they are broadly representative of schools across England. Therefore, broadly speaking, there were no significant differences between the experiences students had of practical work in each of the three schools. Indeed, there were no significant differences between with schools for the types of practical work, or any other external activities, that would be manipulate the results obtained. One key reason for this was the fact that all three schools followed the National Curriculum. The National Curriculum states that all students should be able to:

> a. use a range of scientific methods and techniques to develop and test ideas and explanations
> b. assess risk and work safely in the laboratory, field and workplace
> c. plan and carry out practical and investigative activities, both individually and in groups.
>
> (Department of Education, 2012)

Therefore, whilst the approach to teaching may differ slightly by the teachers in the three schools, it can be said that the nature of practical work that was experienced by the students in all three schools was, essentially, very similar.

4.11: Student age range

In order to determine the age range of the students to be involved in the study, it was decided that A-level students, those in Year 12 and Year 13, would not be included. The reason for this was two-fold. Firstly, students undertaking their A-levels were doing so primarily because they had specifically chosen those subjects. These students were choosing science, suggesting they were not “disenchanted with the school science curriculum” (Cleaves, 2005, p. 482), indeed they were under no compulsion to study them. Secondly, it was difficult to arrange access to A-level students with such focus on examinations at the time of required entry to schools for data collection. Furthermore, it was for this reason that Year 11 students would not be included either: their year is focused primarily on General Certificate in Secondary Education (GCSE) examinations and customary study leave. Therefore it was decided to focus on Year 7 to Year 10 students inclusive. The main reason for including all year groups from Key Stage 3 (Year 7 to Year 9) and Year 10 from Key Stage 4 was to observe attitudes to practical work in the three sciences over the compulsory school years and in doing so meet the research questions.

4.12: The main study method

The main study involved distribution of the three questionnaires (biology, chemistry and physics), observations with semi-structured interviews and focus groups with students. The distribution of the questionnaires occurred during the summer of the academic year for Years 8 to 10 in the three schools. For Year 7 students, as students’ attitudes to school science decline as they progress through secondary school (Barmby et al., 2008; Osborne & Dillon, 2008) and that this decline is seen to appear primarily within the course of the first year of secondary school (Turner, Ireson & Twidle, 2010), it was decided that Year 7 students should be involved at the very beginning of the academic year before their attitudes had become shaped, be that negatively or positively, into an enduring attitude, an attitude that shows a resistance to change (Ajzen & Fishbein, 1980) . Therefore, as a consequence Year 7 students were involved in the study during the start of the new academic term: in the autumn term following the distribution of Years 8 to 10 in the three schools in the summer term.

During the collection of Year 7 questionnaire data, observations of a practical work lesson with semi-structured interviews and focus groups with students in each school were also conducted. By coinciding visits it restricted the amount of disruption to students and teachers within the three schools. The choice of year group and subject was decided on an opportunistic approach. However, in order to get a good broad picture of practical work lessons, it was decided to ensure that all three science subjects would be included and three different year groups from Year 7 to Year 10 inclusive.

4.12.1: The questionnaires

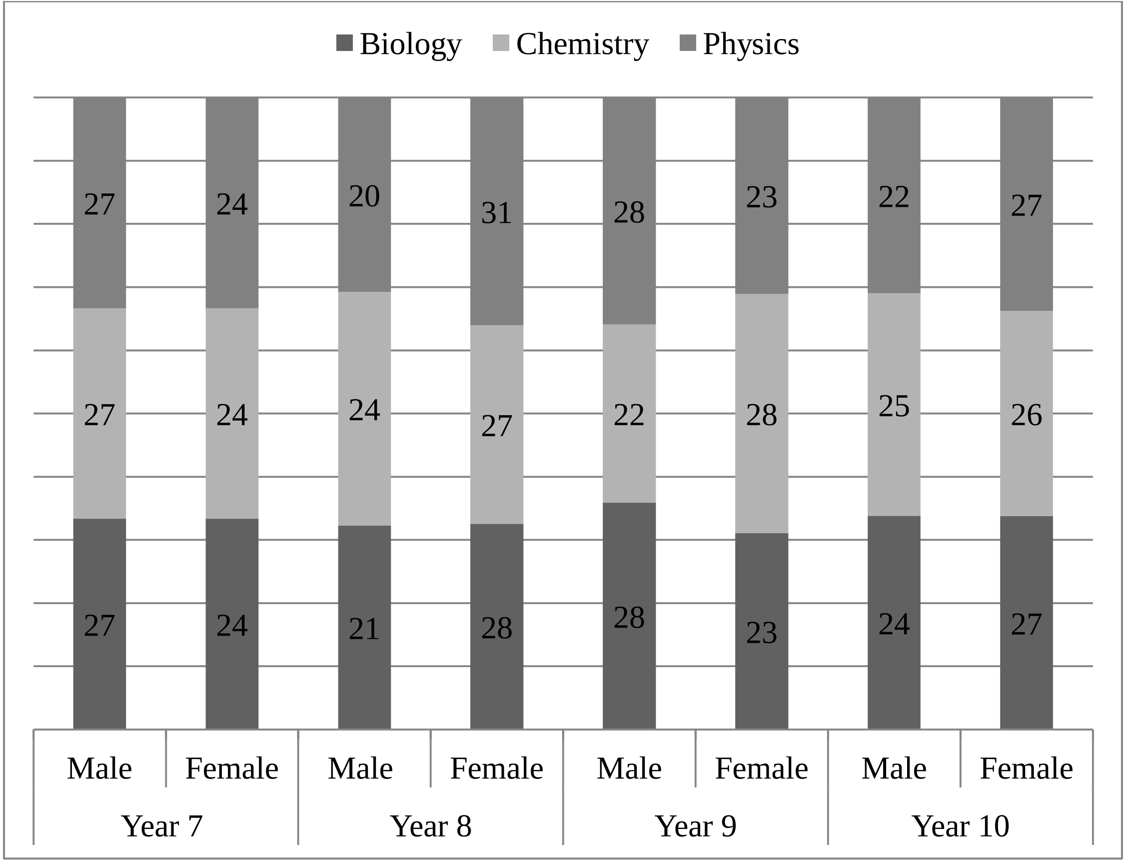
The three questionnaires, biology, chemistry and physics, were prepared for distribution to Year 8, Year 9 and Year 10 students in each of the three schools by the end of the last term of the academic school year, in July. Year 7 questionnaires for biology, chemistry and physics would be distributed in the following academic year in September. It was decided that around two science classes would be involved and taking into account student absences and the like, this would equate to around 51 students per year group in each school. The number of students that finally completed the questionnaires in each school is seen in table 4.16.

Table 4.16: The number of students involved in the study by year

		Biology		Chemistry		Physics		Total
		Male	Female	Male	Female	Male	Female	
School L	Year 7	9	8	9	8	10	7	51
	Year 8	6	11	8	9	6	11	51
	Year 9	8	9	10	7	8	9	51
	Year 10	6	11	9	8	8	9	51
School N	Year 7	8	9	10	7	7	10	51
	Year 8	7	8	10	7	6	11	49
	Year 9	10	7	6	10	10	7	50
	Year 10	8	9	6	11	6	9	49
School Y	Year 7	10	7	8	9	10	7	51
	Year 8	8	9	6	11	8	9	51
	Year 9	10	7	6	11	10	7	51
	Year 10	10	7	10	7	8	9	51
Total:		202		203		202		607

The number of male to female students involved in the main study was 49 percent (295 males) to 51 percent (312 females) respectively and the separation of gender for each year group and subject can be seen in the stacked bar chart in table 4.17. There was no statistically significant difference between the number of males and females involved in the study so the gender balance was acceptable.

Table 4.17: Stacked bar chart to show the gender numbers for each science subject by year



4.12.2: The observations

The three observed lessons involved a Year 7 biology practical work lesson in School Y, a Year 9 chemistry practical work lesson School L and a Year 10 physics practical work lesson in School N. Permission was granted by the Headteacher to conduct and audio-record the observation of the practical work lessons in each school. Furthermore, formal letters from the schools were sent to students asking that if they wished not to take part in the study for any reason they were able to opt-out at any time: there were no issues at any of the three schools. Each observation lasted an hour and semi-structured interviews were conducted during the practical work lessons.

The Year 7 biology lesson focussed on the topic of organisms, behaviour and health from the National Curriculum for Key Stage 3, with the lesson's specific learning objective involving students identifying how objects and cells are adapted for a function. The aim of the practical work was for students to describe the adaptation of a variety of everyday laboratory equipment, such as a tripod, test tube rack and tongs. The students had ten minutes within the one hour lesson to complete this practical work and they were allowed to work in pairs with whoever they wished. Students had to complete a table identifying what the laboratory equipment was, what the function of it was and the adaptations in which allow the functions to be carried out (materials, shape and parts). There were 27 students in the Year 7 group involving 13 males and 14 females.

The Year 9 chemistry lesson focussed on the topic of chemical and material behaviour as taken from the National Curriculum for Key Stage 3, with the lesson's learning objective involving students describing oxidation as the gain of oxygen and reduction as the loss of oxygen. The aim of the practical work in the lesson was for students to record their observations whilst conducting oxidation and reduction reactions by burning a variety of materials, such as iron wool, copper foil and magnesium ribbon. Students then had to answer questions about what their results were telling them. The students worked in groups of three and with some of the more responsible students of the teacher's choosing being able to choose their groups. The practical work took 15 minutes of the hour lesson and involved 16 males and 15 females.

The Year 10 physics lesson focussed on the topic of specific latent heat as part of the National Curriculum and the framework for GCSE by the OCR 21st Century exam board . The practical work involved the students measuring the specific latent heat of fusion of water, recording the temperature of the water and mass of objects involved. The students had to work in pairs and they were allowed to choose who they worked with. The practical work took 15 minutes of the hour lesson and involved 15 males and 15 females.

During the observation to ensure consistency throughout the three schools, semi-structured interview questions were decided. The semi-structured interview questions involved the following key stimuli questions:

1. How do you find doing this practical work?
2. What is it about this practical work that makes you enjoy it?

   [Probe students for specific reasons and if they say they do not enjoy it, ask why]
3. Why would you want to do more of this practical work? If not, why not?

These semi-structured interview stimuli questions came directly from analysis of the questionnaire data and the pilot study observation; this meant that any other areas arising from the questionnaires could be further explored and ensured completeness of data. Whilst during the observation of the students conducting the practical work, the stimuli questions were asked to both individuals and groups of students during the observation.

4.12.3: The focus groups

The three focus groups each conducted following on from the observation in the school. Therefore there was a Year 7 biology focus group in School Y, a Year 9 chemistry focus group in School L and a Year 10 physics focus group in School N. Permission was granted by the Headteacher to conduct and audio-record the focus groups in each school. All focus group students were selected at the end of the lesson observation by the subject teacher and a mixture of abilities and genders were involved to avoid any bias. This meant there were four students involved in each year group, consisting of two girls and two boys for each of the three focus groups. As with the observations, there were no students who opted out. Each focus group lasted no longer than an hour.

In order to ensure that the focus groups were conducted with similar consistency three stimuli questions and three stimuli statements were used in all three schools. The pilot focus group suggested the need for stimuli statements in order that students would engage with discussion than merely asking for their thoughts about practical work. The stimuli questions included:

1. How did you feel about that practical work lessons?
2. Could you give me an example of a practical you really enjoyed or really hated and could you tell me about it
3. Is there anything you would change, do more of or feel should be done differently in your practical lessons?

The focus group stimuli statements that were shown to students for them to give their opinions of included specific wording for the respective biology, chemistry or physics focus group:

Statement 1: practical work has relevance to my learning in my *biology/ chemistry/ physics* lessons

Statement 2: I do understand the practical work I do in my *biology/ chemistry/ physics* lessons

Statement 3: practical work has relevance to my life in my *biology/ chemistry/ physics* lessons

Statement 4: I can do the practical work in my *biology/ chemistry/ physics* lessons Statement 5: I do want more practical work in my *biology/ chemistry/ physics* lessons

These stimuli statements came directly from analysis of the questionnaire data.

4.13: Data analysis and analytical framework

There are four key sources of data within this study: (i) questionnaire data from students, (ii) audio-recordings from the three semi-structured interviews during lesson observations of students and teachers, (iii) audio-recordings from the three focus groups after observed lessons, and (iv) field notes from both observations and focus groups.

The questionnaire data involves inputting and analysing an intended sample of 612 questionnaires (204 biology questionnaire, 204 chemistry questionnaire, 204 physics questionnaire) with 51 questionnaires coming from each year group (Year 7, 8, 9 and 10) in each school. The analysis of the non-parametric data for all three questionnaires involves the use of the Chi-squared statistical test.

The audio-recordings from the observations with semi-structured interviews involves transcribing the raw data with the use of the observational field notes to add the appropriate non-audible actions, such as gestures and actions. The audio-recordings from the focus groups also require transcribing and consolidating with the field notes. As the main reason for the collection of the observations with semi-structured interviews and focus groups is to validate the questionnaire data and probe into particular issues that have arisen from the students' responses in the questionnaire data, the analysis will draw on these two sources in order to further understand their attitudes to practical work in school science. For these reasons the analysis of the questionnaires draws upon the findings from the observations and focus groups.

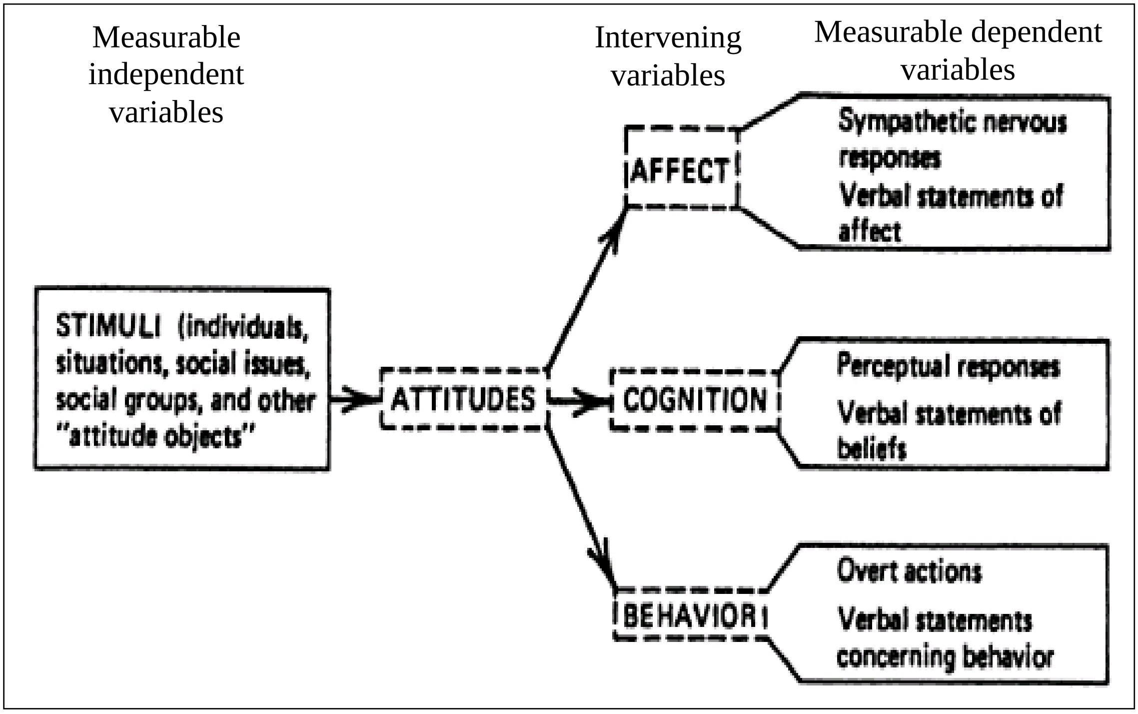
The analytical framework that will be implemented in the following two results and discussion chapters will draw on the data as collected above and on the literature as described and discussed in Chapter 3. It is important to reiterate at this stage that an attitude is a complex concept which is difficult to define and there is currently no agreed upon definition (Olson & Zanna, 1993). However, one of the recent models used in attitudinal research is the multi-component model which involves the three components – cognitive, affective and behavioural. The use of a tripartite model as discussed by Haddock and Zanna (1999) states that "attitudes are overall evaluations of objects that are derived from three general sources of information: (a) cognitive, (b) affective, and (c) behavioral" (p. 77). Indeed, Haddock and Zanna (1999) describe what information each of the three components in the tripartite model provide the researcher: "***Cognitive information*** refers to beliefs or thoughts about an attitude object" (p. 77, bold and italics in original), such as a student expressing their belief that practical work is a useful tool in learning science; "***Affective information*** refers to feelings or emotions associated with an attitude object" (ibid, bold and italics in original), for example, a student may highlight that practical work makes him or her feel happy in, or enjoy, science; "***Behavioral information*** refers to past behaviors or behavioral intentions with respect to an attitude object" (ibid, bold and italics in original), for example a student may start to participate in more practical work lessons or clubs or do more than is expected in a practical work lesson.

In terms of considering the findings in this study, it was decided to follow the tripartite model described here and in Chapter 3 as seen in the literature, for example; Ajzen (2005), Haddock and Zanna (1999), and Manstead (1996). This means analysing the data firstly in terms of the cognitive aspects, secondly affective aspects and thirdly behavioural aspects, of practical work. By addressing the data in relation to these three categories students' attitudes to practical work can be inferred and explored in more detail. Indeed, as Manstead continues (1996):

> many attitude theorists assume that attitudes consist of three components: a set of cognitions about the object, typically referred to as *beliefs;* a set of affective responses to the object, typically referred to as *emotions* or *feelings;* and a set of *behaviours* or *behavioural tendencies* toward the object....the hypothetical construct of attitude to an object is inferred from observable responses to the actual or imagined presence of the object.
>
> (p. 5, italics in original).

Indeed, this suggests that when considering an attitude towards an object, it is the evaluation of the three components – cognitive, affective, and behavioural that provide the information that can be used to infer the individual's general attitude to the object. Therefore by observing students' verbal or non-verbal statements regarding their beliefs (cognition), feelings (affection) and behaviour (behavioural), their attitude to practical work can be therefore be inferred. Indeed, the essence of using the tripartite system as a means of inferring an attitude was first articulated by Rosenberg and Hovland (1960). The understanding of the tripartite model in terms of inferring an attitude can be seen in figure 4.1 below. It shows how the verbal statements within these three categories can be used to infer a student's attitude to a stimulus (practical work):

Figure 4.1: A model of the three components of an attitude (taken "schematic conception of attitudes" figure 1 in Rosenberg & Hovland, 1960, p. 3)



Further to the work by Rosenberg and Hovland (1960), Ajzen (2005) shows how responses to each of the three areas can infer attitudes as seen in table 4.18 (note the term conation is used in place of behaviour):

Table 4.18: A model of how responses to stimuli can be used to infer attitudes (From Ajzen, 2005, p. 4)

	Response category		
Response mode	*Cognition*	*Affect*	*Conation*
Verbal	Expressions of beliefs about attitude object	Expressions of feelings toward attitude object	Expressions of behavioral intentions
Nonverbal	Perceptual reactions to attitude object	Physiological reactions to attitude object	Overt behaviours with respect to attitude object

From the explanations in figure 4.1 and table 4.19, the use of these verbal and non-verbal responses should be, to some extent, consistent in a response. Indeed, for this study, it can be argued that students who hold a positive attitude to practical work might therefore be rationally expected to also claim to believe that practical work was also a useful tool in learning science (cognitive), to find practical work (affective) enjoyable and to hold the view that they are inclined to, committed to, or intent on doing practical work beyond what is expected (behavioural). If a negative attitude to practical work is held then students would verbally claim to believe it was of little cognitive value, feel disaffected by it and dislike doing it. Furthermore, students with negative attitudes to practical work may, when asked to undertake or when undertaking, demonstrate nonverbal responses such as exhibiting facial expressions of boredom (affective) as well as not fully participating in some or all, of the practical task (behavioural). However, nonverbal cognitive responses, whilst harder to assess (Ajzen, 2005) would normally be inferred indirectly through perhaps observation by the researcher of students during practical work lessons. For example, noticing students who are not focused on doing the practical work because they are chatting with friends about unrelated aspects or not taking part would be suggested as hold a negative nonverbal cognitive response.

Yet, whilst the responses to each component of the tripartite model could rationally be assumed to be consistent, they in fact can and often do conflict with each other (Wilson et al., 2000). Rosenberg (1960a) argues that individuals are inclined to change and adapt their attitude to ensure that there is consistency between the three components. Indeed, Kruglanski and Stroebe (2005) suggest how the inconsistency in the individual acts as a *motivation* for them to change their attitudes, but that there is variance across situations and individuals as to the extent of the want for consistency or coherence of the three components. Therefore, this could suggest that students during secondary school when they are finding their identities (Hodson, 1993) and that their attitudes are susceptible to change especially in late adolescence (Krosnick & Alwin, 1989), conflicts between the three components is thus very likely.

In regards to the model seen in figure 4.1 and the fact that the components may not be consistent within an attitude, the question can then be asked as to where an individual’s general disposition or attitudinal statement comes from. For example, when students are probed as to what their attitude is to practical work and claimed they like it, it would seem rational to assume that for those students they would each give positive statements regarding the affective, cognitive and behavioural domains. However, as Abrahams (2009) argues if many students claim to like practical work because it motivates them, it would be expected that they continue to study science. However, whilst many students claim to like practical work, there has been little evidence to suggest that it motivates them to study science (Abrahams, 2011). Therefore, it seems that the *cause* of a student’s general attitudinal statement could be from one or more of the three components - affective, cognitive or behavioural. It could be understood that whichever component is felt strongest by that individual will ultimately form the attitudinal statement. Indeed, if an individual wants:

> congruence between their beliefs and feelings toward objects, then attitudes can be changed by modifying either the beliefs or feelings associated with them. The incongruity thereby aroused may, in the former case, result in the feeling changing to become consistent with the altered beliefs; in the latter case the beliefs may change to become consistent with the altered feeling.
>
> (Rosenberg, 1960b, p. 319)

This suggests that the feelings (affective domain) and the beliefs (cognitive domains) are most prominent in attitude formation and that whichever is modified by a potential external factor can lead to a change in the other. Therefore, within this study, if a student's general attitudinal statement is that they like practical work giving the reason that it is a break from the monotony of theory lessons (Toplis, 2012), then that student may also believe that they learn a lot from it. But it may transpire when probed further that they are unable to explain what they actually learnt, this would suggest that their feeling to practical work is more prominent in the formulation of their attitude. Conversely, when GCSE examinations are approaching for students, it might be expected that they would not enjoy doing practical work giving the reason that they actually *prefer* being spoken to by the teacher or when they do book work because they *believe* it benefits their learning in order to do well in exams. This would be suggesting that their belief of the limitations in learning from practical work is the main reason for their formulation of not liking practical work. If measuring the cognitive and affective components of an attitude:

> ....provides more valid and more precise estimates of attitude extremity and intensity, it is clear that the use of such measurement will enable more effective prediction of the attitude holder's response in a situation which allows for overt action toward the attitude object.

(Rosenberg, 1960b, p. 336).

Therefore, using the verbal cognitive and affective responses the behavioural component might be inferred. Indeed, the behavioural component could non-verbally be seen during observations of, for example, students doing practical work and those that are showing active involvement might therefore show a positive beliefs and feelings towards it.

The analytical framework will be used to analyse the data in order to explore students' attitudes to practical work in Chapter 5 and Chapter 6. In order to do this the analytical framework, that devised by Rosenberg and Hovland (1960), will be used as an analytical tool rather than a design tool to find the affective, behavioural and cognitive components of their attitude towards practical work. Level 1 data in the questionnaire relates to responses to options in the form of either: agree, neither agree or disagree, and disagree. Level 2 data provides the reasons for the selections made by students in Level 1. In this respect, Level 1 data is used to determine the number of students that agreed, or did not agree, with the statement and will be analysed in Chapter 5 and Chapter 6 using Chi Square and percentages to see the emerging picture of where students' attitudes are currently placed in response to the statement. It should be noted here that if the Chi Square analysis cannot be undertaken because one of the three response headings in Level 1 is too small the three groups will be collapsed into two to allow for the statistical analysis to take place. The Level 2 data will then be used to explore the reasons for the responses they gave to the statements in Level 1. The analytical tool will be used to explore the reasons in terms of the three distinct components of an attitude – affective, behavioural and cognitive. Field notes, along with transcripts from the semi-structured interviews made during the observations as well as transcriptions of focus groups sessions, will then be used to provide further in-depth insight into the selections made in the Level 2 data.

To illustrate this point it emerged, when data was collected, relating to responses to statement 1 of the questionnaire (I enjoy doing practical work in biology/ chemistry/ physics lessons) that, in terms of Level 1 data, 75% of all the students in the study agreed. The Level 2 data provided an insight into the reasons for this and it was found that the most popular reasons fell into four areas within the affective domain: (i) preference, (ii) the opportunity to discuss, (iii) the teacher influence and (iv) personal autonomy and freedom. These reasons were then further clarified using the transcripts and field notes from the observations with semi-structured interviews and focus groups. The way that this was achieved was that these data sets were examined for specific examples relating to the reasons given in Level 2. For example if a Level 2 response had included the ‘opportunity to discuss’ examples that illustrated this point were sort within the transcripts and field notes collected. An example of this linkage would be a claim made by a student during a focus group that ‘practical work is really good because I can talk to my friends about what we do’. Further examples of the use of this supporting material can be seen throughout Chapter 5 and Chapter 6.

4.14: Validation and reliability of the study

With collecting any questionnaire data on students’ attitudes there is the uncertainty of whether what students answer on paper actually reflects their fundamental attitudes (Reid, 2011). In order to try to address this, one solution is to use triangulation (Laws, 2003) whereby the researcher is able to see the same results from collecting data from different approaches in order to collaborate or challenge the findings of another approach. In this study, methodological triangulation is used to try to reduce bias and highlight areas that may have gone unnoticed in a single methodological approach (Thurmond, 2001). Therefore, in this study three methodological approaches were used for data collection; primarily the biology questionnaire, chemistry questionnaire and physics questionnaire with, observations including semi-structured interviews and focus groups alongside field notes.

Another issue was data collector bias where discrepancies in the data could favour certain results (Wallen & Fraenkel, 2001). In this study, the questionnaires, observations with semi-structured interviews and focus groups were all administrated by the same researcher in all three schools; because of this, instrumentation threats were also reduced.

4.15: Ethical issues in the study

Confidentiality was adhered to throughout the study; this was done by informing teachers and students not to write any form of identification on the questionnaire papers. As there was no need for the study to identify any of the students or the schools involved in the main study, everything was kept anonymous. During the focus group and observations no names were recorded and when ever referring to the transcripts or field notes, pseudonyms were used at all times to ensure anonymity.

The three schools involved in the main study had all agreed by telephone or email and all Head Teachers were aware of the research being totally anonymous and they were clear of the details of the study. Furthermore, there were no issues relating to psychological harm or misunderstandings from participants as all involved with the main study within the three schools were informed explicitly about the purpose and contents of the research. The questionnaires, observations and focus groups were completed during school time and in the normal school environment under the direction and authority of the members of staff who had willingly agreed for their school and students to participate in the study.

4.16: Summary

The study aims to provide a critical investigation into students' attitudes to practical work at secondary schools in England. It aims to address the following focussed research questions:

1. What are secondary school students' attitudes to practical work in science lessons?

2. To what extent, if at all, do students' attitudes to practical work differ across the three sciences?

3. To what extent, if at all, do students' attitudes to practical work in the three sciences differ within each year group?

In order to answer these questions, the results from the three questionnaires, biology, chemistry and physics as used with Year 7 to Year 10 students in three comprehensive schools across England will be analysed. Further to this, in all three schools a voice-recorded observation of a science practical work lesson incorporating semi-structured interviews, followed by one voice-recorded focus group with four students, and along with observational and focus group field notes, will be used in order to validate and probe further into students' attitudes to practical work in biology, chemistry and physics. Chapter 5 and Chapter 6 will now discuss and analyse the findings from the study in response to the research questions.

Chapter 5

Results and discussion of students' attitudes to practical work in science

5.1: Introduction

This chapter discusses students' attitudes to practical work in science that have emerged from the data collected in this study. The following chapter, chapter 6, will consider the differences and similarities between students' attitudes to practical work when considered in terms of subject - biology, chemistry and physics - and by Year group (Year 7 to Year 10 inclusive). The research questions addressed by the study, relating to students within three schools, are shown below and this chapter will discuss and aim to answer the first one:

Research Question 1: What are secondary school students' attitudes to practical work in science lessons?

Research Question 2: To what extent, if at all, do students' attitudes to practical work differ across the three sciences?

Research Question 3: To what extent, if at all, do students' attitudes to practical work in the three sciences differ within each year group?

These research questions can be divided into two areas, firstly what are secondary school students' attitudes to practical work in general (research question 1) and secondly, the differences and similarities across science and year groups (research questions 2 and 3). Whilst it was originally planned to consider attitudes by age and subject in separate chapters what emerged from the study was that these factors were inextricably entwined and thus they needed to be consider together in order to avoid repetition of the data and discussion surrounding it. As such, it was felt appropriate to reflect this entanglement by addressing these two research questions within a single chapter, that being chapter 6. It is worth noting at this point that claims made in the literature about the *specific* value of practical work in encouraging positive attitudes towards school science, and/or science more generally (see for example, Cerini et al., 2003; Barmby et al., 2008; Osborne & Collins, 2001; Jenkins & Nelson, 2005), are, almost invariably studied only within the much broader context of students' attitudes to school science per se. It is for this reason that this study set out to specifically investigate students' attitudes to practical work as an entity in its own right and, in so doing, better understand what students' claims about its affective value actually meant in terms of motivation, situational interest and individual interest. It is important to reiterate again here the definition of 'practical work' as well as recognising that the term 'practical' or 'practicals' are often used by students to mean practical work. Therefore, throughout this chapter and Chapter 6, 'practical work' is, as defined in Chapter 1, any science activity where students, in groups or individually, manipulate or observe real objects as opposed to virtual tasks that includes teacher demonstrations, textual data or electronic sources (Millar, 2010; SCORE, 2008; Millar, Le Maréchal & Tiberghien, 1999).

Chapter 5 and Chapter 6 draw on three primary data sources, these being: (i) the questionnaires, (ii) the observations of practical work lessons and (iii) the focus groups with students after the observed practical work lesson. A coding system is used in order to refer to the data sources individually. The schools that were involved in the study will be referred to as 'School L', 'School N' and 'School Y' and the teacher in each of those three schools is referred to as 'Teacher L', 'Teacher N' and 'Teacher Y'. When referring to students' quotations, a fictitious name will be given to the student in question that begins with the letter for the school followed by the year group number (7, 8, 9 or 10) and the letter for the science subject (B, C or P). For example, a student coded 'Larry 9C' would be a student from School L in Year 9 during the observation or focus group within chemistry. It should be noted that the pseudonym Larry will only be applied to the same student within the study so that quotes by the same student can easily be followed. In terms of distinguishing between the questionnaire data, the observations and the focus groups, reference will be made in the prose prior to any specific quotation that is used. It might, at this point, be useful to restate that there were 607 questionnaires (comprising 202 biology, 203 chemistry and 202 physics) with the observations and focus groups being carried out as follows: a Year 9 chemistry practical work in School L, a Year 7 biology practical work in School N and a Year 10 physics practical work in School Y. The use of the coding system both ensures anonymity whilst also allowing for connections between the schools, the science subject, the year group and form of data collection to emerge from the data presented.

5.2: What are students' attitudes to practical work in science lessons?

Throughout the research in this study, have offered many reasons to explain their likes and dislikes with regards to practical work. One main issue with these claims is how the terms that are used are often used in a generic, non-psychological, manner. For example, students may claim that practical work 'motivates' or 'interests' them, but their actual meaning is not always in accordance with the psychological meaning of those terms. Thus there is a need to be cautious about what they are actually claiming. Indeed, from the overview of the study's data on students' attitudes, it appears that students do claim to feel positive to practical work. They believe that practical work aids their learning, is enjoyable, and provides an exciting, 'hands-on' way of learning science.

When the fourteen individual statements from all three questionnaires were analysed further, it emerges that students' attitudes to practical work in science were generally positive. However, despite their broadly positive attitude to practical work there were certain statements where students were unable to agree and did highlight some aspects of practical work that they felt negative towards, as seen in table 5.1 where detailed values of percentages are presented.

Table 5.1: Number of students who selected 'agree' and those that did not for each statement (percentages in brackets and bold represents statements with less than 60% agreeing)

Statement	Agree	Did not agree
1. I enjoy doing practical work in biology/ chemistry/ physics lessons	455 (75)	152 (25)
2. I am able to learn from practical work in biology/ chemistry/ physics lessons	473 (78)	134 (22)
3. I prefer practical work to non-practical work in biology/ chemistry/ physics lessons	442 (73)	165 (27)
4. Doing practical work is my favourite part of biology/ chemistry/ physics lessons	396 (65)	212 (35)
5. Practical work helps me understand biology/ chemistry/ physics	434 (71)	173 (29)
6. I find practical work in biology/ chemistry/ physics easy to do	**304 (50)**	**303 (50)**
7. What I do in biology/ chemistry/ physics practical work will be useful when I leave school	**264 (43)**	**343 (57)**
8. What I learn from biology/ chemistry/ physics practical work is always useful for when I leave school	**228 (38)**	**379 (62)**
9. I find practical work a way of seeing how biologists/ chemists/ physicists work in the real world	**319 (53)**	**288 (47)**
10. I think we should do more practical work in biology/ chemistry/ physics lessons	431 (71)	176 (29)
11. For me to learn in biology/ chemistry/ physics lessons, I need to do practical work	**324 (53)**	**283 (47)**
12. I prefer the freedom I have during practical work in biology/ chemistry/ physics lessons	451 (74)	156 (26)
13. My school science environment makes doing practical work easy in my biology/ chemistry/ physics lessons	**350 (58)**	**257 (42)**
14. I do find practical work helps my learning in biology/ chemistry/ physics	421 (69)	186 (31)

When considering how to refer to the percentage of students that did or did not agree with the statements, it was decided, for the sake of consistency, to utilise the approach that OfSTED implement, when inspecting and judging schools, when reporting proportions for large sample sizes (above 100) (Bell, 2005). Table 5.2 shows the expressions of the proportions in words.

Table 5.2: Expressions of proportions in words (taken from table 7 in Bell, 2005, p. 75)

Proportion	Description
97-100%	Vast / Overwhelming majority or almost all
80- 96%	Very large majority, most
65 – 79%	Large majority
51 – 64%	Majority
35 – 49%	Minority
20 – 34%	Small minority
4 – 19%	Very small minority, few
0 – 3%	Almost no/ very few

[Note: 50% does not appear in the original table]

For this study, whilst recognising the arbitrary nature of any cut-off, it was therefore decided, for example, that a value of 60% which would be described by Bell (2005) as a majority was a reasonable point at which to feel a majority of students would agree. So any statement or reason regarding a statement that received 60% of students agreeing (or not agreeing) was referred to as a majority. Therefore using this description of percentages (seen in table 5.2) and table 5.1, it can be reported that the majority of students were able to agree with statements 1, 2, 3, 4, 5, 10, 12 and 14. Therefore, the majority of students claim to enjoy doing practical work believing it is their favourite part of science lessons as they prefer it to non-practical work and believe they have more freedom doing it. The majority of students believe it helps their learning in science because they are able to learn and understand science by doing it and therefore believe they should do more of it. In light of this, the results will be discussed in further detail.

Examining the statements relating to the affective domain, such as enjoyment, preference and freedom (statements 1, 3, 4, 10 and 12), the majority of students felt able to agree with these statements (over 60%). Students reported that they enjoyed doing practical work, it was their favourite part of science lessons and that they preferred it over non-practical work. Indeed, they claimed to want to do more practical work in science lessons and that they preferred the freedom they had during practical work compared to non-practical science lessons – often referred to by the students as ‘theory’. However, when students were asked about the ease of doing practical work (statement 6), the responses showed an equal number of students agreeing and not agreeing with the statement. Indeed, whilst most students reported that the environment they worked in made practical work easy to do, there was a majority of students (as seen in table 5.1) believed it did not. With regards to the cognitive aspects that students believed that with regards to practical work, the majority of students agreed with statements (statements 2, 5 and 14) that they were able to learn and understand by actually doing the practical work. Yet, when students were asked whether to learn in science they *needed* to do practical work (statement 11), it emerged that whilst the majority agreed with this statement there were many (see table 5.1) that felt it was not needed because of the many other methods of learning in science. Interestingly, fewer students were able to agree to statements relating to the value of practical work beyond school science (statements 7, 8 and 9). What was reflected in their responses was how students struggled to see the relevance of practical work to the wider world.

5.3: Findings from the initial overview of the data

The analytical framework to be used for this chapter and chapter 6 will refer to the use of the cognitive, affective, and behavioural domains, as is discussed in the methodology chapter 4 and seen in the theoretical framework that was discussed in Chapter 3. The three areas - cognitive, affective, and behavioural will be used to analyse students’ attitudes to practical work in chapter 6. These components are used to infer a student’s formulated attitude; an attitude being “an evaluated judgement formed by the person”

(Barmby et al., 2008, p.2). An attitude is “the feelings that a person has about an object, based on his or her knowledge and belief about that object” (Barmby et al., 2008, p.2) and then influence him or her to take certain actions because of these feelings. Therefore for this study, a student’s attitude to practical work is based on his or her knowledge and beliefs about practical work which then influences them to like doing or not like doing practical work. Thus, an attitude is made based on the cognitive, affective and behavioural components. In order to address these three areas in light of the findings, a clearer definition of each of these, along with how they link to this study needs to be discussed.

Firstly, the cognitive domain, this relates to the students’ knowledge of practical work (or of science) and what they know about it in order to formulate their attitude of it. The cognitive component involves students thinking about what they know about practical work and their beliefs and ideas about it (Reid, 2006). Students may claim to like practical work therefore because they believe it is of some educational value to them. For example, in this study, a student’s comment about how the practical is a teaching method to learn how to understand parts of a cell:

> Ywain 7B: We looked at sheep cells under the microscope so we learnt about what the cells looked like and how different they were, mine looked like a sweet potato! But like we wouldn’t learn that from a book!

The second area relates to the affective domain. Whilst this study is focussed on the *affective* aspects because it is looking into students *attitudes*, this domain is more than just their attitude of likes or dislikes. This domain reflects students’ feelings and emotions towards an object (Reid, 2006), in this case practical work, and the reasons why they like or dislike it. Such comments as Laben 9C suggests:

> Laben 9C: I like practical work because it is fun. I mean it is better than other stuff, like writing that we do in science

The third area, behaviour relates to a student holding “tendency-towards-actions” (Reid, 2006, p. 4). For example a student holding positive feelings for practical work because they like doing it, and believe they learn from it, should act in a way that suggests this. So they may like the fact they use their hands to manipulate objects or they move about the laboratory, they may even do more than is expected of them in the science practical work lesson. It is important to note that the behaviour aspect of practical work is less descriptive than the affective and cognitive domains, the reason for this, as Barmby et al. (2008) explain, is that attitudes, or rather the affective component of attitude, are linked to beliefs that the student holds (Barmby et al., 2008), the cognitive component, and thus the behaviour aspect tends to be “set in terms of student uptake in the science” (Reid, 2006, p. 9) because it is a consequence of the affective and cognitive components. Considering, as discussed in chapter 4, behaviour is this “tendency-towards-action” (Reid, 2006, p. 4), the cause to take or not take some sort of action, is based on the feelings and beliefs based on the attitude object, practical work. Therefore, behaviour in this study is taken to be the objective component (Barmby et al., 2008), a by-product of affection and cognition. A comment about behaviour would be similar to that by Noddy 10P:

> Noddy 10P: I like to get involved and do things in practical work. I think that is why I like biology. I’m taking it for A-levels because we get to do dissection then and I want to be a vet so it will help me.

From the initial overview of the data, these above three areas have indeed emerged in students’ attitudes to practical work in science. These three areas, cognitive, affective and behavioural, will now be discussed.

5.4: The cognitive domain on students' attitudes to practical work

The purpose of Chapter 5 is to explain the reasons for students' attitudes to practical work across the three sciences by using the analytical tool devised by Rosenberg and Hovland (1960). All the data in the study has been analysed collectively for this chapter in order to answer the first research question: What are secondary school students' attitudes to practical work in science lessons? Then, in Chapter 6, the data analysis draws individually on the three sciences and the Year groups to address research question 2 and 3.

For the rest of Chapter 5, and the following Chapter 6, the analytical approach that was described in Chapter 4 will be used to reflect on and discuss the results of the findings in this study. The Level 2 analysis of the questionnaires provided the descriptive reasoning behind students' choices for being able to agree, or not, to a statement. The general picture of students' attitudes to practical work in science will be presented by drawing on the Level 2 data to ascertain the emerging cognitive, affective and behavioural reasons for students' selection to the Level 1 aspect of the questionnaires. Chapter 5 and Chapter 6 draw on the Level 2 reasons that students selected as being the explanations that emerged for why they felt the way they did towards the statements. These reasons will be expanded and developed further by drawing on the data from the observations with semi-structured interviews and the focus groups. This analytical approach uses the questionnaire data to provide both quantitative and qualitative results. It is important to note, and refer back to table 5.2 by Bell (2005), that whilst recognising the arbitrary nature of any cut-off, throughout Chapter 5 and 6 the term 'many' or 'the majority of' will be used, following OfSTED (Bell, 2005), when 60% or more of students are in agreement or disagreement with the point being made. For example, within the cognitive domain, the quantitative results showed that the large majority of students (78% seen in table 5.1) agreed that they were able to learn from practical work and the qualitative results in the Level 2 data, suggested the main reasons for why 78% of students agreed fell into five distinct areas which will be discussed in this section on the cognitive domain. The five distinct areas from the Level 2 analysis showed the reasons students claimed to learn, or not learn, from practical work as being: the idea that seeing is believe and learning, issues with seeing the phenomena and understanding; knowledge for examinations; the influence of science topics and; aiding memory and recall. Within the questionnaires in general, students did respond positively to the effect that practical work had on their learning in science.

5.4.1: Seeing is believing and learning

A large majority of students (as seen from the Level 1 responses in table 5.1) claimed they learnt from practical work but there was not a consensus (seen from the Level 2 responses) as to whether they believed that in order to learn science they *needed* to do practical work. Indeed, during the focus groups and observations, students spoke about being *able to* learn from practical work but rarely spoke of a *need to* do practical work to learn. The students below exemplify (Lynne from the focus group and Nigel from the observation) that they felt that they needed practical work to learn science but they understood that they need the written work too:

> Lynne 9C: Yeah, I think that to be able to learn something you should do it because otherwise you won’t understand it properly.
>
> Nigel 10P: I think it helps us, like we are able to learn from it because we can see it

Whilst these comments encapsulate the idea that by doing practical work they are able to understand science, results supported by Abrahams (2009), Toplis and Allen (2012) argue that this does not necessarily mean that they are actually able to understand the scientific theory behind the activity. However in this study, students did claim that science lessons needed both practical work and non-practical work and this was echoed throughout the Level 2 responses in the questionnaires. Indeed the point was substantiated further when students were asked during observations how they would distribute practical work in a week, as the following comment encapsulates:

> Nicola 10P: Well we would need half and half cause they go together… like we do at the moment, we'll do practical if we've got the writing part done. They make sure that we've done the writing and the notes on it though before we do practical.

The claim the student is making above, that practical work and theory support each other, is similar to findings by Cerini et al. (2003), Osborne and Collins (2001) and Toplis (2012).

Indeed, a large majority of students (78% seen in table 5.1) expressed the view that they were *able* to learn from practical work in science lessons, because (according to the Level 2 data) they felt they could see for themselves how everything worked rather than just being told what happens. Such reasons were also made clear by students during the observations as the following comments exemplify:

> Lucy 9C: Instead of talking about it we're actually looking at it ourselves
>
> Yvette 7B: When you see things and you do it yourself you remember, but when you just write it down you forget. So like you learn more when you're actually doing stuff.

This high degree of student support seen in these comments for the idea that they are able to learn from practical work supports previous claims made by teachers as to why they incorporated it into their science lessons (Wellington, 1998). Indeed, Wellington (1998) found that teachers saw the main reasons for doing practical work were that it could not only improve students' understanding of science but provided the means to "illustrate, verify or affirm 'theory work'" (p. 7). This reason teachers gave was also a reason for why a large majority of students (71% as seen in table 5.1) felt practical work helped them to understand science: because it gave them the ability to verify and affirm the theory. Students felt they could see what happens themselves during practical work. Whereas, students claimed (within their Level 2 responses) that when a teacher told them what would happen or they read it out of a book, they felt they were not able to understand science as much as through practical work. According to Woodley (2009), practical work can help students to understand scientific concepts and, students in this study did express such views. Indeed, the example below, made by a student during a lesson observation, illustrates how they felt practical work helped them to understand science:

> Lacy 9C: I think that we see experiments in textbooks and when Miss says we can do them that means we can understand about what happened, why it happened, how it happened. And it's better because you can actually relate with what it's saying in the book and you don't really have to like try and think about what it was, you just have to remember.

Certainly in this study, many students claimed (seen in the Level 2 data) that practical work was 'first-hand' so they would be able to learn more because they could see it for themselves, whereas, they saw book and theory work as secondary learning. The view below during the observations support their claims that practical work is seen as 'first-hand' learning:

> Natasha 10P: Well we get first hand experience doing practical work, which is good for learning because we remember unlike learning it from the text book.

Whist the findings in this study are similar to those reported by Wellington (2005) in which students “expressed the importance of “seeing things happening” and felt that it helped you to remember things and perhaps understand them” (p. 102), there were a small minority of students (22% as seen in table 5.1) that believed they were not able to learn from practical work. Of this minority, only 5% of students from the Level 2 data felt they only learnt from the teacher, and 6% (again from the Level 2 data) felt that not every practical lesson taught them something new. Whilst the percentage of students selecting these options was low in this study, these views were echoed in the observations where students discussed that learning from practical work was difficult at times:

> Neil 10P: If it is something new and different then I might learn from it but normally we do the same sort of stuff so we can’t learn much from that.

The statement by Neil is illustrative of others made by students in this study and suggests that by carrying out practical work that is in some sense novel – such as practical work that may excite them or provide a ‘gore’ factor – students feel they will learn from it. However, the fact that the student as in the example spoke of the normal routine practical work being of little educational value is similar to those comments made by Woolnough (1998). In contrast Toplis (2012) found students felt that they did learn science concepts and that this learning was a reason for seeing practical work as important.

5.4.2: Issues with seeing the phenomena and understanding

With regards to practical work aiding understanding in science, there was a small minority of students (29% seen in table 5.1) that felt it did not help their understanding of science. Whilst this was not the majority of students, their Level 2 reasons related to how easy it was for them to obtain the correct answers or see the expected phenomena that the teacher had asked them to see. Although, this ability to ‘see’ the expected phenomena may be down to the maturity of the students as indeed Jenkins (2006) found that as students mature through school they begin to value the use of taking notes as being a more effective means of learning and understanding scientific phenomena. In this study, comments during the observation as seen below did discuss how the practical work could cause them to incorrectly understand scientific phenomena and that they needed the theory to help engage with the practical work - practical work to them, would not work on its own:

> Nancy 10P: Sometimes the practical goes wrong but we don’t know it has and so we get the wrong answer, not knowingly and then we learn the wrong answers, so the book telling us the answer is better.
>
> Lucas 9C: I think that… Like somebody said earlier, I think that without the practical the written work wouldn’t work properly and then without the written work the practical wouldn’t like work. Because it’s like they’re both helping each other, and helping us to then understand.

Indeed, for some students seen during the observation, using practical work to link to science phenomena was difficult and confusing at times as it would not always match up with the theory. Indeed, this is a similar finding to Wellington (2005) who reported how for some students practical work could confuse “them if the result were not as expected and when they did not conform to theory” (p. 102).

An equal number of students involved in the questionnaires who claimed that practical work was not easy (50% seen in table 5.1), did so giving the Level 2 reasons that they would struggle, finding it hard in trying to understand what to do and what they were learning from it. Indeed, during the observations it emerged that practical work was seen as being relatively easy to carry out if students were explicitly told what to do as the examples below explain:

> Nadia 10P: He [the teacher] just doesn’t tell us what we did wrong. He’s just like, yeah, you did this wrong, but then he walks away. It’s well hard to do!
>
> Luke 9C: I can do practical work if I’m given the instructions as to what I’ve got to do. Sometimes I think you get given an experiment and they don’t explain it fully and then you go wrong and then the teacher will like blame you because you haven’t paid attention. But if they don’t give us clear instructions about what to do you just don’t get it or understand as much.

In the comments above, students’ attitudes here to finding practical work easy when given explicit instructions, are similar to the findings by Kempa and Diaz (1990). They reported finding that whilst the most conscientious of students enjoyed doing practical work this was primarily the case when they were given clear and explicit instructions regarding the procedure to follow. Conversely they found that sociable students preferred group discussions in science, and those students who were high achievers preferred the more individual or whole class teacher demonstrations. This was something that whilst not possible to ascertain from only one observation in each of the three schools, was still noted by the researcher within the field notes.

In this study, 50% of students (seen from the Level 1 results in table 5.1) claimed that practical work helped them to understand science which is similar to that reported by Cerini et al. (2003) where 47% of students claimed that practical work made understanding the theory easier in science. Indeed, similar findings were reported by Toplis (2012) where students spoke about how practical work enabled them to link the domain of observables, the aspects of practical work they could see, with the domain of ideas, that which they could not see (Millar, 2010). This may explain why those students in this study (50% seen in table 5.1) who claimed that practical work did not help them understand because it gave them the wrong answers (as explained in their Level 2 responses), were actually placing too much emphasis on practical work producing the phenomena which they thought would mean they understood the science as the comment during an observation explains:

> Lisa 9C: Well if we, when we do practicals and the results are wrong then we don't learn science. But when it does work the results are there for us and we actually see them so we learn and like get the ideas and facts about science then.

Indeed, these comments suggest that when 'doing' practical work, students expect to 'see' the phenomena and they then believe they will understand, such views are similar to those reported by Toplis (2012) who found that students claimed they understood through doing. Indeed, Abrahams and Millar (2008) have claimed that teachers need to spend more time helping students use the ideas that have come from the phenomena. By doing so, this may enable those students like these in this study be able to understand that it is not merely about seeing the end result that is important but understanding the science ideas to explain the phenomena they see.

5.4.3: Knowledge for examinations

Indeed, there was also the belief held by some students from the Level 2 data that they could not enjoy practical work because it was taking up the time they needed to do the theory that was needed more for examinations. There were a small minority of students (26% in response to statement 12 in table 5.1) who claimed that the amount of freedom they had during practical work was not useful with their Level 2 reason being it meant that they then did not learn enough theory in those lessons that they felt they would need in order to do well in examinations. Students' concern about the limitations of what they were able to learn from practical work was a reason for why the older students in Year 10 who in a few months would be sitting their GCSE examinations discussed this in the observations:

> Nicola 10P: Practical work doesn't help me when I'm sitting my science in the hall. It doesn't tell me the answers, the theory helps us with that.

Certainly, the comment made above was indicative of the older students in the study and is similar to the findings by Abrahams and Millar (2008) where they suggest that students are only able to describe what they saw, rather than link to the scientific theory, that, in this case, Nicola needed for her science examination. The discussion between year groups and sciences is explored more in Chapter 6. There were a small minority of students (27% from the Level 1 data seen in table 5.1) that claimed they *preferred* written work because they were able to learn more from it. Certainly, there were comments, during discussions with students as they undertook practical work that highlighted particular reasons as to why they felt that practical work was not always useful in their learning of science. These reasons were more about the practicalities of carrying out practical work, the impact of examinations or the impact the teacher had on their learning through the use of class discussions, as seen below:

> Natalie 10P: I learn more from writing and like when we don't do practicals we get to chat with sir, I like chatting about science with sir.
>
> Leah 9C: ...and then because we haven't written everything down or we haven't finished the practical, we haven't cleaned up in time, we have to stay in during our break to clean it up and stuff...then we don't know the answers for our exams! I mean where's the learning in that? I need to pass my exams so practicals are useless then.

These findings are unlike those by Cerini et al., (2003) and Murphy and Beggs (2003) who report students claiming the importance of practical work to their learning. Although, Cerini et al., (2003) did find students claiming that discussions with teachers was more effective in helping them learn science. Indeed, the students in this study felt that their teacher would provide them with more opportunity to discuss science during non-practical lessons, making sure they understood the concepts for the examinations, better than practical work. Indeed, this was a point that Woodley (2009) claimed to be important if students were to be able to reflect on what they did. However, because students in this study were claiming that a lot of time was spent in practical work lessons setting up and organising equipment as well as drawing results tables and the like, meant they felt this restricted the teacher's opportunity to discuss the associated scientific ideas. Certainly, it has been commented (Millar & Abrahams, 2009) that it is important that the teacher considers the reasons why, and benefits of, doing practical work. By helping students explicitly to link what they see and do (hands-on) with what they observe and know about scientific ideas (minds-on) the more likely it is to be an effective lesson (Millar, 2004) and engage students by challenging them both hands-on and minds-on (SCORE, 2008).

5.4.4: The influence of science topics

Further to this, there was a small minority of students (25% from the Level 1 data in table 5.1) who claimed that they did not enjoy practical work because their Level 2 reason suggested that their liking of the practical work very much depended on the topic they were learning in science. Certainly this finding that the topic determined their liking of the practical work reflects the findings by Turner et al. (2010) where students claimed not to enjoy biology, chemistry or physics in general if they found the topics they were studying too difficult. Interestingly, in this study a small minority of students (29% in Level 1 data from table 5.1) who thought they did not need more practical work in their science lessons did so because they believed that not all topics needed practical work, the main Level 2 reason here. Indeed when students were asked, during the focus groups and observations, how much practical work they thought they should do compared to other methods of learning science and some typical responses are provided below:

> Leanne 9C: I think we need half and half because like… I mean, our exams are mostly written so we need to know the written science and we could put the practical science into our written science.
>
> Nikki 10P: Yeah, I think it's about half and half depending like, I suppose, how much time we have and what the actual experiment is. It's pretty even.

Certainly, these statements are in contrast to those reported by Cleaves (2005) who found students claiming that they were not doing enough practical work in their lessons and that this was making their science lessons boring. Although, a large majority of students (71% of Level 1 data seen in table 5.1) when questioned, did claim to want more practical work in their science lessons even though they felt their current science lessons in a normal school week were equally spread between theory and practical work.

5.4.5: Aiding memory and recall

Of the large majority of students (71%) who claimed they wanted more practical work lessons in the Level 1 data seen in table 5.1, the Level 2 data suggested that 28% of these students did so because they believed that they learnt and remembered more by doing it than if they answered questions from a book. Indeed, comments during the observations substantiate this claim further:

> Yudan 10P: When you see things and you do it yourself you remember but when you just write it down you forget.

Such findings are similar to those reported by Wellington (2005) in which students spoke of practical work as being an "*aide-memoire*" (p.104, italics in original) in the learning process, but that these aspects they were remembering and learning tended to be from practical work that was “out of the ordinary” (p.104). The findings in this study of practical work providing a visual aid to learning through memory also supports the findings by Osborne and Collins (2001) in which students remembered more through the use of practical work. However, as Toplis (2012) discusses, it is primarily the “unique episodes” (p. 544) that remain in students’ memory that may then consequently be re-used when needed. White (1988) also explains that it is these episodes that can influence students’ attitudes. Thus, if a student was to experience something exciting or different it would stand out in their memory as an enjoyable experience. Toplis (2012) also argues it is the common episodes that “can merge into the scripts held in the memory that make concepts understandable and can link ideas and intellectual skills acquired elsewhere” (p.544). Thus, the students in this study who had experienced something exciting in their practical work lessons would then be more likely to remember the experience and remember it as an enjoyable one. Yet, from the researcher’s field notes from the observations and focus groups, it became apparent that students were able to remember what happened but rarely able to discuss the scientific theory behind what had happened.

5.4.6: Conclusions on the cognitive domain

This section has shown that students’ attitudes’ do show that they are able to learn from doing practical work, similar findings to Cerini et al. (2003) and Osborne and Collins (2001). However, the findings go further than that to suggest that what many students are actually claiming is that they are able to remember certain ‘novel’ practical work where they actually see phenomena, there is little to suggest they actually are able to link scientific ideas with the phenomena they see. In this study comments made by students from all three areas of data collection seem to suggest that teachers are delivering practical work in a recipe style manner, similar to the findings by Clackson and Wright (1992). Therefore, students in this study who were doing practical work in a recipe style manner, were able to effectively describe the phenomena that they *saw*, as is reported by Millar and Abrahams (2008) because students were able to describe what they saw. Hence, a small minority of students (22% from Level 1 data seen in table 5.1) in this study claimed they were unable to learn in practical work because the main Level 2 data suggested that they could not get the answers they were meant to be seeing – that is the practical work was not producing the phenomena for them to see. Indeed during observations and focus groups, students were able to explain what they saw or were doing but could not explain the ideas behind it, as the following discussion from an observation shows:

> Nathan 10P: We had like a circle, because obviously the thing is in a circle, and it was divide into eight and we had a jelly baby in each section. We put them in a microwave for like a minute and took them out to see which ones had melted first.
> Researcher: So what did you learn there?
> Nathan 10P: I suppose I'd never known [how] to cook things properly in a microwave, how a microwave works, like you have the turntable in it. I wouldn't have known that if I hadn't done that.

The example above is similar to that reported by Toplis (2012) in which students were able to describe what happened but were unable to explain the scientific theory behind that which they saw. Further to this, there were also claims from the students in the questionnaires and interviews carried out in this study that practical work was not always the most effective way for students to learn. Indeed, for some students, especially in the latter years of school, discussed further in Chapter 6, the theory lessons were more useful in learning what was needed for their theory examinations. This suggests that whilst students in this study claimed to learn from practical work, what they really are claiming is that they are able to see 'phenomena'. Therefore, this can explain why students would rather do non-practical work activities in order to learn what is needed for their theory examinations.

5.5: The affective domain of students' attitudes to practical work

Previous studies (Cerini et al., 2003; Hart et al., 2000; Osborne & Collins, 2001; Parkinson et al., 1998; Wellington, 2005) have reported that students claim to enjoy doing practical work in science and the data in this study found similar. In this study the general findings show that the large majority of students (75% in the Level 1 data seen in table 5.1) claim to enjoy doing practical work in science lessons. The reasons given for their likes and dislikes to practical work within the affective domain that were given in the Level 2 data included: preference, the opportunity to discuss, the teacher influence, and personal autonomy and freedom. These areas will now be discussed in light of the findings.

5.5.1: Preference

From the Level 2 responses, the majority of students claimed that the opportunity that practical work provided them with such as the chance to work and talk, sharing their ideas verbally rather than writing them down, was important to their enjoyment. Indeed, Murphy and Beggs (2003) found similar results when discussing science with students, that they had a preference to doing as opposed to writing. Many researchers including Osborne and Collins (2001) and Toplis (2012), found that students referred to writing and copying from a textbook as a tedious form of learning and that they would *prefer* to be getting 'hands-on' with practical activities. Interestingly however in this study, during the observations and focus groups none of the students involved spoke about practical work being their *favourite* part of science lessons, instead students spoke of *preferring* practical work because of the opportunity of being 'hands-on':

Yiesha 7B: I prefer to get my hands involved, you know like hands on in the practical work unlike theory.

Abrahams (2009) and Toplis (2012) have also spoke of students being able to have a go themselves with scientific equipment because they feel they are more engaged and have a preference to it over other methods of learning. Certainly the enjoyment of ‘doing’ over ‘writing’ was a Level 2 reason many students chose for other arguments in response to other statements including the reason for why they found practical work easy (statement 6). Whilst this statement (Statement 6) in the questionnaire received an equal number of students agreeing as to not choosing to agree (seen in table 5.1), the argument for practical work being easy was in fact not an objective claim but rather that they felt it was *easier* than copying out of a book, as seen in their Level 2 responses. The argument seems to be more the case of them preferring the lack of writing involved in practical work rather than the *relative* ease of doing it. As the comment by one student suggests the perception of relative ease arises primarily from the associated lack of writing that they associated with doing practical work:

Leigh 9C: Well...doing practicals is easier than copying loads of words from our textbook. I mean after a while your hand starts to really ache doing writing and then I can’t hold my pen etc...
Researcher: Do your hands ache doing practical work though when you’re playing with equipment?
Leigh 9C: Not really no, I mean it isn’t intense then but, just, like this one time I burnt my hand on some tong things, hurt but was well funny, but that’s all you can do really.
Researcher: Ouch, that must have hurt though, so do you like writing in science?
Leigh 9C: No way Miss, it’s well boring.

Whilst the above example suggests that practical work has a means of offsetting the boring nature of other learning methods during science lessons, similar to those findings by Abrahams (2009), by the time students are reaching examinations years the need for getting the notes down is seen as more effective for learning (Jenkins, 2006) but they still want to do practical work (Cerini et al., 2003). However, the way that science is portrayed as a *practical* subject could also explain the reasons for not liking non-practical (what students in this study referred to as 'theory') activities.

Whilst there was only a minority (35% from Level 1 data seen in table 5.1) of students in this study that reported it was not their favourite part, their Level 2 argument was that they believed written work was quicker to complete than doing practical work. Indeed, as the following two students exemplify in comments made during lesson observations they discussed how they *preferred* practical work because it made the lesson pass quicker:

> Yiesha 7B: I prefer like doing practicals more than writing 'cause it is more interesting and quicker to get results
>
> Lucky 9C: Well, lessons go faster when we're doing practicals. I prefer them to copying from Miss really.

These comments by two students reveal a view in which science lessons are seen to pass much faster if they undertake practical work, as against 'theory' lessons. In contrast to this Toplis (2012) reports that students felt that they learnt faster during practical work because of the visual aid it provided them, whereas in this study, most students spoke simply of the 'doing' being quicker than the 'writing'.

5.5.2: Opportunities for discussion

It was not just that a large majority of students (75% from Level 1 data) claimed to enjoy doing practical work but also that a large majority of students (65% from Level 1 data seen in table 5.1), also claimed that it was their favourite part of science lessons. Their key Level 2 reason for claiming this was that practical work offered them an opportunity to communicate with friends and other people during lesson time in a way that was not permitted in any other form of regular science lesson. These findings are similar to those reported by Parkinson et al. (1998) that there were frequent student comments about the enjoyment of the social interaction provided by practical work when working in groups. Certainly, for some students in this study, as Lunetta, Hofstein and Clough, (2007) reported, group work, enabled them to work and interact with each other, and at times meant they were able to partake in "meaningful conceptually focused dialogue" (p. 405). Although, in this study students' attitudes also showed that there were times where they struggled to learn during group work because of their discussions turning to chats with friends. Indeed, of the small minority of students (22% from Level 1 data) that felt unable to agree that they were able to learn from practical work, 6% of them (from the Level 2 data) felt that this was because they would just chat with friends on issues unrelated to the practical task in particular or even science in general. These findings here are similar to those by Abrahams (2011) and Bennett (2005) where students' discussions may move away from the focus of the lesson to general chat. Indeed, in this study such an opportunity to communicate with friends was also a reason as to why students also claimed that lessons appeared to pass quicker when doing practical work as they simply enjoyed the opportunity for 'free time' to talk, as the following discussion from an observation suggests:

> Neo 10P: Some of the practicals we do in lessons, are free time for us to like relax.
> Researcher: How do you mean?
> Neo 10P: Well, chat, you know like catch up on the footy gossip! (laughs)
> Nick 10P: He means he gets to chat up his girlfriend, 'cause he works with her during practicals, don't you Neo?
> Neo 10P: She is my partner for practicals so, yeah alright we do chat!
> Nick 10P: And rarely work!

The example above that students use the time to chat with friends has similarly been reported by Abrahams (2011) and Bennett (2005) where students' discussions are can be less focussed on the practical work and more about general conversation.

5.5.3: Teacher influence

Furthermore, in comparing non-practical work to practical work a large majority of students (73% from Level 1 data) claimed that they preferred practical work because their Level 2 reason suggested that they would get bored and disinterested if their teachers were just to tell them what to memorise rather than doing it for themselves. Indeed, the following comments, taken from lesson observations, typify the views expressed by students in this study:

> Louis 9C: It gets boring the teacher telling us stuff, I prefer to do the stuff as it is more interesting that way.
>
> Yikira 7B: ... And the work's fun like if we get to do more hands on instead of writing all the time, copying.

Parkinson et al. (1998) have also reported similar findings to those expressed above, that students did not like practical work when their teachers talked for lengthy periods and especially when the explanations were not clear for them to understand. However, in this study it was found to be more the case that teacher talk was often seen as boring and uninteresting and that, as such, practical work provided a break from theory work.

5.5.4: Personal autonomy and freedom

Of the large majority of students (73%) who selected agree in Level 1 for preferring practical work, another Level 2 reason was how they felt they had the chance to personalise their own learning when doing practical work. Indeed, a large majority of students (71% from Level 1 data) felt they should do more practical work in science lessons giving the Level 2 reason that it gave them the opportunity to personally engage and get more involved in their science lessons. Certainly there was a large majority of students, (74% from Level 1 data), who, when questioned, claimed to like the freedom they experienced during practical work because it provided them with an opportunity to demonstrate independent learning (seen in the Level 2 data) and this was further substantiated during the focus groups as the following example illustrates:

> Yvonne 7B: I like the fact that...[Teacher Y]..., well, sometimes sets us work independently because I like to show that I can work on my own without anyone being there.

The point that student above is making is how practical work can give students the sense of ownership of their learning and previous studies, such as those by Cerini et al., (2003) and Osborne and Collins (2001), have also reported students valuing the personal autonomy that doing practical work provides. Whilst Osborne and Collins (2001) discussed how students felt a sense of ownership and control of their experiences in science education, there were a small minority of students (26% from Level 1 data) in this study that did not like the freedom they had during practical work with the Level 2 reason being that this freedom meant they did not know what they were doing. There were a small number of students who selected the Level 2 reason that explained whilst they felt they had more freedom in practical work than in theory lessons, they were still constrained by what they saw as too many rules. Such attitudes expressed during the observations where, as the examples below suggest, students felt that too much freedom was not always useful:

> Nicholas 10P: Normally it’s just explained to us and we’re left to our own devices to do it and it’s really confusing and I tend to just stand there like, [wondering] what’s going on.

Nadine 10P: In some things, yes, you need like at least a rough outline on what to do so you know roughly like how to do things. But if like… Then sometimes it's that easy you can go away and do it by yourself. Like with that all you had to do is fill up a cup with water, it's not really hard, but other times you need something to help you along.

These comments above suggest there can be instances where there is a problem with not getting the balance right between thinking and doing in practical work and consequently how this can lead to issues effecting student engagement; these are similar findings to those by Abrahams (2009), Abrahams and Millar (2008) and Wellington (2005). Also, Hart et al., (2000) reported that there needs to be more time spent on discussion and reflection as opposed to an array of apparatus and/or an overload of instructions if practical work is to aid students' learning. Indeed, students in this study would benefit from being able to discuss and reflect in order to prevent the confusion from doing practical work. According to Woodley (2009) if the learning outcomes and approach is clearly communicated with the students, to the extent that they are aware what and why they are doing the practical work, then there exists an opportunity for practical work to stimulate and engage students in ways, SCORE (2008) claims, other activities in science cannot. Certainly students in this study did value practical work as an important part of learning science and this was seen through the comments made by students to the researcher during the observations.

5.5.5: Conclusions on the affective domain

In conclusion, what emerged from these statements from the questionnaire about the affective aspects along with support from the observations and focus groups was how students frequently spoke of a preference to practical work over other teaching methods, such as writing, similar findings to Abrahams (2009) and Osborne and Collins (2001). Further to these findings, this section has explained that it is not just a preference over, or for, writing that influences students' attitudes, but also other factors such as personal autonomy and opportunities for discussion. Furthermore, there was a sense of personal engagement through doing practical work and although students were undecided as to whether it was easy to do practical work, they did claim that they enjoyed doing it. As students felt they were taking control of their learning as it gave them a feeling of personal autonomy with regards to their learning in science (Osborne & Collins, 200l; Woodley, 2009). It has also been suggested that practical work can become more meaningful to students when they have a personal interest in undertaking it (Abrahams, 2009) and that if students are made aware as to the aims and purposes of a practical task, it will better engage and stimulate them (SCORE, 2008, Woodley, 2009).

5.6: The behavioural domain of students' attitudes to practical work

This section discusses the findings that relate to how students behave with regards to doing practical work such as when working in groups. Also, this section discusses the value and relevance that students place on practical work and as a consequent whether this has an effect on their behaviour post compulsion and within science generally.

5.6.1: Group work

The environment in which the students in the study carried out practical work was primarily set up for group work and the majority of students (58% from the Level 1 data seen in table 5.1) found their environment for doing practical work easy with their Level 2 reason claiming that they felt confident working in it because they were able to ask for help if or when they needed it. Indeed, from the large majority of students (75% from Level 1 data in table 5.1) who claimed they enjoyed doing practical work, nearly half of these students (42% from Level 2 data) felt that this was because of the opportunity they had to work with equipment alone and in groups with other students. As can be seen in the examples below from the observations, which were very typical of student responses:

Yolanda 7B:	I can actually use science equipment, normally with a partner but still get to touch and have a go which is good.
Lewis 9C:	I enjoy doing getting to play with equipment in practicals and in groups sometimes.

Indeed, as the comments above exemplify, students in this study who favoured doing practical work over non-practical work claimed it was because they were able to use science equipment whilst working in a group. The argument here seen through the examples above that they are able to get ‘hands on’ with equipment in groups is similar to findings reported by Barmby et al., (2008). Toplis (2012) reported how group work in practical work can influence positive affection to practical work where there is a sense of togetherness to which there were similar responses found by students in this study seen in the comments above. Science lessons which enhance participation such as during practical work have been reported to have implications for student motivation and engagement (Smith et al., 2005) yet in this study students commented on being engaged in a *particular* practical for this reason but not in every practical. Indeed, whilst this may be the case for those students who are actively engaged in the practical work there were in this study other cases where the behaviour of students influences their enjoyment. Certainly there were a small minority of students (25% from Level 1 data) who claimed not to enjoy doing practical work. For many of these students this lack of enjoyment arose out of their dislike (seen through their Level 2 response) of having to work in a small group with other students who they thought would distract them from what they were meant to be doing. These Level 2 reasons in the questionnaires were further supported in the observations where students spoke of the anxieties and annoyance of working in pairs and groups with certain students that would not scupper practical work for them as the following students exemplify:

Liam 9C:	Some practicals, if you work with people that are not particularly like happy that you're working with them, sometimes they put you off working or they don't work particularly well and it puts you down.
Lara 9C:	I think it's better when Miss puts us into groups because if I was to, say, go with one of my mates then I know I won't be achieving my full capacity (laughs). We would so just muck about!

Nicole 10P: Well like the boys in my class, I'm not going to say who, always mess around and then Miss will just get really angry with them and then it's like this whole massive thing starts. It's just annoying, we don't do anything then.

These comments above suggest that the influence of behaviour of students within a class can impact on the rest of them not only during that particular practical work lesson but on a student's attitude to practical work itself and this has been noted by Abrahams (2009). As has Wellington (1994) discusses, when practical work is carried out in groups, particular students can dominate, be problematic which in turn can cause friction for other members of the group, as has been reported in this study. Indeed, behaviour of students in groups within practical work has been reported by Hodson (1993) as varying substantially and that due to individual students' characteristics, some groups may be good at practical work whilst others can be good at avoiding practical work entirely and potentially criticise or disrupt others: aspects that were commented by students in this study in the observations and focus groups. According to Solomon (1989) working in groups has become a typical approach in practical work. Indeed, for most schools and indeed the schools in this study, it is more economical to have enough equipment for pairs or groups as opposed to individuals. Therefore, as Solomon (1989) claims, this means that more students are working with other people and whilst in an ideal world they would be able to get along amicably in a 'minds-on' and 'hands-on' way, many students struggle to work and discuss the way that their teachers would like. Indeed, as was seen in this study, during secondary school when students are more inclined to crave approval from their peers over their teachers (Solomon, 1989), this may produce some issues between those that want to get on and those that want to mess around. Indeed, students did discuss how during group work there can cause issues with dominating students not effectively working with the less-domineering students, as also reported by Wellington (1994). Furthermore, some students commented also during focus groups, that they would take roles which involve little or no science, such as drawing out a results table with no understanding of the science behind the data collected, similar to that reported by Wellington (1994). Certainly, teachers when asked what would improve their confidence in teaching practical work, students' behaviour was a high ranking issue in SCORE (2008) and indeed teachers in this study commented on how the behaviour of the class would impact on what practical work would be carried out. This suggests that teachers are very much aware of the issues with student behaviour when doing practical work. In this study, the influence of peer interactions during group work did effect students' attitudes, and how the teacher organised the groups for many students did interfere with their desired peer interactions, similar to the findings by Smith et al. (2005).

5.6.2: Value of practical work beyond the lesson

With regard to how students feel about the value of practical work, beyond the realms of the science lessons, only a minority of students felt that what they *did* (43% from Level 1 data in table 5.1) and what they *learnt* (38% from Level 1 data in table 5.1) in science practical work would be useful to them when they left school. The main Level 2 reasons for why they agreed for both *learning* and *doing* were based on: career aspirations, the skills it gave them and the experience for later life.

5.6.3: Career aspirations

In this study, doing and learning in practical work had very little impact on students' career aspirations, with most students (seen in the Level 2 data) claiming they would not consider a job in a science profession that used practical work. Indeed, for the majority of students they were unable to agree to the usefulness of what they *did* and what they *learnt* in practical work for when they left school (57% and 62% respectively from the Level 1 data in table 5.1) mainly because they had no intention at the time of questioning, to work in the science profession (seen in the Level 2 data). These findings are similar to those by Jenkins and Nelson (2005) who also reported that a career in science was of no great appeal to students but they did claim that school science was valuable and did benefit their career chances. In this study, students during the observations and focus groups did talk about how studying science was a benefit for their career, even if they had no intention to go into a science profession. The example below from a focus group is indicative of student responses where they would not totally ignore what they saw as benefits of what they did in practical work to them upon leaving school and getting a job:

> Leo 9C: Well, I think it has something to do with my life because if I was to eventually get a job in something to do with science then I do think it would help me to know what to do if I did that.

What students are suggesting is how practical work has very little impact on their decisions in choosing a career or job, or to study post compulsion, but they do value practical work as part of science which they see as being a valuable subject itself. However, these findings contradict with claims made by teachers that practical work encourages students to continue in studying science and taking up a science-related career (SCORE, 2008).

5.6.4: Connections with the real world

From the comments during the observations, students discussed whether there was a connection between what they were learning from practical work and its impact on their life, what emerged was how uncertain students were of any connection:

> Lucinda 9C: I don’t know for sure but I know that one of the science teachers said that you’re more likely to get a job if you do get a science qualification, so I guess what we learn from science practical is important.
>
> Neo 10P: It’s just something you get on with, it’s not really… It doesn’t really make a difference.
> Naomi 10P: It’s different if you want to like do physics or something in your life.
> Neo 10P: Yeah, if you want it as a job.
> Naomi 10P: Yeah. But if you don’t then to be honest there’s not really that much point of just measuring a cup.

The claim these students are making relating to the relevance of *learning* in practical work has been reported by (Woodley, 2009) where when students are aware of why and what they are doing during practical work, it has the potential to impact on their engagement with it. Yet, Barmby et al. (2008) have discussed how students struggle to see the connection between the work they do in the laboratory and the relevance to their daily lives, aspects that were commented upon by students in the above examples. What the students in this study seem to be highlighting is the conflict that is going on in their thoughts, that whilst they understand practical work plays an important part of science, they are not able to see the relevance of *every* practical they do *all* of the time. Indeed, this seems to parallel the view of science as being seen as valuable and yet the majority of students do not wish to study it (Toplis, 2012), the idea that is “important but not for me” (Jenkins and Nelson, 2005, p. 41).

Whilst the majority of students may not think what they *do* or *learn* from practical work holds much relevance to them upon leaving school, the majority of them (53% from

Level 1 data seen in table 5.1) did feel that that practical work was a way of seeing how scientists work in the real world. The Level 2 reason for this is that students claimed that whilst it may not be as complex as what scientists do, what they did do was like a beginner's course. Yet the minority of students (47%) in the questionnaire (from the Level 1 data seen in table 5.1) did not agree because they were unsure of what a scientist did (seen in Level 2 data). Furthermore, for some students their Level 2 reasons suggested that what they did in practical work was not always about working like a scientist did in the real world as their teacher could not show them everything that happens. Certainly, SCORE (2008) discussed how teachers felt practical work was useful in explain how scientists work in the real world, although Jenkins and Nelson (2005) found that few students aspired to become scientists.

5.6.5: Skills from practical work

The skills that practical work gives and develops in them, such as how it encouraged team work and to be conscious of working with other students, was also a Level 2 reason for why what they did was useful upon leaving school. Indeed, practical work has been argued as providing and developing skills like practical skills and manipulative skills by science graduates according to Wellington (1998), aspects that students did begin to discuss with the research during the observations. Although the Confederation of British Industry (2011) would argue that there are not enough students leaving school with these necessary practical skills for the workplace and a minority of students in this study (43% from Level 1 data seen in table 5.1) did struggle to see the relevance of what they were doing in their practical work upon leaving school. However, this is perhaps down to the amount of opportunities students have to have a go at practical work, as indeed the large majority of students (71% seen from the Level 1 data in table 5.1) felt that they should do more practical work in their science lessons. A minority of students

(38% from Level 1 data) who did agree that what they learnt from practical work was useful gave the reason that practical work provided experiences for later life such as gain a better understanding of why and how certain things happen and work. Wellington (1998) also reported that whilst science graduates claimed practical work provides students with skills useful to life, he argues that there is little evidence to suggest that these skills learnt are of any transferable or vocational value. Parkinson (2004) claims that if it can be argued that the skills practical work teaches are valuable to many other subjects, it then may hold that practical work is making a valuable contribution to the rest of the student's life. Yet the evidence on the transferability of these skills suggests that it may be more hopeful than is realistically possible (Toplis, 2012) and indeed the majority of students in this study (62% from Level 2) could not see the usefulness of what they learnt in practical work for when they left school.

5.6.6: Conclusions on the behavioural domain

This section on the behavioural aspects such as the value and feelings to doing practical have suggested that group work can impact on students' attitudes to doing practical work (Hodson, 1993) and that this can influence the type of discussions that are carried out (Solomon, 1989). This section has also found that practical work can have some impact on students beyond the classroom depending on their own formed attitudes as to what they intend to do upon leaving school. Indeed, some students felt that practical work was useful in seeing how scientists work in the real world.

5.7: Conclusions in response to research question 1

In conclusion to research question 1 the findings suggest that students' attitudes to practical work often fall under the three areas of an attitude – cognitive, affective and behavioural -and that the majority of reasons lie in the cognitive and affective domains.

Within the cognitive domain, in this chapter the students involved discussed how they felt they were able to see for themselves and hence understand the theory by seeing it in practice. Whilst some students claimed they needed practical work to learn, some discussed the difficulty in seeing the results and the ease of doing the practical work. Indeed, some students spoke about their concerns with practical work giving them the wrong answers which had implications to their learning for examinations.

Indeed, in this chapter within the affective component, whilst most students claimed that they felt practical work was their favourite part of science lessons, this was more an issue about their *preferences*. There were many students that felt they enjoyed the ‘hands-on’ aspects of practical work but others also discussed how they preferred the non-practical activities. Students also showed feelings regarding personal autonomy in practical work and the implication that this depended on the openness of the aims and purposes of what they were doing.

This chapter has discussed aspects of the behaviour component. These range from the issues within the practical work lesson to beyond the laboratory in the real world. Students made claims regarding group work, the options of talking and working with their friends and the impact of issues regarding behaviour of members of the class. Beyond this, students spoke of the impact of practical work on their choice of career and the application to real world science including the claim of the learning skills. However, there seemed to be the underlying attitude that whilst practical work was important in science, science was not for them.

One conclusion which has emerged from the findings for research question 1 is how the types of reasons the students gave in response to the statements tended to be year restrictive in that, for example, students in the lower years were more likely to claim that practical work benefitted their learning than Year 10 students who were not sitting a practical examination, and therefore were more inclined to claim that theory benefitted their learning in science. Also, whilst in this section the differences between the three sciences were not specifically drawn upon the data showed that there were some significant differences into how students responded to each science in each age group. Therefore in order to analyse these relationships further in light of the data, the next chapter, chapter 6, will address research question 2 and 3 together because of the reasons for students' attitudes showing an entanglement between the year group – age of the students – and the science subject.

The next chapter, Chapter 6, will discuss, in relation to the emergent findings from the data, (i) the cognitive domain (ii) the affective domain, and (iii) the behavioural domain in practical work.

Chapter 6

Results and discussion of students' attitudes to practical work in each of the sciences and year groups

6.1: Introduction

This chapter considers differences and similarities that have emerged between students' attitudes to practical work when considered in terms of subject - biology, chemistry and physics - and year group (Year 7 to Year 10 inclusive). The research questions addressed in this chapter, relating to students within three schools, are:

> Research Question 2: To what extent, if at all, do students' attitudes to practical work differ across the three sciences?
>
> Research Question 3: To what extent, if at all, do students' attitudes to practical work in the three sciences differ within each year group?

The chapter uses the analytical framework that was discussed in Chapter 4 and developed further upon discussing students' general attitudes to practical work in science as seen in Chapter 5. The approach uses the cognitive, affective and behavioural domains of an attitude to discuss students' attitudes to practical work in biology, chemistry and physics and in Year 7 to Year 10 inclusive. The chapter begins by discussing the cognitive domain and looking at the conceptual understanding, procedural understanding and what students recollect. Having considered the role of practical work in the cognitive domain it moves on to consider its role in the affective domain in terms of the motivation, personal interest, situational interest and preference that students' attitudes to practical work generate. The chapter then considers the relevance of practical work in terms of student behaviour before concluding by answering research questions 2 and 3.

6.2: The cognitive domain

The cognitive domain as discussed in the previous chapters relates to “beliefs or thoughts about an attitude object” (Haddock & Zanna, 1999, p. 77), such as a student expressing their belief that practical work is a useful activity in which to learn science. It is the domain involving students thinking about practical work and discussing their ideas about it (Reid, 2006) in terms of their understanding and learning in it. In order to discuss the role of practical work in the cognitive domain the data will be considered in three sections. Each section will consider one of three distinct components within the cognitive domain. The first of these sections will consider conceptual understanding, referred to by Gott and Duggan (2002) as a “knowledge base of substantive concepts such as the laws of motion, solubility or respiration which are underpinned by scientific facts” (p. 186). The focus of the first section will therefore be on the data in which students have made claims, or commented upon, practical work in terms of its influencing their knowledge of concepts and scientific facts. The second section will consider the area of procedural understanding which, in this study, refers to those situations in which students discuss those aspects of practical work related to the ‘doing’ with, and manipulation of, objects and materials, and the general processes involves in undertaking practical work. Gott and Duggan (2002) describe procedural understanding as being:

> ‘the thinking behind the doing’ of science and include concepts such as deciding how many measurements to take, over what range and with what sample, how to interpret the pattern in the resulting data and how to evaluate the whole task.
> (p. 186).

The third section considers the issue of recollection in terms of the impact that practical work has on students’ ability to recollect what they did and learnt with objects and material and/or what they did and learnt about the associated scientific ideas (Abrahams

& Millar, 2008). In this respect this section will focus on the comments and claims made by students in which they discuss the use of practical work as an "*aide-memoire*" (Wellington, 2005, p. 104).

6.2.1: Conceptual understanding

Similarities and differences between the sciences and the year groups emerged in terms of students' attitudes to the influence of practical work on their conceptual understanding. In general, a majority of students (78% and 71% respectively) claimed that they were able to learn from practical work and that it helped their understanding of science. This study shows that a majority of students claimed that practical work helped them to learn, understand and recall scientific concepts. A finding that is much larger proportion of students when compared with the study by Abrahams (2009) who found that only a relatively small minority of students (8%) claimed practical work helped their understanding and learning in science. However, the generally positive picture of practical work, in terms of students' perceptions about its value in terms of developing their conceptual understanding, was not uniformly shared across all sciences and across all year groups and it is to these differences that I now turn.

First, beyond the generic similarities between the three sciences there were also some subtle differences in students' attitudes to the effectiveness of learning and understanding through practical work between biology, chemistry and physics. Within the questionnaire data it was apparent that, for statements relating to how effective practical work is in learning - statements 2, 5, 11 and 14, the average percentage of students who selected 'agree' ranged from 50% to 84%, with physics and chemistry holding a larger percentage for all four statements compared with biology. The findings here from the questionnaires suggest that whilst the majority of students' believe they learn from practical work across the three sciences, it is primarily biology where the percentage of students that felt they were able to learn from practical work was lower than chemistry and physics; this can be seen in table 6.1.

Table 6.1: Percentage of students that agreed to four statements across the sciences (raw data in brackets)

Statement	Percentage that agreed in biology	Percentage that agreed in chemistry	Percentage that agreed in physics
2. I am able to learn from practical work in biology/ chemistry/ physics lessons	74% (149)	76% (155)	84% (169)
5. Practical work helps me understand biology/ chemistry/ physics	66% (134)	75% (152)	73% (148)
11. For me to learn in biology/ chemistry/ physics lessons, I need to do practical work	50% (100)	57% (115)	54% (109)
14. I do find practical work helps my learning in biology/ chemistry/ physics	67% (136)	71% (144)	70% (141)

From these four statements (statement 2, 5 and 14) in the questionnaires that related to the effectiveness of practical work in developing conceptual understanding, there were no statistically significant differences in how the students responded for statements 5 and 14 across the three sciences when combining all year groups. However, there was a statistically significant difference between the number of students that agreed to statement 2, for biology practical work when compared with physics ($\chi^2 = 5.91$, $p < 0.05$). This difference showed that more students were able to agree that they could learn from physics practical work than biology practical work. Statement 2, relating to the ability to learn when doing practical work in science, was the most agreed with statement in the questionnaire when the results from all year groups and across the three sciences were combined. Indeed, the highest percentage of students that agreed to the statement was in physics (84%) followed by chemistry (76%) and finally biology (74%). This difference, between biology and physics was found to be statistically significant ($\chi^2 = 5.91$, $p < 0.05$) suggesting that physics students were statistically more likely to claim that they could learn from undertaking practical work than could biology students. However, it emerged that, students' attitudes to biology practical work was far more likely to be influenced by the nature of the practical work itself. What also emerged was the fact that 48% of physics students, compared to only 37% of biology students, saw the ability to observe the scientific phenomena for themselves through the working of the practical work, rather than merely being told what would happen by a teacher, as being important in helping them learn from undertaking the task.

Certainly, of those students who agreed with their ability to learn in practical work, 37% of students involved in the biology questionnaire explained they were able to see how everything worked through the practical as opposed to being told what happens by the teacher. Through further questioning in discussions with students about the ability to learn from practical work, they were able to provide examples of practical work which demonstrated how they were able to learn and understand from seeing and doing during it, as these Year 7 students explained during a focus group:

> Yara 7B: We got to dissect that chicken, that was alright.
> Researcher: What happened in the dissecting of the chicken then?
> Yousef 7B: We were like taking a bone out of a chicken leg.
> Researcher: A bone out of a chicken leg?
> Yousef 7B: Like showing us the marrow.
> Yara 7B: Showing us all the tendons and the muscles and different parts.

The finding here that students saw it important to see the scientific phenomena for themselves by doing the practical work, suggests that they want to be able to learn by themselves a sense of personal autonomy in their learning in biology. This is similar to Cerini et al. (2003) and Toplis (2012) who found that students believed that if they had produced the phenomena then they were convinced that they had learnt the associated scientific ideas. Whilst some practical work is used by the teacher to help students link the domain of ideas with the domain of observations, it is how teachers use practical work to get students to *do* with and manipulate objects that students in this study are actually claiming to learn from. In that, when students claim they are able to learn from practical work, what is reflected in their attitudes is that they actually feel they are able to learn how to use objects, manipulate objects and perform tasks with the objects. Their claims do not appear to be suggesting that they were able to link the two domains. Indeed, Blumenfeld and Meece (1988) reported that students can be engaged and interested in what they are *doing* but this can be without any cognitive engagement and little actual learning of scientific concepts. Indeed, during many conversations with students during observations and focus groups, students discussed how it was getting the opportunity to manipulate objects that helped them to learn, as the following comment illustrates:

> Yettie 7B: I think I am able to learning doing practical work as we get the chance to have a go and do things with science stuff in the lab.

Whilst it appears as if these students were supporting the old adage that ‘I hear and I forget; I see and I remember; I do and I understand’ a view endorsed by the House of Commons Science and Technology Committee (2011). However, whilst the latter claimed that “students learn better by doing as this helps them to understand” (p.1) what emerged from this study unlike the finding of Abrahams and Millar (2008) in which it was found that a large proportion of students felt that part of the effectiveness of practical work was, from their perspective, that it helped them to develop their conceptual understanding, was that the learning referred to by students related essentially to procedural, rather than conceptual, understanding. The following comment from an observation explains this further:

> Lorna 9C: We get to use acids, like hydrochloric and we learn how to follow the acid rules to use them safely so that we do better practicals.

The example above by Lorna exemplifies how what students mean by learning from practical work is actually better seen as learning procedural understandings rather than conceptual understandings, such as how to use acid safely and correctly in a piece of practical work.

In response to statement 2, of the questionnaire for chemistry and physics, the data showed some statistically significant differences that demonstrate the difference in how students see the effect that practical work has on learning within each of the sciences. Indeed, the results showed there were statistically fewer Year 10 students (69%) in chemistry that felt they were able to learn from practical work, when compared to Year 8 students (88%, $\chi^2 = 5.795$, $p < 0.05$). Also, statistically fewer Year 10 students (74%) felt they were able to learn from practical work in physics, compared with Year 8 students (90%, $\chi^2 = 4.737$, $p < 0.05$) and Year 9 students (90%, $\chi^2 = 4.737$, $p < 0.05$). A popular reason for students' attitudes showing they were able to learn from practical work related to the fact they were able to see for themselves, and work through the practical elements of the theory rather than being told by the teacher or a textbook. As the following examples from the observations show, students further consolidated these findings from the questionnaires:

> Lesley 9C: Well, it is fun and, well, like in physics, it helps us learn quite a lot because you can see the stuff happening instead of just seeing it in a textbook.
>
> Leona 9C: It's a lot more fun than just sitting down and writing about physics stuff because if we did that every lesson then we won't learn really only learn how to write better.
>
> Nigel 10P: It's better than like copying text down because we can see it happen in front of us and that helps us understand it.
> Yaqub 7B: I just learn from actually seeing the stuff, like the chemicals mix up in a practical but I can't see the chemicals change in a book or just by the teacher telling me.

Whilst biology students expressed the view, in response to statement 11, that practical work was a useful medium for learning this view was not shared by students in chemistry and physics. Indeed, 53% of Year 10 student in chemistry and 71% in physics whilst claiming that practical work was an interesting and fun activity nevertheless selected the option in the questionnaire that indicated that they preferred written work for learning. This might have been because, as the following example illustrates, some students felt that written work, in contrast to practical work, provided them with something concrete to refer back to for the purpose of later examination revision:

> Norbert 10P: Like our exams are all written now so like we don't need a lot of practicals. But like on your exam, cause we don't know what will be in it, it might have some questions about practicals and if you just sat there and copied down loads of stuff about the practical you're not really going to know properly what it is, so then you need the practical as well as the written stuff.

This seems to suggest that as students mature, and the pressure to succeed in examinations grows, they feel a developing need a balance of both theory and practical but, with exams being written, there is the need to write rather than do. Such feelings that they needed them both to fully benefit their learning, rather than just through practical work alone was seen through the comments during the observation and focus groups in the examples below:

> Nelly 10P: I think it's different for people because I think people learn in different ways. I think some people prefer to write down whereas other people prefer to do it. Just need a bit of both.
>
> Nigel 10P: It's better than like copying out of a textbook because it helps us understand it. I understand what we're doing and so on but I think I need to write it down to actually learn.

Whilst these students also spoke about being able to learn better from practical work there was a slight difference in terms of why they felt able to learn from chemistry practical work as compared to practical work in biology or physics. This finding emerged from the chemistry questionnaire where 43% of those students that felt that they were able to learn from practical work, did so because they were less bored than if they were writing. Indeed comments during the Year 9 observation substantiated the questionnaire's finding here:

> Lewis 9C: It gets you involved in it and you learn a lot more.
>
> Lola 9C: Because we learn more by doing it.
>
> Lenny 9C: I think you learn better if you remember the experiment instead of being told.

Conversely, many Level 2 responses that were selected after disagreeing that practical work does not able them to learn in chemistry reflected the view that it depended on what they were doing as to whether they learnt anything, Year 10 students also commented on how not every practical they did taught them something new and that it was just an opportunity to chat with friends. For physics, the Level 2 responses whilst they were similar to chemistry, there were also additional reasons including how they learnt more from writing and especially for Year 7, Year 8 and Year 9, from the teacher as opposed to the practical work:

> Nadia 10P: Yeah, I'd probably agree with that because like when we do practicals we don't really know like sometimes what will happen, so if you're writing and like you learn it that way then the teacher does it as a demo and it's easier, I guess, for us.

Similarly for statement 14, statistically fewer students in Year 10 (51%) felt that they found practical work helps their learning in physics when compared with Year 7 (75%, $\chi^2 = 5.915$, $p < 0.05$), Year 8 (71%, $\chi^2 = 4.022$, $p < 0.05$), and Year 9 students (82%, $\chi^2 = 11.096$, $p < 0.001$). For chemistry statistically less Year 10 students (59%) found practical work helped their learning in contrast to Year 9 students (80%, $\chi^2 = 5.322$, $p < 0.05$). What this seems to suggest is that as students progress from Year 8 to Year 10 the significance of practical work for chemistry and physics as a learning tool declines which is reminiscent of the findings by Barmby et al. (2008) and Bennett and Hogarth (2009). Indeed, there were comments during the observation and focus groups with the older students that echoed this view that in this example that physics practical work was not a useful learning tool:

> Researcher: Oh right, okay. What do you think to this practical then? What are your thoughts on practical work?
> Naomi 10P: You don't really learn much.
> Researcher: You don't learn much?
> Naomi 10P: No.
> Nat 10P: No.
> Researcher: Why do you both think this?
> Naomi 10P: We do them, but I just enjoy being able to chat, I mean free time is limited in school and this is a good time to actually catch up! I can't learn from putting some equipment together...
> Nat 10P: ... neither can I. It is just very limiting to us. I mean I can't explain most practical I do but I know how to do it but I just can't explain it, unlike written stuff.
>
> Nigel 10P: We get to learn from our mistakes, I guess.

Yet, in this study, when considering by year groups for each science, the picture becomes different with students' attitudes separating the sciences. Indeed, for physics between the year groups, there were statistically significant differences when comparing Year 10 with Year 8 and Year 9 for statements relating to learning in practical 2, 5 and 14. The percentage of students that agreed with these statements can be seen in table 6.2.

Table 6.2: Percentage of students across the year groups that agreed to four statements in physics (raw data given in brackets)

Statement	Percentage agreed in Year 7	Percentage agreed in Year 8	Percentage agreed in Year 9	Percentage agreed in Year 10
2. I am able to learn from practical work in physics lessons	80% (41)	90% (46)	90% (46)	74% (36)
5. Practical work helps me understand physics	73% (37)	78% (40)	86% (44)	55% (27)
14. I do find practical work helps my learning in physics	75% (38)	71% (36)	82% (42)	51% (25)

Indeed, for physics, it was only Year 7 students where the ability to learn from practical work (statement 2) was not the statement that was agreed with by most students. For students in Year 8, Year 9 and Year 10, statement 2 was the highest agreed with statement with the majority of them claiming that practical work enabled them to learn in physics. These students who agreed with this statement all selected the same reason why, in that they claimed they were able to see for themselves how everything worked as opposed to being just *told* what would or should happen in physics. Also, whilst there were no statistical differences between how students in Year 7, Year 8 and Year 10 responded to this statement in physics compared to biology and chemistry, there was in Year 9. This statistical significant difference for statement 2 showed that the majority of students were able to agree that they were able to learn from practical work in physics (90%, $\chi^2 = 9.490$, $p < 0.01$) than in biology (65%). Furthermore, for statement 5, whilst there were no statistically significant differences in how Year 7 or Year 10 responded for each science to it there were for Year 8 and Year 9. Indeed in Year 8, statistically more students ($\chi^2 = 4.330$, $p < 0.05$) felt they were able to agree that practical work helped them to understand physics (78%) than for biology (59%) – seen in statement 5. This was echoed further in Year 9 where there were more students who felt practical work helped them to understand physics (86%) than for biology (59%, $\chi^2 = 9.650$, $p < 0.01$). Just as with statement 2, the most selected reason for why those students in Year 8 and Year 9 were able to agree for biology and physics was the same - in that they could see for themselves as opposed to someone else telling them. Therefore, even though students in Year 8 and Year 9 responded to statement 2 and statement 5 in the same way, what is reflected in the statistics is that as students mature over these two years their negative attitudes to learning and understanding in physics practical work increases compared to biology. Their ability to *see* physics in action makes them feel they are able to understand and learn in physics. The findings in this study on practical work in physics aiding understanding and learning was also reported by Owen, Dickson, Stanisstreet and Boyes (2008) when questioning students in Year 7 to Year 11 on their attitudes to physics. In this study, students spoke of practical work in physics as being an activity where they were mentally involved performing the practical work, similar to Owen et al., (2008). As the physical sciences are seen as difficult by students (Simon and Osborne, 2010), it could be argued that as practical work is seen by the majority of students (75%) in this study as enjoyable, it because the part of physics that is less complex and more of an opportunity to become engaged.

Considering the differences and similarities to the three statements (Statement 2, 5 and 14) for biology, the percentage of students that agreed to each are given in table 6.3 by year group.

Table 6.3: Percentage of students across the year groups that agreed to four statements in biology (raw data given in brackets)

Statement	Percentage agreed in Year 7	Percentage agreed in Year 8	Percentage agreed in Year 9	Percentage agreed in Year 10
2. I am able to learn from practical work in biology lessons	75% (38)	76% (37)	65% (33)	80% (41)
5. Practical work helps me understand biology	80% (41)	59% (29)	59% (30)	67% (34)
14. I do find practical work helps my learning in biology	71% (36)	71% (35)	65% (33)	63% (32)

Whilst there were no significant differences between Years 8, 9 and 10 for these statements in biology, there was a significant difference between Year 7 and Year 8 and

Year 7 and Year 9 for statement 5. This statement was the most agreed with statement by Year 7 for biology practical work. Indeed, 80% of Year 7 students agreed that practical work helped them to understand in biology but there were fewer students agreeing in Year 8 (59%, $\chi^2 = 5.350$, $p < 0.05$) and Year 9 (59%, $\chi^2 = 5.607$, $p < 0.05$). The reason why those students in Year 7 claimed to agree was that by doing the practical work they were actively taking part and not getting bored. This suggests that students believe that 'hand-on' practical work – irrespective of whether they are engaged in a 'minds-on' sense – will have a positive impact on their learning. However, Toplis and Allen (2012) argue that students being actively engaged in practical work does not necessarily mean they will learn the science concepts. Indeed, if students are not helped by practical work and guidance by the teacher to link what they see (domain of observables) with the scientific ideas (domain of ideas) (Millar, 2004) then there is little opportunity for learning to occur. Research by Abrahams, Reiss and Sharpe (2011) found that the majority of practical work lessons, that were observed as part of the Getting Practical: Improving Practical Work in Science (IPWiS) programme, were, to a large extent, ineffective at getting students to *learn* about the ideas but was largely effective at getting students to *do* with objects and materials. Therefore, it is understandable that when students were asked, in more detail, during observations and focus groups to explain what they felt they had been able to learn from practical work, nearly all students spoke of being able to manipulate objects rather than being able to discuss the scientific ideas:

> Nelly 10P: I'm not sure but I think we are learning about how to use a thermometer
> Noddy 10P: No, we're learning what to do with a thermometer, we learnt how to use it in Year 7.
>
> Yamelia 7B: We are learning how to use a microscope by looking at cells.

In both the cases above, the students were clearly unaware of what they were actually meant to be learning with Teacher N's learning objectives, in the Year 10 lesson, being to get the students to calculate the specific latent heat of water. Similarly in the Year 7 lesson that Yamelia is referring to, Teacher Y was actually trying to get them to look at the cell structure. In both these cases the findings support earlier results reported by Abrahams et al. (2011). In both cases, students were making claims of learning how to *do* with equipment rather than *learning* the scientific ideas. Conversely, for those older students (Year 8 and Year 9) who agreed, they claimed they could better understand when they saw what happens themselves unlike when they are told or when they read textbooks. Indeed, according to Delargey (2001), "Comenius would argue that this leads to a better retention of knowledge as the students experience this knowledge directly through their own senses" (p.83). In this study, whilst students were aware that they may not always understand what the teacher wanted them to understand from the practical work, they did comment on the effectiveness as a tool to their learning in sciences. Indeed, students claimed, during the observations and focus groups, that practical work was a useful method of understanding science and being able to learn by doing. The following examples from the observations demonstrate this:

> Leonard 9C: I've read things out of textbooks and then I never understand it afterwards until I've actually done it.
>
> Norman 10P: Yeah, because like if you're just copying it you might not like understand it and you don't ask. You might just like be copying it and not taking it in, but like if you're doing it yourself then you understand what's going on.

Norman is exemplifying an attitude that was held by the majority of students in the study. Indeed, 78% claimed they were able to learn from practical work. Yet, what Norman and many students in this study were suggesting is that in order to learn from practical work they have to be doing it themselves. The belief that getting ‘hands-on’ with the equipment means they are therefore able to understand.

Another story also emerges in chemistry when looking at the three statements (statement 2, 5 and 14) within and across the year groups. There were two statistical significant differences across the sciences for Year 9. The first statistical difference was where more Year 9 students felt practical work helped them to understand chemistry (84% - statement 5) than biology (59%, $\chi^2 = 7.820$, $p < 0.01$). Second, statement 2 showed that there were more students who claimed to agree that they were able to learn from practical work in chemistry (74%, $\chi^2 = 4.520$, $p < 0.05$) than in biology (65%). There were no other statistical differences across the sciences for the other year groups. When comparing the year groups within chemistry, the percentages by year for chemistry can be seen in table 6.4.

Table 6.4: Percentage of students across the year groups that agreed to four statements in chemistry (raw data in brackets)

Statement	Percentage agreed in Year 7	Percentage agreed in Year 8	Percentage agreed in Year 9	Percentage agreed in Year 10
2. I am able to learn from practical work in chemistry lessons	75% (38)	88% (45)	74% (37)	69% (35)
5. Practical work helps me understand chemistry	78% (40)	71% (36)	84% (42)	67% (34)
14. I do find practical work helps my learning in chemistry	75% (38)	71% (36)	80% (40)	59% (30)

From these findings there were statistically significant differences when comparing the number of students that agreed with statement 2 in Year 10 with Year 8 ($\chi^2 = 5.795$, $p < 0.05$). There was also a statistical significant difference between Year 10 and Year 9 ($\chi^2 = 4.073$, $p < 0.05$). In both cases the number of students that agreed to the statements was much lower for Year 10 than Year 8 and Year 9 for statement 2 and 5 respectively. Indeed, statement 5, regarding how practical work helps students’ understanding in chemistry, was the most agreed with statement by Year 9 students (84%) when compared to the other year groups.

The main reasons for Year 7, 8 and 10 students agreeing to the three statements on understanding and learning related to their ability to see chemistry and how it works so that they could understand it better than being told what happens. Yet for Year 9, these students agreed because they were able to get actively involved, and so were more able to learn from it. However, in response to statement 14, students also felt that practical work helped them in their module exams. When discussing with students during observations, students actually seemed to suggest that it was the ability to *remember* as opposed to learn the scientific ideas as the following comments during an observation suggests:

Lloyd 9C: I think you learn more from practical work because you remember it.

Yan 7B: You learn more because you remember but when you just write it down you forget.

However, by Year 10 students during the observation were not as supportive of chemistry practical work in terms of its contribution to their learning and understanding of chemistry concepts. Whilst some students spoke about being able to learn from practical work, other students claimed that they would struggle to understand or learn as the following students, during a practical lesson observations, explained:

Nora 10P: It is hard to learn because the practical work can go wrong or we make mistakes and then we can’t learn.

Neve 10P: Sometimes we don’t really know what is going to happen or what to look for, so then it is better if we’re writing because then you learn it properly and just know the answers.

One possible reason for the decline in students' attitudes to learning and understanding in practical work is how chemistry is seen as a difficult subject to study (Johnstone, 1991). Indeed, Johnstone (1999) discusses that whilst a lot of chemistry practical work refers to the senses such as the colour changes and escape of gases, there are the more detailed aspects such as the atoms, molecules that are not accessible to the senses and require more thought. As students are unable to physically sense the more detailed aspects of chemistry through practical work, it instead requires them to conceptually think to understand and connect the scientific thoughts with that which they observe and this is where the difficulty can arise (Hussein & Reid, 2009). Indeed, it is understandable that if students struggle with conceptually understanding the practical work, as they progress through to GCSE, it is the theory that they are more inclined to want to know when they are studying for theory examinations.

Another finding in response to statement 11 suggests that just over half the students in the study were able to agree that to learn in their science lessons they *needed* to do practical work. The percentages across the year groups and sciences to this statement can be seen in table 6.5.

Table 6.5: Percentage of students across the year groups that agreed to statement 11 in biology, chemistry and physics (raw data in brackets)

Statement	Percentage agreed in Year 7	Percentage agreed in Year 8	Percentage agreed in Year 9	Percentage agreed in Year 10	Average across year groups
11. For me to learn in biology lessons, I need to do practical work	53% (27)	51% (25)	53% (27)	41% (21)	50%
11. For me to learn in chemistry lessons, I need to do practical work	69% (35)	45% (23)	66% (33)	47% (24)	57%
11. For me to learn in physics lessons, I need to do practical work	69% (35)	63% (32)	55% (28)	29% (14)	54%
Average across sciences	64%	53%	58%	39%	53%

If, as students in this study claimed that they were able to learn from practical work, it might seem that this percentage of students would be greater and that they would claim to learn scientific ideas. However, instead what this study has found is that students are aware of the many forms of learning in science and how they learn in different ways – not just through practical work but written work, teacher talk and discussions. Although, the students in this study did not go as far as those in the study Toplis (2012) where students spoke of being visual, auditory or kinaesthetic but they did acknowledge that practical work was just a more interesting way of learning so they pay more attention doing it. Indeed, that was the main argument felt by half the students (50%) who in the study agreed that they needed to do practical work to learn in science. There were no reasons suggested that if they did not do practical work they would not learn in science or that it helps their understanding or makes scientific concepts more accessible. There was one slight decrease in Year 8, which did increase again by Year 9, and that was in response to whether in order to learn in chemistry they needed practical work. There were statistically fewer students in Year 8 than Year 7 ($\chi^2 = 5.755$, $p < 0.05$) and Year 9 ($\chi^2 = 4.465$, $p < 0.05$) that agreed. What many students in Year 8 claimed was that all they are taught in chemistry could not be carried out through practical work, they needed the theory too. The finding here that they needed the theory to support their learning suggests students were more aware of the limitations of practical work. The students in this study seemed less inclined to be committed to the benefits of practical work and learning, unlike those in studies where they spoke of practical work as providing them with the learning opportunities in supporting and understanding theory (Cerini et al., 2003) and that it makes scientific concepts accessible (Osborne & Collins, 2001).

Examining the data further within physics, there was statistically fewer students in Year 10 that agreed than in Year 9 ((χ^2 = 7.112, $p < 0.01$), Year 8 (χ^2 = 11.749, $p < 0.001$)and Year 7 (χ^2 = 16.045, $p < 0.001$). Furthermore in chemistry, there were statistically fewer students that agreed in Year 10 than Year 7 (χ^2 = 4.865, $p < 0.05$). Of those students in Year 10 that were not able to agree with the statement nearly half (49%) claimed this was because it was not possible to learn everything from practical work and that whilst it was enjoyable, they would not always have the written work to refer back to after the lesson. During observations and focus groups with Year 10 students, they commented on how the problems with practical work meant whilst it was acknowledge as an aspect of learning in physics, it was not always *needed:*

> Nicholas 10P: It can make the lesson a bit more exciting but its not really something that's needed, I mean we can't learn a lot with like plugging stuff in sockets if we haven't got it in our books to read up about.
>
> Natalie 10P: It depends on the topic, like if it was something on, I don't know, the solar system or something then I'd like do a practical...Well actually, no, I'd do a bit of both on that because we need to know the names and stuff of the planets.

Indeed, as Hodson (1998b) argues that because knowledge is assumed to come from observation, practical work is then focussed on the *doing* as opposed to *thinking* that practical work can produce the phenomena *and* that students can therefore derive the theory from the observation. What students suggest in this study is that as they begin to progress to GCSE level, they are aware of their own difficulties in understanding and thinking about the theory from the practical work they do. Indeed, Cerini et al. (2003) reported that many students felt that the new theory they were learning for their GCSEs was *sometimes* backed up by practical work and they frequently spoke of the pressure to get the right results in the practical work they did do during their GCSE years. The claims the students in this study were making about conceptual understanding in practical work are better thought of in terms of their ability to remember what happened and what they actually *did* with objects – the *doing* as opposed to the *learning.* This finding reinforces the report by SCORE (2008) where only 30% of teachers placed the development of conceptual understanding in the top three purposes of practical work and that students find it difficult to identify the conceptual understanding that their teacher's intended them to learn as a consequence of undertaking the practical work.

6.2.2: Procedural Understanding

In this study, students did comment on the opportunities that practical work gave them with regards to procedural understanding. Of the students that agreed that doing practical work helped their learning in biology (statement 14), there were a few students (18%) that felt practical work helped them as if they went wrong they could learn from their mistakes. Whilst there were fewer students in chemistry and physics (both 9% of students), there were comments made during the observations of students claiming that practical work gave them the opportunity to get hands-on and learn from their mistakes in how to better do practical work:

> Yoda 7B: Yeah, when I'm doing it I can actually understand what we have to do and I can like find out myself instead of just trying to figure out what he's saying.
>
> Neil 10P: If the practical goes wrong we get to learn from our mistakes and see how to use the equipment better next time so it doesn't happen again.

However, the students in this study claimed that by being hands-on and practising practical work gave them a chance to be better engaged in, and as a consequence learn more effectively, what they were doing in science. Comments made by students in the observations related to the fact that they felt that they were getting hands-on experience with the equipment and made this connection between engagement in doing and learning:

> Yal 7B: Yeah, and you get involved more, you start to do things with science equipment and learn how it works which gets me involved. I want to know what all the equipment does so I can use it myself.
>
> Natty 10P: I think getting hands-on, helps us to use equipment safely, like the thermometers. And if you find out for yourself you understand what actually happens so that can help you in a test so you can explain what's happened, what you did and what the results were.

These comments appear to suggest that students feel that through the use of practical work they are able to take ownership of their learning and therefore, bring about an effect on their understanding and learning in the science. Indeed, previous studies such as Osborne and Collins (2001) and Turner et al. (2010), have reported on the importance of students feeling personally engaged with the activities they carry out in practical work because it is useful as a means of preventing disruption and enhancing the learning experience. However during practical work, procedural understanding involves the ability to understand concepts such as "reliability and validity, measurement and calibration, data collection, measurement uncertainty, the ability to interpret evidence" (Roberts et al., 2010, p. 379) and these were aspects which students in this study did discuss the difficulties in carrying out such procedures. The comments made by students during observations did discuss the difficulties of certain aspects of practical work because of issues with equipment and practicalities of doing it:

> Nelson 10P: We put this weight on a crane and had to keep the pen tied to the weight or something, but like we had to take it off every 10 minutes and it kept falling off, I don't know why we had to keep doing it over and over again, repeating it.
> Nicola 10P: That was making it a fair test but the equipment was exactly fair and the tables kept moving it so I think it wasn't a fair test at all.

There were also concerns raised about how to use the equipment safely as students in this study did discuss how they were often anxious of the methods during practical work. They felt that because they might not be able to understand what to do, or that the equipment was dangerous to use it made them worried about carrying it out as this comment from the observation suggests:

> Nicole 10P: But it's quite scary sometimes, not like physics but like in chemistry when we're using all the chemicals and stuff, if like the Bunsen starts to catch other things on fire, or sir tells us that the chemicals are like corrosive. I get scared then.

The concerns these students are making about issues relating to the procedural understanding suggest that this is where they make their claims of the value of practical work on their learning. Whilst they are able to remember particular practical work that went wrong, they still struggled to understand the scientific ideas linked to it. Their attitudes to procedural understanding seem to suggest they are still unsure of how to do practical work, how to improve their readings or reliability of their results; these are all areas that Roberts et al., (2010) claim can be improved by students carrying out practice investigations which focus on a specific procedural understanding.

6.2.3: Recollection

The use of practical work as a means to help in the recollection of aspects of biology, chemistry or physics was something often claimed by students in this study, as seen in the comments below:

> Yvonne 7B: Practicals are good for remembering stuff in biology.
>
> Liam 9C: 'Cause practicals involve me doing it, I remember the chemistry.
>
> Nathan 10P: It is useful to remember what happens, like with the jelly baby practical because we saw it happen there and then.

Students felt that practical work helped them to recollect material from science lesson because it enabled them to *see* for themselves, through first-hand experience as opposed to learning through the use of secondary sources such as textbooks or teacher talk, phenomena and procedures. Details of the percentage by science and year group are presented in table 6.6 that shows the percentages of students that agreed with statement 2 *and* selected as a reason for doing so the opportunity that practical work provided in terms of seeing an event or phenomenon first hand.

Table 6.6: Percentage of students that selected 'agree' to statement 2 and selected the Level 2 option relating to seeing for themselves by science and year group (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	50% (19)	61% (23)	63% (26)	58%
Year 8	38% (14)	56% (25)	50% (23)	48%
Year 9	61% (20)	41% (15)	52% (24)	51%
Year 10	51% (21)	51% (18)	67% (24)	56%
Average percentage across year groups	50%	52%	58%	53%

For statement 5, as seen in table 6.7, there were fewer students in physics that claimed they agreed that practical work helped them to understand in science because they could see the phenomena themselves than in biology (47%) and chemistry (43%). Furthermore, fewer Year 7 (32%) students across the sciences on average agreed that they could understand by observing the phenomena when compared to Year 9 (46%).

Table 6.7: Percentage of students that selected 'agree' to statement 5 and selected the Level 2 option relating to seeing for themselves by science and year group (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	32% (13)	38% (15)	27% (10)	32%
Year 8	45% (13)	44% (16)	30% (12)	40%
Year 9	57% (17)	38% (16)	43% (19)	46%
Year 10	53% (18)	50% (17)	30% (8)	44%
Average percentage across year groups	47%	43%	32%	41%

Yet considering the percentage of students that agreed to statement 14, they agreed that practical work helped their learning in biology, chemistry and physics there were few students that felt being able to see the results at first hand in order to recollect them in the future, as seen in table 6.8.

Table 6.8: Percentage of students that selected 'agree' to statement 14 and selected the Level 2 option relating to seeing for themselves by science and year group (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	39% (14)	21% (8)	18% (7)	26%
Year 8	37% (13)	33% (12)	31% (11)	34%
Year 9	33% (11)	25% (10)	19% (8)	26%
Year 10	34% (11)	20% (6)	48% (12)	34%
Average percentage across year groups	36%	25%	29%	30%

Indeed, comparing the results for statements 2, 5 and 14, it appears that whilst students do claim practical work helps them to see the phenomena it does not necessarily mean that they are able recollect it for future reference. Indeed, whilst the percentage of students who agreed to all of these three statements was lower for biology than physics and chemistry, as seen in table 6.9, the percentage of students that selected the reason was higher (see table 6.6, 6.7, and 6.8).

Table 6.9: Percentage of students that selected ‘agree’ to statements 2, 5 and 14 for biology, chemistry and physics (raw data in brackets)

Statement	Biology percentage that agreed	Chemistry percentage that agreed	Physics percentage that agree
2. I am able to learn from practical work in biology lessons	74% (149)	76% (155)	84% (169)
5. Practical work helps me understand biology	66% (134)	75% (152)	73% (148)
14. I do find practical work helps my learning in biology	67% (136)	71% (144)	70% (141)

The possible reason for this finding is perhaps due to the perceived difficulty of chemistry and physics compared to biology in learning (Bevins, Byrne, Brodie & Price, 2011; Johnstone, 1991), especially in terms of understanding what they observed in relation to the scientific concepts (Hussein & Reid, 2009; Johnstone, 1999) that they find it hard to know what to recollect as the comment below suggests:

> Lara 9C: In chemistry practicals, I am so confused with all the things that are going on, the flashes, the smells, the colour changes that I am unsure what it is I need to remember!
>
> Natalia 10P: Sometimes in physics it is not easy to see the physical stuff that sir wants us to see and if I don’t see it with my eyes then I can’t remember it.

As the above comments suggest, that were common to those in this study, they struggled to know what they were to recollect and that sometimes it was not easy to see the science they were meant to be recollecting,

Certainly, the highest agreed statement by students in Year 7, with regards to biology (80%), was statement 5 because they felt they could see and recollect the biology concepts. This was due to the fact that for Year 7 students biology practical work involved dissection that they saw as relevant to life, similar to the findings by Osborne et al. (2003). Whilst dissection is not carried out frequently in biology it does produce hot debates in discussions with students (Murray & Reiss, 2005) as was found in this study. Dissection in biology practical work produces what Abrahams and Millar (2008) refer to as the "'gore' factor" (p. 1962) and, they argue, that whilst such events become unique "episodes" (White, 1988) – that students recollect doing – they struggle to remember the *actual* scientific ideas, as indeed was found in this study. It is these types of episodes that students tend to recollect and that it is the recollection of the novelty factor, such as the 'gore factor' that engages the students (Toplis, 2012), as students reported in this study. As students in this study can *recall* what happened in a particular piece of practical work, students then claim and indeed believe they have learnt and understood the science from it. However, the learning of ideas, the 'minds-on' aspect did not seem to have occurred in this study, potentially due to the limited proportion of practical work lessons that are actually linking 'hands-on' and 'minds-on' (Abrahams et al.,2011) or that the students simply could not remember (Toplis, 2012). During a focus group in School Y, Yasmine discussed with the researcher how she was able to remember aspects of a chicken leg because she was able to see the actual parts in front of her:

> Yasmine 7B: He showed us them so we could like get an idea of what they actually look like instead of like seeing them in cartoon and like seeing pictures of them, because if we didn't see them straight up in front of us we wouldn't have a good… We wouldn't be able to remember it really well.

What is being suggested here is that students felt better able to recollect what they had learnt from this practical because they took an active part in what they were doing in a way they had never done so before:

> Researcher: Okay. So what do you remember from the chicken?
> Yasmina 7B: Well, I remember seeing the muscles and the tendons and ligaments and how they moved with each other.

The finding here, that students showed a keen interest in this dissection of a chicken leg, is similar to the work by Holstermann, Grube and Bögeholz (2009) that found students enjoyed the hands-on experience of dissection more than other practical work based activities. Furthermore, the finding here that students report on the recollection of the dissection, being able to *see* the tendons of the chicken leg and so on, was also reported in Holstermann et al., (2009) where students commented on recollecting through seeing the structures and mechanisms involved during the dissection. Due to the fact students evidently find it easier to recollect memorable events – which in itself is unsurprising given that they are in some sense more memorable – they seemingly believe that such recollections are evidence of conceptual understanding. When students were asked in the questionnaire as to whether they should do more practical work in biology, chemistry or physics, of the large majority of students (71%) that agreed, of this 71%, there were 28% of students that believed it was because they were able to recollect more doing the practical work compared to answering questions from a textbook. Indeed, the when comparing between the year groups fewer Year 10 students agree with this reason than Year 7 students, as seen in table 6.10.

Table 6.10: Percentage of students that selected 'agree' to statement 10 (I think we should do more practical work in biology/ chemistry/ physics lessons) and selected the Level 2 option relating to learning and remembering by science and year group (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	35% (11)	26% (9)	38% (14)	33%
Year 8	31% (12)	24% (10)	29% (12)	28%
Year 9	31% (11)	36% (14)	33% (13)	33%
Year 10	11% (4)	19% (6)	19%(5)	17%
Average percentage across year groups	27%	26%	30%	28%

Possible reasons for why students by Year 10 are not able to agree that they are able to remember more doing practical work could be due to the perceived dearth of practical work by GCSE level as reported by teachers (SCORE, 2008). Or indeed, that by Year 10, students are aware of the need to know the theory rather than the practical work for the GCSE examinations. Indeed, teachers from the three schools in this study claimed that the current focus from GCSE courses on assessment is limiting and detrimentally impacting on the practical work done in science, similar to the findings by SCORE (2008). Consequently, this could explain why students in this study reflected on the pressure of learning the theory for the examinations.

During the focus group with Year 9 students they were able to recollect two experiments that illustrate the unique episodes discussed by White (1988) that not only makes for an unrealistic image of science (Abrahams, 2007) *but* the students were unable to fully explain the scientific ideas, they could only describe what it was they *saw*:

> Leanne 9C: In [Teacher L's] class she had this like pot of… I don't know what it was. And she put a substance in it and it just went black in like two seconds.
> Researcher: Why did it do that?
> Leanne 9C: I'm not sure, I guess it burnt.
>
> Lynne 9C: I remember when we were doing about base metals and I think it was sodium. [Teacher L] put it in water and it fizzed and it was really interesting to know the reactivity and how reactive things were, because you can't really do that for yourself. You can't really buy sodium, potassium or rubidium anywhere.
> Researcher: Can you tell me what you were learning about sodium?
> Lynne 9C: That it reacted with the water and is a base metal. I think that was what we were learning.

In this study, what is reflected in the data is how because students were able to recollect what they saw and were able to discuss what they did these practical work lessons were effective at getting students to do that. Students in this study were able to “recall things they did with objects or materials, or observed when carrying out the task, and key features of the data collected” (Abrahams & Millar, 2008, p.1949). However, because the students were unable to discuss the scientific ideas behind that which they observed, the practical work discussed in this study was not effective in getting the students to *think* about what they saw in relation to the scientific ideas. This therefore suggests that whilst students were claiming to recollect the scientific learning, they were actually claiming to recollect what they observed or did with objects. Indeed, within the physics and chemistry observations, students were also unable to explain the scientific ideas behind the actual practical work they were doing but they were able to discuss what they saw, as the following comments suggest:

> Nikki 10P: Well, there was a practical we did with power packs and the lad kept turning the lights off
> Researcher: What did you learn?
> Nikki 10P: I’m not sure, but we were bending the light with prisms and stuff
>
> Lacy 9C: We burnt something and the flame was green, not sure why it went green, guess it was something to do with oxygen but it was a really pretty green.

What has emerged from this study is that whilst students claim to learn and understand biology, chemistry and physics through practical work it is not scientific ideas that they are recollect but instead the actual events and observations from the practical work. These findings are similar to those reported by Osborne and Collins (2001) where they found students commenting on how biology was favoured because they liked to learn about themselves and because of the connection of the practical work relating to the learning about the human body. Furthermore, it meant that “scientific concepts were more accessible and more easily retained when supported by practical involvement” (ibid, p. 458). The fact they are doing and seeing biology, chemistry or physics in action meant that they at least thought they were learning through practical work. Students seem to feel that they were therefore more able to remember and consequently learn and understand. It is important to note that this study was only concerned with the *claims* students made regarding the learning value of practical work and not the *actual* reality of what was *actually* learnt.

6.3: The affective domain

The affective domain, as discussed in Chapter 3, Chapter 4 and Chapter 5, refers to the "feelings or emotions associated with an attitude object" (Haddock & Zanna, 1999, p. 77). For example, students may highlight that practical work makes them feel happy in, or enjoy, science or show their excitement, or boredom, whilst doing practical work in biology, chemistry or physics. Within this domain, key phrases such as *motivation, personal interest* - also known as individual interest but will be referred in this chapter as personal interest, *situational interest and preference* are referred to and these have been discussed in Chapter 3.

Motivation is "an inner drive to action" (Bandura, 1986, p.243) which, if operationalised, might manifest itself in students opting to study science at 'A' level or taking part in an after school science club and can endure over time. In contrast personal interest reflects an intrinsic keenness (Dohn, 2011) – it holds students' attention, in this case for doing practical work. Personal interest, relates to interest within the individual that is sustained and relatively stable (Hidi & Harackiewicz, 2000). Personal interest, in this study, would be seen when students have been stimulated by the practical work carried out in lessons, in which they then claim, due to this intrinsic desire, to continue carrying out practical work beyond the classroom. Situational interest is where an activity (such as practical work) in a situation (science lesson) creates “a more immediate affective reaction that may or may not last” (Hidi & Harackiewicz, 2000, p.152). This situational interest relates to the enjoyment experienced by a student only in that situation (lesson) and might reflect the fact that they simply have a *preference for* doing practical work over written work as they find the former more enjoyable than the latter. Tsai, Kunter, Lüdtke, Trautwein, and Ryan (2008) explain that unlike personal interest, which is a stable construct, the affect of situational interest is restricted to, and lacks continuation beyond, the lesson. Preference in this section will be referred to when discussing students’ claims in liking practical work *more than* or *less than* other aspects of learning in biology, chemistry or physics. The first section to be discussed within the affective domain is motivation.

6.3.1: Motivation

Throughout this chapter, the use of the term motivation will follow from Bandura’s (1986) claim that "a motive is an inner drive to action” (p. 243) and, as such, should not be confused with its use by students when these are reported where its meaning is better understood as implying situational interests.

As discussed in the literature review on attitudes in Chapter 3, it has been suggested (SCORE, 2008 and Hodson, 1990) that practical work is used to generate motivation in science. In this study, and the results here are similar to those reported by Abrahams (2009), students spoke, as the following three examples from the observations illustrate, about motivation when describing the value of practical work:

Yannick 7B:	Like...if we didn’t do practical work, we wouldn’t be motivated in science
Lola 9C:	It’s great because it makes me motivated to do science

Naya 10P: I enjoy doing practical work because it motivates me to find out more about what we are studying

However, when students were asked to explain how practical work motivates them, they seemed to find it difficult to articulate in detail what they actually meant. Indeed, what this study found was that for many students, motivation meant only that they enjoyed a particular lesson. This is suggesting less of long-term, enduring, motivation than it is short-term situational interest:

Neo 10P: It makes the lesson interesting but that's it...I mean...well... you're not going to sit there and measure the mass of how much water, a cup and a lid weigh when you're at home?

Naya 10P: Unless you want to be a scientist out of school!

What emerges from this study is that what students really mean when they claim that practical work motivates them is that they would rather be *doing* practical work than sitting listening to the teacher or having to write. Therefore if students are personally interested in practical work they will want to consistently take part in and do more beyond the lesson (such as joining science clubs) whilst if their interest is merely situational in nature they will need to be offered practical work in every lesson in order to keep their attitude towards school science positive.

When considering the responses to the statement regarding their ability to learn from practical work in science (statement 2), many students (30%) who agreed, did so because they claimed that they would be more engaged in practical work than if they were writing. As seen in table 6.11 students were more engaged by biology practical work (33%) than in physics practical work (26%) and this engagement was more pronounced in Year 9 than Year 10.

Table 6.11: Percentage of students that selected 'agree' to statement 2 and selected the Level 2 option relating to engagement in practical work by science and year group (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	34% (13)	21% (8)	32% (13)	29%
Year 8	35% (13)	29% (13)	28% (13)	31%
Year 9	33% (11)	43% (16)	35% (16)	37%
Year 10	29% (12)	31% (11)	8% (3)	23%
Average percentage across year groups	33%	31%	26%	30%

Certainly by Year 10, students are more aware of the pressures of examinations and therefore are more aware about the need to know the theory. The implications of such GCSE pressures which students discussed in this study meant that practical work becomes less important to them. Teachers in this study, as were reported by SCORE (2008), claimed that the assessment demands of GCSE restricted the amount of practical work they could sometimes carry out. According to Owen et al., (2008), they claim that "students' views about the value of different education activities would coincide with those of teachers" (p. 126). Therefore and as was found in this study, if teachers claim that GCSE pressures mean the educational value of practical work is lost, students should and were seen to concur (Owen et al., 2008). Indeed, the older students in this study did prefer the lack of practical work activities because they perceived them to be of little educational value, similar to those students reported by Owen et al. (2008).

Considering statement 3, where students agreed that they preferred practical work to non-practical work in science lessons, the majority of students (60%) felt that they would get very bored and uninterested if a teacher told them what to memorise rather than doing the practical themselves. Certainly the opportunity of doing practical work to prevent boredom and disinterest in the lesson is claimed by many students in Year 10 (68%) and many students responding to physics (63%), unlike Year 7 students (57%)

and students responding to biology (59%) where there are fewer students who agreed, as seen in table 6.12.

Table 6.12: Percentage of students that selected 'agree' to statement 3 and selected the Level 2 option relating to boredom by science and year group (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	49% (18)	56% (22)	66% (29)	57%
Year 8	47% (17)	69% (24)	61% (27)	59%
Year 9	69% (22)	63% (24)	49% (22)	60%
Year 10	72% (23)	57% (21)	74% (17)	68%
Average percentage across year groups	59%	61%	63%	61%

What these results suggest is how students' claims about the motivational value of practical work are better understood in terms of a situational interest, in that what they appear to be claiming is that practical work makes a *particular* lesson more interesting as they do not become bored with too much writing and/or they are able to get up and do things with objects. However, the focus of this section of the study was to probe deeper into how motivation might manifest itself, in comments, by students about their involvement in such activities as the school science club or to their undertaking further research on a topic studied in school whilst at home. Furthermore, if practical work does motivate students then not only might they be expected to refer to this in their comments in focus groups, as well as in their questionnaire responses, but also it might be anticipated that students motivated towards these science subjects might indicate a desire to carry on with one, or a combination of all three, sciences post-compulsion. If this is the case then biology, which it has been suggested (Abrahams 2011) involves the least amount of practical work when compared with chemistry or physics, might reasonably be expected to be the least popular at A-level if practical work was the *single* main motivational factor influencing student subject choice post compulsion. Yet this does not appear to be the case according to Smith (2011) who discusses how biology is currently the most popular of the three sciences to be studied post-compulsion and how the government aims to increase the intake for chemistry and physics “without adversely affecting recruitment to biology” (p. 63). In this study however, when students were asked if they enjoyed doing practical work in science lessons (statement 1), comparing the percentage of students that agreed across the sciences, biology had the lowest number of students claiming to enjoy practical work in the science (73%), with more students claiming to enjoy practical work in physics (78%), as seen in table 6.13. Indeed, statement 1 was the most agreed with statement by students in Year 7 and Year 10 for practical work in chemistry.

Table 6.13: Percentage of students that selected ‘agree’ to statement 1 (I enjoy doing practical work in biology, chemistry and physics lessons) by science and year group (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	78% (40)	80% (41)	80% (41)	80%
Year 8	69% (34)	69% (35)	88% (45)	75%
Year 9	71% (36)	74% (37)	84% (43)	76%
Year 10	73% (37)	73% (37)	59% (29)	68%
Average percentage across year groups	73%	74%	78%	75%

When examining across the sciences in each year group, there was a statistically significant difference between Year 8 students’ enjoyment of physics when compared to biology and chemistry. Indeed, there were statistically more students that enjoyed physics practical work than biology ($\chi^2 = 5.350$, $p < 0.05$) or chemistry ($\chi^2 = 5.800$, $p < 0.05$). Considering the reasons why there were more Year 8 students who enjoyed physics practical work than biology or chemistry practical work, the most agreed reasons for enjoying practical work was because they liked working and talking with friends rather than writing. However, when considering why fewer Year 8 students agreed in biology and chemistry, their reasons for not enjoying it was down to the topics that the practical work was covering as to why they like it or not. Indeed similar findings to this study were reported by Williams, Stanisstreet, Spall, Boyes and Dickson (2003), when for physics it was found that some students enjoyed some topics whilst others did not, and that any changes to the topics studied could influence positively or negatively on their attitudes. Although this study found that there were more students in Year 8 that enjoyed practical work in physics than biology or chemistry, Parkinson et al. (1998) found chemistry practical work being most favoured by students in this age group. Furthermore, Owen et al. (2008) found a decrease in students' liking of doing experiments in physics starting from Year 7 to Year 11, with no increase in Year 8. In this study, the reasons given by Year 8 students for liking to do practical work suggest that the topics they were studying in physics practical work at the time of questioning were more enjoyable than biology or chemistry practical work.

However, whilst biology practical work had the lowest percentage across the year groups, practical work in physics was least enjoyed by Year 10 students. Indeed, considering Year 10 with regards to physics practical work, there were statistically fewer students that agreed to statement 1 compared to Year 7 ($\chi^2 = 5.353$, $p < 0.05$), Year 8 ($\chi^2 = 10.962$, $p < 0.001$) and Year 9 ($\chi^2 = 7.828$, $p < 0.01$). There were no statistically significant differences for statement 1 across the years in biology or chemistry. This suggests that whilst students claim to enjoy practical work in physics, by Year 10, students are less positive. The finding in this study, that students' enjoyment to practical work in physics declined, mirrors the reported decline in enjoyment to physics in previous studies (Osborne et al., 1998; Owen et al., 2008; and Parkinson et al., 1998). Williams et al., (2003) reported on students claiming physics was boring and difficult in Year 10 as students in this study commented on. This change in attitude from Year 7 to Year 10 that has emerged in this study for physics and physics practical work might possibly be understood in terms of how physics changes from Year 7 to Year 10 as it progressively becomes more quantitative and less descriptive (Owen et al., 2008). However, by Year 10, students are more pragmatic in that they are aware of how important it is to know the theory for examinations and comments to this effect in this study are similar to those reported by Owen et al. (2008).

Whilst they may not carry out a lot of practical work in biology, students in this study did comment on how the practical work that they did do in biology was memorable and had an effect on them, compared to the practical work they carried out in chemistry and physics. From the responses to statement 10 in the biology questionnaire, 37% of students felt that more practical work was beneficial because they are able to better associate themselves with the work and therefore better engage with the science. Indeed, there were comments during the observations and focus groups that substantiated these claims further:

Naya 10P: I don't mind like… I like practicals in biology. I like dissecting stuff, that interests me and biology's my favourite subject, so I don't mind it then. I just don't like physics work because it just bores me. Like, sticking wires together and just seeing a light bulb, not as good as seeing a heart!
Researcher: Are you intending to take physics, chemistry, or biology for A level?
Naya 10P: Well, I want to be a pathologist so I want to take biology but not physics and chemistry.

Lorna 9C: I want to be a vet so I think I need to see lots of dissections and stuff but like chemistry is a bit pointless but knowing the chemicals for medicine might be useful just we never do anything in school like that.

Ned 10P: I don't want to do practical that is like measure the mass of this and that...I loved the dissection stuff though cause we got all messy from the blood and stuff.
Researcher: Do you want to study biology at A-level or anything?
Ned 10P: Ha! No, I want to work with wood, I like carving stuff so maybe a carpenter like person but I do just like doing practicals in biology.

Whilst students Naya 10P and Lorna 9C were two students who wanted to continue in a career in a related area and, as such, their responses seemed indicative of an personal interest in studying biology. In contrast the positive comments by Ned 10P appears to reflect what might be referred to as a ‘wow’ factor (Turner et al., 2010) and whilst they expressed no desire to pursue biology post-compulsion it does appear that the dissection that they recollect has been effective in generating situational interest discussed later, it has little effect on their motivation in science. Two distinct reasons have emerged here for these three students’ positive attitudes to practical work, and these need not be mutually exclusive. First there is a clear personal interest in dissection – with two of the students wanting to study a biology orientated degree subject when they left school. In both these cases the two students could personally relate to what they were doing and thus were able to see the relevance to them for their chosen career. The second reason, the ‘wow’ factor, is where students see something that is not the norm within a science lesson which is reminiscent of what Abrahams (2009) refers to as “the ‘whiz’, ‘bang’, ‘pops’” of what are atypical, and highly memorable, practical science lessons (p.14). Whilst this ‘wow’ factor seems to be effective in generating positive attitudes to biology, chemistry and physics in school this appears, in many cases, to be only a short-term effect.

This section on motivation has shown students’ motivation to do practical work in biology, chemistry and physics, does decline over the period of secondary schooling. Indeed, research has shown that during adolescence students’ academic motivation declines (Anderman & Maehr, 1994; Harter, 1981). However, in this study, the decline was found to be more pronounced with regards to practical work in physics over the year groups than biology or chemistry. This is perhaps, as has been suggested, due to physics becoming more mathematical than descriptive by the latter years of secondary school (Owen et al. 2008) than biology or chemistry. This section has also considered how what students refer to as motivation might better be understood and described as a situational interest. It is to consideration of personal interest and situational interest that this chapter now turns.

6.3.2: Personal interest

In this study, personal interest is defined in terms of Bergin (1999) as the "dispositional preferences people hold, or what enduring preferences they have for certain activities or domains of knowledge" (p. 87). So students holding a personal interest in practical work would be seen to not only enjoy carrying it out in lessons, but would also enjoy and take part in practical work outside of the lesson. They indeed may join a science club, carry out some of their own investigations outside the lesson or use their practical knowledge beyond the lesson. An indication of personal interest will be seen if a student comments specifically on their own interest in practical work beyond the lesson, as the example during an observation below exemplifies:

> Ysabel 7B: I dissected a chicken leg with Sir. I knew about it and had done some other stuff at home about it cause it was really...it interested me, so like when my mum broke her leg and the doctor told us about where it was, like, my dad didn't know but because I like knew, I could tell dad about the tendons, the muscles and things... I found it really interesting.

Students' attitudes to practical work across biology, chemistry and physics did demonstrate that those who held a personal interest in practical work showed keenness and attention in carrying out the practical work. In this study, whilst many spoke of preferring practical work over other non-practical work methods of teaching such as writing, there were a few students, as the following example suggests, who were keen to undertake practical work for its own sake and also claimed that they wanted to continue with science post compulsion:

Researcher: So how you doing? Are you just sending her off to do the measuring and just sort of supervising her?

Nikhil 10P: (laughs) No, we’re very much a team but she loves this sort of thing, so it makes sense she does it so the answers are right as she’s done this before.

Researcher: Oh okay. Is this right? How come you know what to do?

Nora 10P: Yeah, I help out in a club [school science club] and we did this the other week and actually that’s what I do.

Researcher: What you do?

Nora 10P: I always do everything when I work with him, I just like doing everything, I mean it is just really interesting to me, but I want to go into medicine so....

Nikhil 10P: You’re a geek!

Nora 10P: No, you’re just lazy!

What Nora 10P is showing is an apparent personal interest for the practical work they are doing and they are aware of the importance of science because of their want to study medicine. Whilst Nora 10P seems to exemplify a positive attitude to practical work because she appreciates it as being personally important, unlike the attitude of Nikhil 10P, as the following example shows:

Researcher: So what do you think to practical work?

Nikhil 10P: I like it but like, just cause it makes the lesson a bit better. I mean I get to chat and don’t have to write much, can share the work like this.

The comments made by Nikhil 10P here suggests an attitude to practical work that was characteristic of the views more commonly held by students in this study. They wanted to get the results, to complete the work in the lesson, and have a break from writing that a hands-on task provided, but anything more than that was of little interest. They again demonstrate a preference of doing practical work to writing. Whilst there was little personal interest here for doing practical work, what their comments suggest, and is common to many students in the study, is a degree of situational interest. Whilst there were a few students in the study that held a personal interest in studying practical work, this tended to be distinctive of those students that were actively aware of a career path upon leaving school. Whereas other students, although positive about practical work, tended to be so because they saw it simply as an alternative to writing - as the example during the observation below explains:

> Researcher: What are your thoughts about practical work? Do you need to do it in your lessons?
> Llewellyn 9C: Yes, I couldn't imagine not doing practical work, I need to know how to do things, it would make science a lot harder and I need the experience.
> Researcher: You need the experience? How come?
> Llewellyn 9C: Well I want to be a vet or something with animals so practicals are important cause they will be useful practice for then. Like that's why I've joined Miss's science club too so I can do more.
> Researcher: A few of you want to be vets here and a science club, impressive! Are you carrying science on for A-level then?
> Llewellyn 9C: Yes, well not all sciences, definitely chemistry and biology, not sure on physics though.

This attitude that practical work would be a means of 'practice' for a chosen career path, along with the fact that this student had joined a science club, suggests a personal interest towards practical work. Renninger (1998) reported that when students are taking an active role in practical work they are more likely to be able to learn and understand what they are doing. If students increase their knowledge in what they are doing, they increase their personal interest, as was found in Abrahams and Sharpe (2010) and that a high degree of personal interest is a key feature of a student's intrinsic motivation in the activity, similar to Linnenbrink and Pintrich (2002). A student who holds a personal interest in doing practical work might therefore also be expected to also hold an intrinsic motivation to continue studying any of the sciences, not just practical work.

Indeed, whilst the questionnaires showed students enjoyed doing practical work in biology (73%) and chemistry (74%), it was physics (78%) where there were a few more students that agreed here. This finding comes at a time when physics has been reported to hold a “continuing decline the school cohort that chooses to study physics” (Reiss et al., 2011, p. 273) in post compulsion. Whilst students claim to enjoy practical work, it does not appear to be impacting on their decision making post compulsion. Although, as Woolnough (1994) claims many students “do not reject science for anti-science reasons but because they positively want to do something else!” (p. 373). If a student chooses to be a vet, as suggested by a few students in this study, they will want to continue with biology and chemistry because of the needs of that particular career. But they may also wish to join science clubs and/ or take up any opportunities available to gain practical work experience (such as dissections) that will have some relevance to being a vet. Their *personal* career choices, for some students in Year 10 in this study, impacted on their decision making for subject choices post compulsion. Indeed, when examining the questionnaire data from the Year 10 students in response to statement 7, there was only 1 student out of 51 that had selected the option of wanting to be a biologist. There were no Year 10 students in the questionnaire that claimed to want to be a chemist or a physicist and yet 73% and 59% respectively still claimed to enjoy doing practical work in those sciences. This suggests that enjoyment in practical work does *not* necessarily entail a desire to pursue science in the post compulsory phase of their education. Indeed, it is *not* enjoyment alone that increases retention in science but a personal interest to study science. For most students enjoy doing practical work in science *but* if they do not hold a personal interest in either studying a particular science or a science related career, this study suggests that students are less likely to continue in biology, chemistry or physics post compulsion. For the large majority of students in this study practical work was not impacting on their personal interest, but their situational interest which will now be discussed.

6.3.3: Situational interest

Situational interest in this study relates to a non-enduring interest that is stimulated in a particular environment or situation (Bergin, 1999; Hidi & Harackiewicz, 2000) which is in the short term susceptible to teacher influences (Hidi & Anderson, 1992). Situational interest is where the student would only show keenness to doing practical work during the lesson which does not continue beyond that particular lesson as the example during the observation illustrates:

> Lily 9C: Well, practical work is a bit sort of just for my lesson I mean I don't do much science outside the school so it doesn't really affect me other than when I'm in my lessons. I just like to do it so I don't have to write and then I'm like doing something interesting and not being bored by work.

In the above example Lily 9C was characterising a view that was held by many students involved in the study, this is referred to as a situational interest. Situational interest, as used here, is "defined as temporary interest that arises spontaneously due to environmental factors" Schraw, Flowerday and Lehman (2001, p.211). This type of interest can be generated in individuals from "content, activities, stimuli, or environmental conditions" (Bergin 1999, p. 87). Unlike personal interest, its effect is short-term and it can be heavily influenced by a teacher within a lesson. For example, a teacher who allows students to undertake practical work if they are showing good behaviour may find that the students are good purely for the sake of having the opportunity to do practical work over other work. Due to the fact that students are unlikely to maintain their situational interest for a long period of time after any particular practical lesson (Hidi & Harackiewicz, 2000) the frequent use of practical work might, prior to students being asked to select subjects for post-compulsory study, impact positively on their choice to continue studying either biology, chemistry or physics or a combination of these.

When students were asked if practical work was their favourite part of the lessons, 65% of students claimed that it was, with their main reasons given being that it made the lesson go quicker, allowed them to chat with friends and use scientific equipment. These three reasons are far from favouring science practical work for any science related reasons such as improving their scientific skills or scientific knowledge, of which neither option was popular by students in response to statement 4. Looking in more detail at the differences and similarities between the sciences and the year groups, the picture becomes less positive, as seen in table 6.14.

Table 6.14: Percentage of students that agree to statement 4 (Doing practical work is my favourite part of biology/chemistry/physics lessons) by science and year group (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	78% (40)	80% (41)	76% (39)	78%
Year 8	53% (26)	65% (33)	78% (40)	65%
Year 9	59% (30)	74% (37)	75% (38)	69%
Year 10	57% (29)	45% (23)	41% (20)	48%
Average percentage across year groups	62%	66%	68%	65%

What was found here was that within each subject a trend emerged. The trend showed that as students progressed through secondary school, their attitude to practical work as being their favourite part of biology, chemistry and physics lessons decrease. Looking at chemistry and physics, Year 10 students were favoured practical work less than those in the other year groups. Indeed, there were statistically fewer students that favoured practical work in chemistry and physics in Year 10 than students in Year 7 (chemistry:

$\chi^2 = 13.589$, $p < 0.001$ and physics: $\chi^2 = 13.133$, $p < 0.001$), Year 8 (chemistry: $\chi^2 = 3.960$, $p < 0.05$ and physics: $\chi^2 = 14.733$, $p < 0.001$) and Year 9 (chemistry: $\chi^2 = 8.745$, $p < 0.01$ and physics: $\chi^2 = 11.646$, $p < 0.001$). What these results suggest is that by Year 10 students do not favour physics or chemistry practical work and at a time when students are studying for GCSE examinations, the assessment system pressures students to know the theory and so older students are not considering practical work because of its enjoyment factor, but on whether it can prepare them for said examinations (Owen et al., 2008). However, biology is often favoured over these two subjects, chemistry and physics, because it is perceived as a less difficult subject by students (Bevins et al., 2011). Yet Turner et al. (2010) have reported students enjoying practical work in chemistry and Thompson and Soyibo (2002) claim that doing more in lessons does enhance their attitudes to chemistry. Although, as chemistry and physics involve not only observation, but also requires students to conceptually engage and understand theory this can be a difficult learning process for students and can lead to disaffection, causing negative attitudes for the science (Hussein & Reid, 2009). Yet if, as reported by Abrahams and Millar (2008) and Abrahams et al., (2011), teachers are, most of the time, using practical work merely as a means of getting students to observe a phenomena, then no connection is made between *doing* and *learning*. This suggests that students would find it enjoyable because they are just *doing* with objects and not having to engage their minds with the scientific theory, unlike being questioned by the teacher or answering questions from the textbook.

Conversely, for biology, students favoured practical work less by the time they reached Year 8, as seen in the table 6.13. Indeed, there were statistically more students in Year 7 that favoured practical work in biology than Year 8 ($\chi^2 = 7.170$, $p < 0.01$), Year 9 ($\chi^2 = 4.554$, $p < 0.05$), and Year 10 ($\chi^2 = 5.420$, $p < 0.05$). What this suggests is that unlike physics and chemistry, attitudes to biology practical work seem to decrease by the time students are in Year 8. Although, in Year 8, there were statistically more students that favoured practical work in physics over practical work in biology ($\chi^2 = 7.170$, $p < 0.01$). However unlike physics, students' attitudes to biology practical work where they claim it to be their favourite part of biology, does not significantly decrease from Year 8 to Year 10. Indeed these findings here mirror students' attitudes to science per se. According to Spall, Stanisstreet, Dickson and Boyes (2004), they reported, that whilst there was a decrease in students' enjoyment in biology, it was not as steep as the drop in enjoyment for physics. However, the reason for the decline in students' favouritism towards practical work in biology from the data suggests that students begin to see elements of practical work fun and others boring unlike, in Year 7 where students enjoy manipulating equipment, communicating with their group during the practical work. Indeed, this change by Year 10 from seeing practical work as fun to boring, suggests that this may be due to the pressures of examinations with forthcoming GCSEs where teachers are pushed into getting through the syllabus to the detriment of enjoyment (Spall et al., 2004). The decline in the proportion of students favouring practical work in their lessons suggests that as students progress through school, practical work is not their most enjoyed part of their biology, chemistry or physics lessons. The enjoyment of practical work found in this study appears, given that if practical work did not occur in *every* lesson, students became disaffected, best understood in terms of non-enduring situational interest which is similar to the findings reported by Abrahams (2009).

6.3.4: Preference

Preference in this study refers to when students claim a "relative preference (containing comparative terms such as better than, less than, more than)" (Abrahams, 2009, p.2342) such as preferring practical work *over* other learning activities in science.

When students were questioned in statement 3 as to whether they prefer practical work to non-practical work in their science lessons, there were more students that preferred practical work in physics (77%) than biology (68%) or chemistry (73%), as seen in table 6.15. The main reason for students preferring practical work was because students claimed it was better for them to do it than listen to the teacher telling them what to memorise. Certainly, practical work was preferred, over other non-practical work such as writing and listening to the teacher, and 73% of all students felt this way.

Table 6.15: Percentage of students that agreed to statement 3 (I prefer practical work to non-practical work in biology/ chemistry/ physics lessons) across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	73% (37)	76% (39)	86% (44)	78%
Year 8	73% (36)	69% (35)	86% (44)	76%
Year 9	63% (32)	76% (38)	88% (45)	76%
Year 10	63% (32)	73% (37)	47% (23)	61%
Average percentage across year groups	68%	73%	77%	73%

Furthermore, in this study students' preference to practical work over non-practical work in physics was less stable than their preference to practical work in biology and chemistry. There were statistically fewer students in Year 10 that preferred practical work to non-practical work in physics compared to Year 7 (χ^2 = 17.488, $p < 0.001$), Year 8 (χ^2 = 17.488, $p < 0.001$) and Year 9 (χ^2 = 19.585, $p < 0.001$). Across the sciences in the year groups, there were statistically more students in Year 8 that preferred practical work to non-practical work in physics than chemistry (χ^2 = 4.550, $p < 0.05$). By Year 9, there were more students that preferred practical work to non-practical in physics than biology (χ^2 = 8.950, $p < 0.001$). Yet by Year 10, there were statistically fewer Year 10 students that preferred practical work to non-practical work in physics than chemistry (χ^2 = 6.830, $p < 0.001$).

What has emerged from this study is that whilst the majority of Year 7, Year 8 and Year 9 students preferred practical work to non-practical work, by Year 10, students' preferences changed and declined. This concurs with the literature on students' attitudes to physics which declines over the secondary school period (Owen et al., 2008; Reiss et al., 2011).

In response to statement 6, students were not, as seen in chapter 5, able to claim that practical work was ease to do in science – only half the students agreed. Examining the data between year groups and sciences as seen in table 6.16, what emerges is how doing practical work becomes less easy as students progress from Year 7 to Year 10 in all three sciences.

Table 6.16: Percentage of students that agreed to statement 6 (I find practical work in biology/ chemistry/ physics easy to do) across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	59% (30)	75% (38)	76% (39)	59%
Year 8	53% (26)	39% (20)	78% (40)	53%
Year 9	41% (21)	58% (29)	75% (38)	41%
Year 10	41% (21)	47% (24)	41% (20)	41%
Average percentage across year groups	59%	75%	76%	59%

Whilst the reason that many students gave was that practical work was easier than copying out of a book (47% of students in biology, 42% in chemistry and 52% in physics) by Year 10 this was not always the case. By Year 10, students were more aware of both the difficulties and ease of doing practical work. Certainly of the students that did not agree for biology (59%), chemistry (53%) and physics (59%), students claimed that some practical work they did in the three sciences was easy but some could also be hard. There were statistical differences between the sciences and the year groups here. Within physics, there were statistically more students in Year 9 that felt practical work was easy than in Year 10 ($\chi^2 = 4.123$, $p < 0.05$). For chemistry, there were statistically more in Year 7 than Year 8 ($\chi^2 = 12.950$, $p < 0.001$) or Year 10 ($\chi^2 = 8.061$, $p < 0.001$) that found practical work easy. The only statistically significant finding in the year groups was within Year 7 where students were felt chemistry was easy to do practical work in compared to physics ($\chi^2 = 7.020$, $p < 0.01$). What these results seem to suggest here is that whilst students do claim to enjoy practical work in physics and chemistry, but as with enjoyment as students progress through school, they do actually find that the practical work is not always easy. Also, the findings are suggesting that students' attitude to the ease of doing biology practical work is stable and less subject to change from Year 7 to Year 10. As discussed by Johnstone (1999), physics and chemistry are difficult for students to learn because of the nature of the science themselves. It requires students to not only *do* but *think* about what and why that which they have observed has happened (Abrahams & Millar, 2008). This is indeed very difficult for a student learning to link the descriptive observations with the scientific concepts from merely carrying out a piece of practical work (Hussein & Reid, 2009). Some Year 10 students were unable to find doing practical work easy *all of the time* because they found it hard to link what they did with what they were learning in science. Indeed, some Year 10 students found other activities in the three sciences to be educationally more effective. These findings are similar to those by Owen et al. (2008) where students began to see practical work as being less effective educationally and so were less attracted as indeed were students in this study.

Considering how students showed both personal and situational interest in this study it is interesting to consider what they claim when they say they like, or prefer practical work. From many of the students a common reason for liking practical work appeared to be that they simply preferred it to writing, copying from a book or listening to the teacher. Furthermore, from the questionnaires, there were three distinct reasons for preferring practical work that students claimed; (i) preference over writing, (ii) preference over copying or other book work and (iii) preference over listening to the teacher. Of these three areas of preference, in the questionnaire upon agreeing to liking practical work the Level 2 responses (the reasons for agreeing with the statement) fell into three similar reasons, there were three Level 2 reasons that were associated with preference over writing, three with preference over copying or working from a book (textbook) and one with preference over listening to the teacher, and the percentage of students that agreed to each of these Level 2 reasons can be seen in table 6.17. Of these reasons for liking practical work, it was clear that preference over writing was the preferred reason for liking practical work. Overall, preference over writing was a more prominent reason for liking practical work in biology, and a preference over listening to the teacher was popular in physics.

Table 6.17: Percentage of students that agreed to Level 2 reasons

	Statement followed by Level 2 reason	Percentage of students that agree to Level 2 in biology	Percentage of students that agree to Level 2 in chemistry	Percentage of students that agree to Level 2 in physics
Preference over Writing	1a) I like working and talking with friends sharing answers, rather than writing	26%	35%	33%
	1b) I learn from doing it, not just writing	32%	19%	23%
	2b) If I am more into the lesson I am going to learn more than if I was bored writing	24%	24%	22%
Preference over copying book/textbook work	6a) It is always easier than copying out of a book	23%	22%	26%
	10b) I learn and remember more doing practical than if I answer questions from a textbook	19%	19%	22%
	14b) Book work is secondary learning but practical work is first hand so I learn more and see it for myself	24%	18%	19%
Preference over listening to the teacher	3a) I get very bored and less interested when a teacher is just telling me what to memorise rather than doing it myself	40%	45%	47%

Students' attitudes showing a preference to practical work over other teaching methods were further substantiated in the observation and focus groups. As the following examples show, students explained why they enjoyed practical work in terms of it being seen as a preferable option rather than of it being liked in its own right:

> Nial 10P: It's good because it's like different rather than sat copying off the board, you're doing something more like hands on.
>
> Yvie 7B: I like it because it's like hands on, like I get to use my hands instead of writing all the time.
>
> Lenny 9C: I love practical work because it is better than listening to the teacher, which is boring.

Further to these comments that suggest that practical work is seen as the preferred option to writing the questionnaires also found activities that were preferred in the three sciences. Statements 1, 6, 10 and 12 were all responded to with reasons that preferred practical work over other activities within a science lesson and these can be seen in table 6.18.

Table 6.18: The most common Level 2 reasons when students had agreed to the four statements

Statement	Biology	Chemistry	Physics
1. I enjoy doing practical work in biology/ chemistry/ physics lessons	32%: b) They are able to learn from doing it not just writing	35%: a) I like working and talking with friends sharing answers, rather than writing	33%: a) I like working and talking with friends sharing answers, rather than writing
6. I find practical work in biology/ chemistry/ physics easy to do	29%: h) Some of the things I do in biology is easy but some of it can be hard	29%: h) Some of the things I do in chemistry is easy but some of it can be hard	29%: h) Some of the things I do in physics is easy but some of it can be hard
10. I think we should do more practical work in biology/ chemistry/ physics lessons	37%: a) I personally take in and engage more with practical work	40%: a) I personally take in and engage more with practical work	34%: a) I personally take in and engage more with practical work
12. I prefer the freedom I have during practical work in biology/ chemistry/ physics lessons	31%: a) I can learn independently and at my own pace	33%: a) I can learn independently and at my own pace	34%: a) I can learn independently and at my own pace

What table 6.18 illustrates is the extent to which students give similar reasons for what they perceive as the affective value of practical work in biology, chemistry and physics. Indeed, what emerges is a preference for practical work over writing, their preference for doing, and their belief that they are able to learn independently from it. These reasons are similar to the findings reported in other studies such as those by Toplis (2012), Hodson (1990) and Denney and Chennell (1986).

However, there were times during the actual process of undertaking practical work where students perceived it as being rather difficult. Although the majority of students preferred to do practical work in science, there was a minority of students (10%) that preferred written work to practical work. A comment echoed in the observations explains how they find themselves just wanting to sit and write rather than do a practical:

> Neville 10P: I don't particularly like practicals, I like writing more than practicals, so…
> Researcher: You like writing more than practicals?
> Neville 10P: Yeah.
> Researcher: What is it about practicals that you don't like?
> Neville 10P: I haven't got the energy to do it.
> Researcher: What would you rather do?
> Neville 10P: Just sitting there writing.

Also, a few students, as the following examples illustrate, felt practical work was not preferable to writing because of another reason rather than just not having the energy as Neville describes. This reason related to behavioural issues involving other students in the class and how the teacher went about managing the practical work. At such times those students expressed the view that they would prefer to be writing notes in their books rather than doing practical work as the following comments from the observations (Neve & Laila) and focus group (Yaseen) suggests:

> Neve 10P: Well like, I just prefer sitting down copying because it's much easier and like if someone messes around during it and the teacher gets stressy it's just like… There's no point.
>
> Laila 9C: Yeah, sometimes I think you get given an experiment and they don't explain it fully and then you go wrong and then the teacher will like blame you because you haven't paid attention but if you do then you don't get as much.
>
> Yaseen 7Y: Well sometimes some of the other lads can be silly and it can make the practical lesson go wrong and then I just would rather be sat down copying the answers off the board.

Indeed, whilst such issues were discussed during the observations and focus groups, there were only a small minority of students in Year 9 (3%) and Year 8 (2%) that selected this option with only 1 of these 5 students coming from physics and the rest split evenly between chemistry and physics. In the questionnaires, these students drew attention to the fact that some students would mess around and thus distract others in the class from what they were doing. According to Kidman (2012), students need time for "undirected activity" where the teacher permits the student to investigate a topic and that this inevitably means the "student may choose to fiddle with equipment" (p. 42). By doing this, Kidman (2012) suggests that teachers will then be able to begin the teaching of the topic. Indeed, if students are so excited at doing with objects as indeed were the lower year groups in this study, having the students play with equipment would mean they familiarised themselves with that equipment. This then potentially means that the teacher could actually focus the students on getting minds-on with what they are doing as opposed to students messing about with the equipment as was commented by students and teachers in this study.

Another emerging issue with regards to preference for doing practical work was how students would explain how the practical work was a break in the lesson to give them the opportunity of at least spending some of the lesson doing something that they thought was exciting, as the students during the focus group explained:

> Nelson 10P: It probably just makes the lesson a bit more like…
> Nicola 10P: Exciting.
> Nelson 10P: Yeah, instead of just sitting there, but it's not really something that's needed or like…

Whilst students frequently expressed a preference for practical work over other methods of teaching and learning science there were also other reasons for their claims to like *doing* $practical work per se because of how this linked in with issues beyond the laboratory.

6.4: The behavioural domain

The behavioural domain, as discussed in chapters 3, 4 and 5, is referred to as “a set of *behaviours* or *behavioural tendencies* toward the object” (Manstead, 1996, p. 5). That is how they act or what they do towards the object being observed. Therefore, behaviour relates to how students act during practical work in school and how they perceive they act within the laboratory in which they conduct practical work. This section will discuss students’ attitudes to carrying out practical work in relation to their use of scientific equipment, to working independently or with friends in groups as well as to the laboratory in which they undertake their practical work. This section also refers to the relevance of practical work and how they view practical work in connection to the real world.

6.4.1: Practical work carried out in school

Students’ attitudes to carrying out practical work in school fall into three areas. The first being the environment that they carry it out, the second the use of scientific equipment and the third relates to the use of individual or group work whilst doing practical work.

The school environment in relation to practical work refers to the actual laboratory where students carry it out. Within the school environment, there were many students (58%) in this study that claimed their school science environment made doing practical work easy in their lessons. Of those that agreed to statement 13, the reason across the sciences was similar - 53% for biology, 53% for physics, 55% for chemistry. Students felt that they liked and felt confident in their environment and being able to ask for help if they needed it. However, examining the sciences individually across the year groups, there is a steady decline in students’ attitudes to the ease of doing practical work in the laboratory as seen in table 6.19.

Table 6.19: Percentage of students that agreed to statement 13 (My school science environment makes doing practical work easy in my biology/ chemistry/ physics lessons) across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	71% (36)	75% (38)	75% (38)	73%
Year 8	57% (28)	57% (29)	67% (34)	60%
Year 9	45% (23)	60% (30)	61% (31)	55%
Year 10	43% (22)	53% (27)	29% (14)	42%
Average percentage across year groups	54%	61%	58%	58%

Certainly by Year 10, there were statistically fewer students claimed that the environment made doing practical work easy to do in physics when compared to Year 7 (χ^2 = 21.129, $p < 0.001$), Year 8 (χ^2 = 14.530, $p < 0.001$) and Year 9 (χ^2 = 10.477, $p < 0.01$). In biology, the number of Year 7 students claiming that the environment makes doing practical work easy was statistically more when compared with Year 9 (χ^2 = 6.795, $p < 0.01$) and Year 10 (χ^2 = 7.834, $p < 0.01$). Furthermore within chemistry, there were statistically more students in Year 7 than Year 10 (χ^2 = 5.132, $p < 0.05$) that claimed ease of doing practical work in their science environment. Indeed, for Year 7 statement 13 was agreed highly for all sciences; the statement was most agreed with by Year 7 students for physics. The main reason was that these students claimed that they were confident in the environment for which they worked in and could easily ask for help if they needed it. Such claims were also seen during the observations as the comments below suggest:

> Yikira 7B: I feel that I am able to really have a go in practical work, [Teacher Y] is always there to help and I can ask when I'm stuck. The science stuff we use like the Bunsen burners are there and everything we need, it is a great lab to do practicals in.

Whilst Year 7 students claimed that they found the environment easy to carry out practical work, by Year 10, students that were not agreeing felt that the ease of conducting practical work in the laboratory depended on what they were doing. Certainly, some students during the observation discussed the difficulty with carrying out practical work in their laboratory as the examples below illustrate:

Nadine 10P: Sometimes, what sir is asking us to do is really difficult in our lab [laboratory] because like the equipment won't work properly or something breaks easily.

Nial 10P: Most of the time we are using stuff we have done since Year 7 like stop clocks, thermometers, power pack. We never get to have a go on something new. I mean ok so the school is always skint and stuff but we end up missing out sometimes.
Researcher: How do you mean?
Nial 10P: Well like we can't do exciting stuff in practicals because we don't have the equipment or if we do we have like one between ten of us, I mean come on!

The data suggests that in Year 7 students are excited about using equipment and working in a laboratory environment. Indeed, students have been reported as being excited about simply being allowed to work in a scientific environment and getting the chance to have a go with scientific equipment (Abrahams, 2009). By Year 10 however, the novelty of such an experience becomes less of an absolute enjoyment but more of a preference over other science activities and they begin to be bored in science due to the lack of practical work they are allowed to do (Williams et al., 2003). Also, in this study, as highlighted by Nial 10P, some schools struggle financially to set up their laboratories with the correct equipment or indeed enough of the equipment (SCORE, 2008). The implications of this mean that students may not be able to carry out the work in the best way or have to work in groups, which can have impact on student participation and learning. Indeed, teachers reported by SCORE (2008) claimed that the lack of resources and facilities was a barrier in conducting practical work.

However, by Year 10, students began to feel negative towards doing practical work in chemistry and physics and with that they felt that the laboratory did not help their ability to *do* the practical work either. Indeed, there were statistically fewer Year 10 students who felt the school science laboratory made doing practical work easy in physics than chemistry ($\chi^2 = 6.140$, $p < 0.05$). What has emerged from this study is that as students progress from Year 7 to Year 10 they begin to feel that the school science laboratory does not make doing practical work easier. Certainly, the fact that some Year 10 students claimed they felt bored in their laboratory was suggesting that the difficult nature of doing practical work in physics and chemistry (Johnstone, 1999) meant they were unable to enjoy working in it. Indeed, as students progress through secondary school they are beginning to feel the pressure of not only the difficulties in learning a complex subject like chemistry or physics (Bevins et al., 2011; Johnstone, 1991) but also GCSE examinations. At this point, Spall et al. (2004) argue that students are beginning to be aware of the workload which in turn leads to more homework and theory work. As was commented in this study, students by Year 10 have more written work in lessons and a lack of practical work, similar findings were reported by Williams et al. (2003). Therefore, it would be difficult for students to give a response to whether the laboratory makes doing practical work easy, when their lessons involve less practical work and more written work in such an environment that is set up with equipment, such as gas taps, for doing as opposed to writing (Donnelly, 1998).

Students in the study did claim that they enjoyed using scientific equipment and because of this they enjoyed doing practical work. The following examples during the observations demonstrate how, through using science equipment students claim that they feel more positively to practical work:

Lola 9C: Especially when you like use the Bunsen burners because it's like more fun.

Yanis 7B: I found it fun because we learnt how to use a microscope properly.

Whilst these examples above were expressed during the observation and focus groups, the questionnaire also substantiates such claims. Indeed, across the three sciences, an average of 46% of students involved in the three questionnaires commented, in response to statement 4, that doing practical work meant the lesson would seem to go quicker because they would be able to use science equipment, as seen in table 6.20.

Table 6.20: Percentage of students that agreed to statement 4 and selected the Level 2 option of being able to use science equipment across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	50% (20)	56% (23)	49% (19)	52%
Year 8	50% (13)	45% (15)	45% (18)	47%
Year 9	27% (8)	62% (23)	50% (19)	46%
Year 10	34% (10)	48% (11)	35% (7)	39%
Average percentage across year groups	40%	53%	45%	46%

However, what is emerging here is how, by Year 10, students do not prefer practical work because they are unlike Year 7 students who are excited about using (potentially for the first time) real scientific equipment. Instead, by Year 10 they are beginning to be aware of using both written and practical methods in science, especially for their GCSE examinations (Owen et al., 2008).

Despite the fact that students claim they enjoy using scientific equipment in their practical work, there were nonetheless a few students that felt anxious in carrying out practical work for reasons relating to either the use of equipment or problems with the method of how to conduct it. The following example during the observation illustrates the issues that students raised in terms of their worries about using certain equipment:

> Noah 10P: But it's quite scary.
> Researcher: Tell me why.
> Noah 10P: Not physics but like in chemistry when we're using all the chemicals and stuff, if like the Bunsen…

What emerged from this study has been how students' apprehension about using unfamiliar equipment can affect their attitude towards practical work. Indeed, Parkinson (2004) discusses how students like clear instructions so that they know what to do and what to achieve and this was corroborated in this study were it was found that being told explicitly what to do, including associated safety issues, meant that students did not feel a heightened level of apprehension for a task.

Another emerging issue in this study was students' attitudes to practical work in relation to individual and group work. Students did discuss, both within the questionnaire and during the observations, the fact that they enjoyed the aspects of group work and individual work. One main reason for this was that students felt group and individual practical work gave them the freedom and personal autonomy in learning in science. Certainly, when students were asked if they prefer the freedom they have during practical work in their science lessons, the majority of students for biology (70%), chemistry (75%) and physics (78%) preferred the freedom during practical work as seen in table 6.21.

Table 6.21: Percentage of students that agreed to statement 12 across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	63% (32)	78% (40)	75% (38)	72%
Year 8	73% (36)	80% (41)	86% (44)	80%
Year 9	76% (39)	76% (38)	86% (44)	80%
Year 10	67% (34)	65% (33)	65% (32)	66%
Average percentage across year groups	70%	75%	78%	74%

However, across the year groups there is a decline in students preferring this freedom, especially in physics. Indeed, there were statistically fewer students in Year 10 that claimed to prefer the freedom during practical work in physics compared to Year 8 ($\chi^2 = 6.024$, $p < 0.05$) and Year 9 ($\chi^2 = 6.024$, $p < 0.05$). Certainly when considering the main reason for the preference to freedom in practical work, the opportunity for students to work independently and at their own pace was the main reason for 34% of Year 7 students who selected agree compared to 41% in Year 10. This finding that students preferred the freedom during practical work to work independently was also discussed by the students in the observations. There were comments during the observations where students spoke of enjoying working independently because they were able to show the teacher that they were capable of doing it, as the following student explains:

> Yin 7B: I like the fact that our teacher, well, sometimes sets us work independently because I like to show that I can work on my own without anyone being there to tell me or show me what to do

Whilst the comment by Yin 7B explains why students preferred working independently, some students commented during the observation that by doing more practical work they were able to increase their confidence in undertaking practical work:

> Louise 9C: Yeah because I used to be a really like… I used to be like really… Not scared but I didn't want to do practicals because I thought they'd go wrong and I used to not like Bunsen burners and stuff

like that, and doing more practicals has like helped me realise that…
Lorna 9C: Increased your confidence.

Indeed, students in this study felt that the teachers trusted them to use science equipment on their own; equipment that may have been expensive and/or dangerous if not used safely which is a similar finding to that by Toplis (2012)

With regards to group work, students' attitudes suggested that whilst they enjoyed the freedom of independent work, they also preferred the freedom of being able to help and receive help from working with their friends during group work. Whilst there were few who suggested they liked to use practical work to merely chat with friends, 24% of all students felt that they benefitted from working with friends. Students explained how they use the opportunity to discuss ideas about what they are doing in practical work. The following discussion during an observation is in response to being asked by the researcher why they think they prefer to do practical work:

Yoko 7B: I think like working together.
Yan 7B: Yeah because when we've done practical work before we always like worked together and do stuff like…
Yasin 7B: And we like listen to each other while we do it.

Further to this, students in Year 10, as the following comment explains, also preferred to work like this because it meant they were able to discuss and help each other with the theory work:

Natty 10P: When we work in groups, we can chat about what we are doing and what we are trying to find out. We like bat ideas off each other and that means we are helping and learning together.

Indeed, as these comments suggest, responses to the questionnaires also showed that even though students enjoyed the relative freedom offered by practical lesson, compared to non-practical lessons, they did like to know what they were meant to be doing and preferred to work with other people when they felt less confident about the task. There were statistically significantly fewer students that felt the benefit of working with friends in biology (13%) practical work than chemistry (29%, χ^2 = 14.92, $p < 0.001$) and physics (29%, χ^2 = 14.32, $p < 0.001$). What this could suggest is that due to the perceived difficulty in studying chemistry and physics in school (Bevins et al., 2011) and the fact that these sciences are often least favoured (Turner et al., 2010), students seem to find a sense of support and reassurance in working with their friends during practical work. The fact that chemistry and physics are seen as difficult sciences (Bevins et al., 2011; Johnstone, 1991) is another suggestion as to why students enjoy working together with friends as opposed to on their own.

When students were asked if they wanted to conduct more practical work, the majority of students agreed for biology (70%), chemistry (72%) and physics (71%), as seen in table 6.22.

Table 6.22: Percentage of students that agreed to statement 12 across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	61% (31)	69% (35)	73% (37)	67%
Year 8	80% (39)	82% (42)	80% (41)	81%
Year 9	71% (36)	78% (39)	76% (39)	75%
Year 10	69% (35)	61% (31)	53% (26)	61%
Average percentage across year groups	70%	72%	71%	71%

Whilst students' attitudes to conducting more practical work were, on average, similar across the three sciences taken across all year groups there were statistical differences between the year groups. There were statistically fewer students in Year 10 that felt they should do more practical work in physics than Year 7 (χ^2 = 4.071, $p < 0.05$), Year 8 (χ^2

= 8.443, $p < 0.01$) or Year 9 ($\chi^2 = 6.020$, $p < 0.05$). In chemistry there were also statistically fewer Year 10 students that agreed to statement 10 than Year 8 ($\chi^2 = 5.830$, $p < 0.05$). With biology, there were fewer students in Year 7 that felt they wanted more practical work in biology than Year 8 students ($\chi^2 = 4.210$, $p < 0.05$). Indeed students during the observations discussed students were wanted more practical work in Year 9 but by Year 10 students were responding less positively towards doing more, as the examples suggest below:

Lisa 9C:	I think it would be good to do more practical work
Researcher:	In all your sciences?
Lisa 9C:	Well not so much biology, but maybe chemistry and definitely physics as that can be hard without practical work
Nancy 10P:	It can be fun to work in groups doing practical work but really, more practical work would just a waste of time. I mean I don't learn or gain much from it we need to spend more time on the exam stuff.

What these findings suggest is that as students progress through their secondary education they become less attracted by practical activities - findings similar to those reported by Owen et al. (2008). The decline in wanting to do more practical work starts from Year 8 for all the three sciences. However, for physics this study has shown that there is a statistically significant drop by Year 10 compared to the other year groups in students' attitude to doing more practical work in their lessons. One possible reason for this decline, as Owen et al. (2008) suggest, is that by Year 10 students are beginning to believe practical activities are less effective in helping to develop their conceptual understanding of science – a pre-requisite if they are to do well in their examinations.

6.4.2: Relevance

This section is about how students see or do not see the relevance of practical work beyond the confines of the laboratory. Whilst there have been reports that what students do and what they learn in science practical work has relevance to their lives and careers were not as positive in this study. Indeed in response to statements 7 and 8, almost half of students (44% and 38% respectively) were able to agree that what they *did* in practical work and what they *learnt* from practical work as being useful for when they left school. What statements 7 and 8 suggest is that students' attitudes to what they do and learn in practical work are not as positive as might have been hoped if, as is often claimed, practical work is a significant motivating factor (Roberts and Gott, 2008). Indeed, part of the reason for this appears to be that they do not believe that practical work has any relevance to them outside of the school laboratory and in particular with regards to their future careers. However, when examining the data by year and science the results begin to show some statistically significant differences. As the results seen in table 6.23 and 6.24 for statements 7 and 8 respectively suggest that as students mature, for many students they do not see the relevance of what they learn or do in practical work as being useful upon leaving school.

Table 6.23: Percentage of students that agreed to statement 7 (What I do in biology/ chemistry/ physics practical work will be useful when I leave school) across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	53% (27)	59% (30)	55% (28)	56%
Year 8	35% (17)	29% (15)	55% (28)	40%
Year 9	47% (24)	40% (20)	49% (25)	45%
Year 10	43% (22)	25% (13)	31% (15)	33%
Average percentage across year groups	44%	38%	47%	43%

Table 6.24: Percentage of students that agreed to statement 8 (What I learn from biology/ chemistry/ physics practical work is always useful for when I leave school) across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	45% (23)	59% (30)	45% (23)	50%
Year 8	22% (11)	22% (11)	61% (31)	35%
Year 9	39% (20)	32% (16)	49% (25)	40%
Year 10	24% (12)	25% (13)	27% (13)	25%
Average percentage across year groups	33%	34%	45%	37%

Indeed, what emerged with regards to physics for statement 7 was that fewer students in Year 10 felt that what they *did* in practical work was useful for when they left school when compared to Year 7 ($\chi^2 = 6.015$, $p < 0.05$) and Year 8 ($\chi^2 = 6.015$, $p < 0.05$). For chemistry, there were statistically more students in Year 7 that claimed what they *did* would be useful upon leaving school when compared to Year 8 ($\chi^2 = 8.947$, $p < 0.001$) and Year 10 ($\chi^2 = 11.619$, $p < 0.001$).

For statement 8 in chemistry in that there were more Year 7 students that felt what they *learnt* was useful for leaving school than Year 8 ($\chi^2 = 14.723$, $p < 0.001$), Year 9 ($\chi^2 = 7.324$, $p < 0.01$) and Year 10 ($\chi^2 = 11.619$, $p < 0.001$). In physics, the statistical difference was found where fewer Year 10 students felt that what they *learnt* in practical work was useful upon leaving school compared with Year 9 ($\chi^2 = 5.365$, $p < 0.05$) and Year 8 ($\chi^2 = 11.900$, $p < 0.001$). For biology, there were statistically more students in Year 7 that felt what they *learnt* in practical work was useful after school compared to Year 8 ($\chi^2 = 5.710$, $p < 0.05$) or Year 10 ($\chi^2 = 5.263$, $p < 0.05$).

Across the sciences in the year groups, it was only Year 8 where there were statistically more students that saw the relevance of what they *did* and what they *learnt* in physics upon leaving school than biology ($\chi^2 = 4.120$, $p < 0.05$ and $\chi^2 = 15.080$, $p < 0.001$

respectively) or chemistry (χ^2 = 6.790, p < 0.01 and χ^2 = 16.190, p < 0.001 respectively). This finding suggests that students in Year 8 claim that physics has more relevance to their life upon leaving school than biology or chemistry. Their reason for more agreement in physics was that students felt that if they needed to know or explain in the future about particular practical work they had done, they would be able to. Students did comment on how what they learnt in practical work in the sciences would be useful for a job if they went into such a career. These findings are similar to those reported by Parkinson et al. (1998) who found that students in Key Stage 3 saw the sciences as important but as in this study, by Key Stage 4 whilst they still thought science was important, they were not intent on a career in science. Indeed, within the responses to statement 7 and 8 there were many students who felt that a career in science was not for them and, as such, saw no relevance of practical work beyond their science lessons.

The data suggests that the practical work carried out in the three sciences has little impact on students seeing any relevance to their latter life or career. Indeed as students in the focus group explain:

> Leanne 9C: The practicals we do in school aren't relevant. I mean I don't do much science outside the school so it doesn't really affect me other than when I'm in my lessons. I'm not going to like need any of it in any job I have, I don't think so anyway.
>
> Nelson 10P: How can any of the practicals we do have any relevance to our lives? I mean learning and doing like practicals with weights on cranes...it isn't really gonna help me when I'm getting a job, is it?!

Whilst both these students commented on enjoying practical work, what they are suggesting is that they do not see the relevance of it and this was a widely shared view amongst the students within this study.

When students were asked if what they did in practical work was a way of seeing how scientists worked in the real world, there were few students that could agree for biology (42%), chemistry (59%) and physics (56%) on average across the year groups. Another emerging finding is how as students mature, fewer students are able to see what they do as being a way of seeing how scientists work in the real world, as seen in table 6.25.

Table 6.25: Percentage of students that agreed to statement 9 (I find practical work a way of seeing how biologists/ chemists/ physicists work in the real world) across the sciences and the year groups (raw data in brackets)

	Percentage of students in biology	Percentage of students in chemistry	Percentage of students in physics	Average percentage across the sciences
Year 7	47% (24)	80% (41)	67% (34)	65%
Year 8	37% (18)	45% (23)	71% (36)	51%
Year 9	41% (21)	58% (29)	49% (25)	49%
Year 10	43% (22)	53% (27)	39% (19)	45%
Average percentage across year groups	42%	59%	56%	52%

There were statistically fewer Year 10 students that felt physics practical work was a way of seeing how physicists worked when compared to Year 7 (χ^2 = 7.8040, $p < 0.01$) and Year 8 (χ^2 = 10.219, $p < 0.001$) , there was also statistically fewer Year 9 than Year 8 students in response to this statement (χ^2 = 4.935, $p < 0.05$). This suggests that by Year 9 students are not seeing the relevance of physics practical work in seeing how a physicist works in the real world; and this concurs with students' enjoyment in physics practical work dropping by Year 9. For chemistry, the decline starts by Year 8 as there were statistically more students in Year 7 that felt practical work was a way of seeing how chemists work in the real world than compared to Year 8 (χ^2 = 13.589, $p < 0.001$), Year 9 (χ^2 = 5.951, $p < 0.05$) and Year 10 (χ^2 = 8.647, $p < 0.01$).

Conversely, attitudes to biology practical work in seeing how a biologist works in the real world, remains stable throughout the year groups. This coincides with students' attitudes to biology that remain stable throughout secondary school (Spall et al., 2004) because students see the relevance of biology to their lives compared to the other two sciences (Cleaves, 2005; Osborne et al., 2003). However, comparing across the sciences in Year 7, there were statistically fewer students that felt practical work was useful in seeing how biologists work than compared to physicists ($\chi^2 = 4.000$, $p < 0.05$) or chemists ($\chi^2 = 12.260$, $p < 0.001$). Yet, by Year 8, statistically more students claimed that practical work was useful at seeing what a physicist did than what a chemist ($\chi^2 = 6.790$, $p < 0.001$) or biologist ($\chi^2 = 11.530$, $p < 0.001$) did.

What the responses to statement 9 seems to suggest is that the role of practical work in chemistry is more effective at helping students to understand what chemists do, compared with how practical work biology and physics helps develop an understanding of the work of biologists and physicists. However, according to Toplis and Allen (2012) the idea that practical work is working as a scientist is open to "criticism in that different needs, approaches and resources available to professional scientists and to school students are very different" (p. 4). Certainly, students claimed that whilst it was not exactly like that scientists did and that their teacher could not show them everything, it would show a little of what a scientist might do. Some students also argued that they were unsure of what a scientist actually did as the comment below explains:

> Nick 10P: I don't know if it is exactly what a scientist does, I mean I can guess a bit for a chemist like a pharmacy type job but physicists or biologist I wouldn't really know. Maybe the teacher didn't bother teaching us that!

Indeed, when looking in the questionnaires, one student selected the option that they wanted to be a biologist but there were no students who claimed they wanted to be a physicist or a chemist. As the comments from students during the observations make the point that whilst students do value practical work in their learning, the relevance of practical work depends on their career choices beyond post compulsion science:

Lloyd 9C: Well practicals can be useful to other subjects in school, like the biology dissection we do will help me in PE GCSE to understand the human body, but I want to be a sports teacher and so I can't see physics or chemistry practicals helping me I mean I'm not going to set up chemicals during a PE lesson!

Neo 10P: Practicals may help in my GCSEs but beyond that it is pointless for my life! Unless you want a career in some practical physics or at a chemist or biologists like a doctor you aren't going to be using the practicals again so it just depends what you want to do after school.
Researcher: What do you want to do?
Neo 10P: I don't know, I think maybe something with sports or something.

Students in this study did see science practical work as important but if their careers aspirations were such that they did not need it, it was seen as being of little, if any, relevance to their lives. This concurs with the findings by Jenkins and Nelson (2005) that students saw the importance of science but felt it was not a subject for them to continue to study.

6.5: Conclusions to research question 2

The main conclusion that can be drawn for addressing research question 2 – namely 'To what extent, if at all, do students' attitudes to practical work differ across the three sciences' - is that students' attitudes to practical work differ not only across the three sciences but also across year groups. Students start secondary school claiming to enjoy practical work in all three sciences, holding positive beliefs for the affective and cognitive value of it. Consequently they are enthusiastic and think it is relevant to their lives. However, by the time they reach Year 10 their attitudes to practical work in biology, chemistry and physics differ to the extent at which physics practical work is perceived less positively than biology). This conclusion is similar to students' attitudes to sciences per se where their attitudes to biology, chemistry and physics are relatively positive at the start of secondary (Owen et al., 2008; Spall et al., 2004; Woodward & Woodward, 1998).

Indeed, in this study with regards to biology practical work, across the year groups their attitudes were more stable and any differences tended to be within the domains relating to the affective and conceptual understanding of practical work. Indeed, whilst practical work was not seen as their favourite part in biology lessons, it remained as an enjoyable part as they progressed through school. Unlike the findings by Bevins et al. (2011) and Cleaves (2005) with regards to biology per se, there were not many students that preferred biology *practical work* over chemistry or physics because of it being easier to do or more relevant to their lives.

Within chemistry, students' attitudes to practical work were less stable than biology and the differences across the year groups fell mainly within the affective domain and the relevance of it. Chemistry practical work was more popular than biology practical work, especially in Key Stage 3, although not as popular as physics. The findings here are unlike those by Parkinson et al., (1998) who reported that chemistry practical work received the most favourable comments by Key Stage 3 students and chemistry was seen as the most popular science.

Within physics, students' attitudes to practical work are positive within the lower year groups, they hold positive affective and cognitive arguments for their enjoyment in the lower years. However, by Year 10 their attitudes have declined and their reasons relate more to the cognitive domain than the other two domains. Furthermore, it is apparent that students' enjoyment for physics practical work is generally much higher than biology. Although, as physics is perceived as difficult (Osborne & Collins, 2001; Bevins et al., 2011) by students, the practical work seems to play a role in making it more bearable as indeed Parkinson et al. (1998) reported that the lack of practical work in physics was the main reason for girls, especially, not to enjoy the subject.

6.6: Conclusions to research question 3

In conclusion to research question 3 – namely 'To what extent, if at all, do students' attitudes to practical work in the three sciences differ within each year group - this study has found that their attitudes to each science do change according to the year group they are in. Certainly from Year 7, through to Year 10, there is a change in their attitudes to practical work. Starting from Year 7 students' attitudes to practical work relate mainly to the affective domain and essentially involve "'absolute' claims" (Abrahams, 2009, p. 2342) in the sense that they claim it motivates them, they enjoy because they enjoy the hands-on element of school science. By the time they reach Year 10 students are finding practical work still as enjoyable but their feelings are more about the cognitive aspects of practical work. They begin to question the value of practical work in terms of helping to develop their conceptual understanding which is becoming particularly relevant to them at this stage in their education due to the pressures of GCSE examinations, a finding also reported by Owen et al. (2008).

An overview of the data for Year 7 students in this study, feel positive in regards to all aspects of practical work in biology, chemistry and physics. They believe they are able to learn from practical work in all three sciences in that they are able to *see* the phenomena and learn how to use scientific equipment (Toplis, 2012). They feel that it is an enjoyable part of their science lessons and not only motivates (Parkinson et al., 1998) and interests them but it is their preferred method of learning (Abrahams, 2009; Hodson, 1990; Hofstein & Lunetta, 1982). With regards to *doing* practical work, fewer students found doing physics practical work easy when compared to biology or physics. There were also fewer students claiming practical work in biology was a way of seeing how a biologist works when compared to chemistry or physics. By Year 8, students' attitudes to practical work begin to differ statistically across the three sciences. Students' attitudes to practical work in biology and chemistry were not statistically different but when compared to physics, there was a significant change and indeed the comments during the observations reflected this. Students in this year group enjoyed physics practical work more than biology or chemistry and claimed it to be their favourite part physics lessons compared to biology. Parkinson et al. (1998) reported that when physics lacked practical work, students cited it as their least favourite science, although this was primarily an attitude held by the girls as opposed to girls *and* boys. Chemistry practical work was seen as being easier to do and what they *did* and *learnt* from it was seen to be more relevant to them than physics. Indeed, chemistry practical work was seen to show them more about what a chemist did than physics about a physicist.

In the latter year groups of this study, students' attitudes begin to be dominated less by affective considerations and more by cognitive issues, as indeed other studies have reported (Owen et al., 2008). In Year 9, students' attitudes to practical work differed between the sciences within primarily the cognitive domain. They begin to feel that the potential learning and understanding opportunities from practical work in physics are much higher than chemistry or especially biology. In this year group, fewer students not only felt biology practical work benefited their conceptual development in biology but it was also not seen by many as being the preferred option over non-practical work when compared to their attitudes to physics. By Year 10, students' maturity has developed (Owen et al., 2008) in such a way that they show themselves to be quite savvy to the benefits and limitations of practical work. In this year group, there was a sense of stability of their attitudes to practical work between biology, chemistry and physics. Although, there were more students who preferred practical work to non – practical work and felt the laboratory made doing practical work easy in chemistry when compared to physics, there were no other significant difference between the sciences for this year group. Students' comments suggested that whilst they valued practical work as part of biology, chemistry and physics, it was of little relevance to their lives unless they wanted a career in science (Jenkins & Nelson, 2005).

6.7: Summary

This chapter has examined students' attitudes to practical work in terms of the cognitive, affective and behavioural domains. It has shown that whilst there are similarities across the sciences and across the year groups, there are some significant differences between them across these three domains. This study has shown that the differences suggest it is misleading to talk of students' attitudes to practical work in *science* per se and that instead the focus needs to move towards looking at their attitudes in each of the individual sciences.

In this study, students' attitudes to practical work across the biology, chemistry and physics decline as they progress through secondary school. There were two particular reasons for this decline. First the nature of the practical work that is being carried out in the particular science becomes more complex and difficult for students to learn from -

physics becomes more mathematical (Owen et al., 2008). Second, students are personally developing and becoming aware of the importance of cognitive issues compared to affective ones. So by Year 10 where lessons are more assessment driven for GCSE examinations, means students see practical work as being less effective in their learning than other activities in sciences.

Students' attitudes regarding the enjoyment in doing practical work in biology, chemistry and physics, but what is really meant by this enjoyment might be better seen as a preference for practical work over other methods of teaching science – rather than an enjoyment for it per se. This might, to a large extent, be understood as a consequence of a greater number of 'wow' factors in the physical sciences. There were signs that students held a more sustainable positive attitude to practical work in biology, chemistry or physics providing they held a personal interest for doing it, which in this study was rarely seen.

Students who claimed that practical work interested them or motivated them were referring more to a short-term situational interest that would not persist beyond the end of that particular lesson (Hidi & Harackiewicz, 2000). Short-term situational interest appeared to arise in many cases amongst students who were, from their questionnaire responses and comments, less inclined to want to study any of the three sciences post compulsion. Instead for these students, they saw practical work as an opportunity for a break from written work, listening to the teacher, or simply to be able to chat with friends (Abrahams 2009; Bennett, 2005; Hodson, 1990; Hofstein & Lunetta, 1982; Toplis, 2012). The latter reason was seen to be more apparent in physics, where students reported that the difficulty of the practical work could, in some instances, lead them to dislike doing it but in other cases, practical work was an escape from the difficulty of the theory. However, what has also emerged is that whilst students find physics and chemistry difficult to learn they see the use of practical work as an enjoyable alternative. Indeed, by Year 10 the penultimate year of compulsory science education, practical work in physics does not appear to generate any enduring personal interest. Indeed, as has been argued by Abrahams (2009) and Toplis (2012), if practical work was an effective motivating factor then it would be expected that the number of students studying sciences – and particularly physics - would be much higher post compulsion than is currently the case given the large proportion of time spent undertaking practical work in the UK (SCORE, 2008).

This chapter has also examined the perceived learning value of practical work within biology, chemistry and physics and within year groups. What has become apparent is that students do claim practical work in biology, chemistry and physics can have implications for their learning, but the advantages (and to a lesser extent the disadvantages) depend on the year group. However, whilst this study did not evaluate the extent of any learning associated with practical tasks it appears, from student comments, that they assume that because they are *doing* practical work they will inevitably, as if by osmosis, learn the science even if they simply follow the prescribed instructions in a relatively unthinking manner.

It would appear that students' positive attitudes to the value of practical work in developing their understanding of science are based, primarily, on the view that it is "generally effective in getting students to do what is intended with physical objects" (Abrahams & Millar, 2008, p.1945) rather than in developing their conceptual understanding. As discussed in this chapter, when students were asked to explain what they had learnt, the majority of students were only able to explain what they *did* rather than explain the intended learning outcomes of the practical work. Certainly, practical work in all three sciences has been reported as being “much less effective in getting them to use the intended scientific ideas to guide their actions and reflect upon the data they collect” (ibid, p.1945). The idea that they do and they understand, as Toplis (2012) suggests, may be “that the visual or kinaesthetic experiences provided by practical work provide a cue or stimulus that allows them to access prior learning from memory” (p.544). And whilst similar claims about practical work providing such a cue or ‘anchor’ have been proposed as a reason for using practical work (White, 1979), research by Abrahams and Millar (2008) found that practical work primarily provides cues only for the qualitative descriptive accounts of what was undertaken rather than for any scientific understanding. Indeed, it has emerged in this study that student’ positive attitudes to the learning value of practical work are more likely to be due to the fact that they *prefer* doing it to other methods of teaching – particularly methods involving writing – rather than its actual effectiveness as a means of developing conceptual ideas in either biology, chemistry or physics. Certainly by Year 10 students are aware that for examinations they need a conceptual understanding of the subject so their perceived value of practical work decreases.

The final section discussed in this chapter related to what was referred to as the behavioural domain which found that students feel positive in working in the laboratory. However, the year groups responded differently in their attitudes to using equipment and working in groups or individually during the practical work. Indeed, during the lower years of secondary school, students are content with either group or individual work as it is seen as a means of demonstrating their ability to the teacher. However, by Year 10, students are more concerned with finding and knowing the answers for their GCSE examinations (Owen et al., 2008) that group work was the preferred option because it meant they were able to discuss with a work colleague. This was certainly the case for physics where students felt it benefitted their learning, when it is better meant that they were able to *do* in order to observe the phenomena rather than *think* about what it is they have found or are learning about. This was primarily due to the complexity of the nature of physics, and the difficultly for students to *think* and *connect* what they see with the scientific theory (Owen et al., 2008; Johnstone, 1999).

Also, within the behavioural domain, students' attitude to the relevance of practical work in biology, chemistry and physics was discussed. This study found that whilst Year 7 hold a somewhat naïve attitude that everything they do and learn in biology, chemistry and physics practical work has relevance to them and their lives, by Year 10 students have become more conscious of the limitations of it to them and their lives. The impact of GCSE examinations has led Year 10 students to value practical work in all three sciences differently to Year 7 students both with regards to the educational importance (Owen et al., 2008) and the opportunities for their future careers. Certainly, whilst students valued practical work as an important part of science, as Jenkins and Nelson (2005) found for students' attitudes to science, it is not relevant to most students' career choices.

The next chapter, Chapter 7, will conclude the findings and discuss the implications of this study.

Chapter 7

Conclusions and implications

7.1: Introduction

This chapter draws together and discusses the key findings from the study. The chapter has five main areas. First, the chapter addresses, in section 7.2, the three research questions set out in the methodology chapter and discussed in chapters, Chapter 5 and Chapter 6. Next, section 7.3, then evaluates the study and its findings with the benefit of hindsight and the implications of the decisions made. Towards the end of that section suggestions are made as to the potential areas for further future research. The third section, section 7.4, suggests how the study has contributed to the transfer of educational knowledge and understanding. Then, section 7.5 offers some implications of the findings for practice and research which includes implications for teachers, policy makers and future researchers. To complete this chapter, section 7.6 provides some closing thoughts on the study.

7.2: Research findings

As each of the three research questions have been addressed and answered in Chapter 5 and Chapter 6 the aim of this chapter is not to simply re-present the findings again but rather to revisit each research question in turn in order to highlight the main findings of this study in light of each of these questions.

7.2.1: What are students' attitudes to practical work in school science lessons?

Practical work was seen as a positive part of science lessons by students in the study. Whilst there were various factors within the cognitive, affective and behavioural domains that contributed towards students' positive, or negative, attitudes to practical work, the most evident were those that related to the affective and cognitive domain. The reasons given within the affective domain were with regards to *preference* for practical work over other non-practical methods of teaching science as well as the fact that they liked the idea that practical work offered them a greater level of personal autonomy – including the opportunity to talk with friends whilst they were working.

Within the cognitive domain, students' attitudes to practical work were found to impact on their conceptual and procedural understanding in so far as they felt practical work enabled them to see, for themselves, the theory in action. Although it was not possible to ascertain if every time they did practical work they saw what their teacher expected them to see, or whether they learnt from it, it did appear from both the comments students made and observations of them during the practical work lessons that it provided them with an anchor. However, there were concerns that when the practical work did not 'produce' the correct results or that it was difficult, then the older students were especially concerned that they might not subsequently know the answers for their non-practical work GCSE examinations. Indeed, not all students saw practical work as *always* being the best way of learning in science. Indeed, when students' attitudes were explored further what emerged is how their beliefs of learning are better seen as beliefs about being able to successfully *do* the practical work that has been asked of them in order to produce and *see* the phenomena. Whilst it was not part of this study to assess the extent to which students' claims to learn more effectively from doing practical than from non-practical methods of teaching, when they were asked to explain what they learnt from practical work they were only able to describe what they did and what they saw.

Indeed, in all year groups, and all three sciences, students were able to recollect the practical work they did but struggled to be able to explain the scientific concepts that the teacher might reasonably have intended them to learn from it. Many students were less inclined to agree that doing practical work was easy in biology, chemistry and physics because they struggled to understand it at times and, for Year 10 students other methods were seen more effective at developing conceptual understanding, similar to that reported by Owen et al. (2008). Studies by Hussein and Reid (2009) and Johnstone (1999) have explained how for the sciences, it is difficult for students to connect what they observed during the practical work with the scientific concepts that they are meant to be learning. Certainly the practical tasks that students were able to recollect involved some sort of visual or kinaesthetic effects, such as the practical task that students in Year 10 during the focus group discussed with the researcher about the jelly baby in the microwave (seen in Chapter 5). So the uniqueness of the practical work is what remained with these students as opposed to the scientific concepts behind them.

Within the affective domain it is evident that the majority of students, from all year groups, do enjoy practical work as a part of biology, chemistry and physics lessons. Many students in the lower years gave ‘absolute’ claims of how fun practical work was, whilst the older students gave reasons relating to preference over other aspects of learning in the sciences and, in particular, the opportunity it provided to avoid writing or listening to the teacher.

Practical work that was in some sense ‘novel’ (Abrahams & Millar, 2008, p. 1962) did instil a situational interest in students. Many students were able to describe a unique practical task *but* there was no evidence to suggest that their motivation to study science, or that they felt more positive towards science in general had been affected. The use of practical in this study appeared to be related to a more short-term motivation in that for many students, their interest did not appear to continue beyond the end of the lesson. Indeed, the fact that the majority of students in this study wanted more practical work in their biology, chemistry and physics lessons because they preferred it to other activities, suggested that their interest was more situational than personal.

Within the behavioural domain, students’ attitudes did show that they enjoyed manipulating objects and getting ‘hands-on’ within the laboratory during biology, chemistry and physics lessons. Students were found to *simply* enjoy the opportunities practical work give them to have a go in all three sciences, although the lower year groups preferred this to the older students because, as discussed earlier, the older students questioned the value of learning, for examination success, through practical work. Group work is another aspect within this domain that changes according to the year group and the science being studied. The lower years prefer being able to show the teacher they can do it themselves whereas the older students prefer the opportunity to work and chat in groups, especially in the harder subject like physics.

As students progressed through school it emerged that they began to feel that practical work lacks relevance to real life. This correlates with students’ attitudes to the sciences where students struggle to see the links physics and chemistry have to their lives as has been reported by both Bevins et al. (2011) and Spall et al., (2004). With regards to the relevance of practical work to students’ lives, there were few students, within all year groups and across the three sciences, that felt what they did, and what they learnt, would be of use upon leaving school. Indeed, many students did not feel that practical work was providing them with an insight into what biologists, chemists and physicists did as functioning scientists. The attitude that emerged throughout the study was that for many students, practical work was both enjoyable and to a certain extent important but a career in science was not an idea they readily entertained. Such findings echo the findings reported Jenkins and Nelson (2005) who found that whilst students saw science as being important they were not attracted to it as a career they would want.

In answering this first research question, the study has found, in general, students' attitudes to practical work in science, as represented through those within the study:

- Students do hold positive attitudes to practical work within school science lessons.
- Students' attitudes relating to being able to *learn* about science concepts through practical work are better thought of as reflecting their beliefs that being able to *do* and *see* – the procedural aspects of practical work – is synonymous with having learnt.
- Students' attitudes are influenced by his or her personal and situational interests in the science being studied. For many students, practical work is a situational interest that does not continue past the end of the particular science lesson.
- Practical work is not able to stimulate long term motivation in *all* students *all* of the time.
- School practical work was seen as an important part of science but this was equally as important as the non-practical work aspects.

- Students do *prefer* practical work to other methods in science due to personal autonomy and opportunities to talk with friends.
- Students like to be ‘hands-on’ with practical work but the behaviour of the class can impact on this enjoyment.

7.2.2: To what extent, if at all, do students’ attitudes to practical work differ across the three sciences?

Whilst students’ attitudes to practical work in biology, chemistry and physics did show some similarities, there were differences in their attitudes between each of the three sciences.

Students were more positive about practical work in physics in Years 7 to Year 9 than they were in Year 10. It emerged that students in the lower years claimed doing physics practical work was enjoyable and referred positively to both the cognitive and affective aspects of practical work when questioned on these. As physics is seen as the harder of the three science subjects (Bevins et al., 2011), it is understandable that students feel the ‘hands-on’ aspects aids learning in physics and makes it more accessible to them; especially if recipe style practical work is involved or where students are only required to carry produce and see a particular phenomenon. However, as students progress through school, as with attitudes to physics and chemistry (Barmby et al., 2008; Lyons, 2006; Osborne et al., 2003), so too do students’ attitudes to practical work across these two sciences decline. Attitudes to practical work in biology, whilst there was a slight decline by Year 8, were stable throughout secondary school, which parallels reports on students’ attitudes to biology (Osborne et al., 2003). Within the cognitive domain, students in Year 7 felt that practical work helped their learning and understanding in the sciences as well as giving them an opportunity to learn how to use science equipment.

By Year 10, students were more aware that for the harder sciences, physics and chemistry (Bevins et al., 2011 and Johnstone, 1999).

Overall what has emerged has been the fact that students' attitudes to practical work differed according to the science being studied. Whilst the reasons for students' attitudes to practical work in each of the three sciences differed, with regards to the cognitive and behavioural aspects, affective aspects were referred to in all sciences. As students progress through school, the reasons for liking or not liking practical work in any one science differed from those relating to the affective domain through to the cognitive domain by Year 10.

In answer to this research question on students' attitudes to practical work across the three sciences, the findings in the three schools showed that students' attitudes to:

- practical work do change according to the science they are studying.
- physics practical work were consistently more positive than their attitudes to biology or chemistry practical work.
- biology practical work were seen to be least favoured of the three sciences.
- chemistry practical work are stable and tend to provoke less difference in attitudes through Year 7 to Year 10.

7.2.3: To what extent, if at all, do students' attitudes to practical work in the three sciences differ within each year group?

In answer to this research question the study has found that, in general, students' attitudes to practical work do differ according to the year group and the science. Indeed, in Year 7 students find practical work in all three sciences enjoyable, similar findings have previously been reported by Spall et al., (2004) who found this year group enjoy both biology *and* physics. However, by Year 10, there is a smaller proportion of students enjoying practical work in physics but no significant change in biology.

Year 7 students were found to feel positive towards practical work in biology, chemistry and physics. What they seem to believe is that because they enjoyed it and felt they could get hands on with the equipment, they would therefore be *learning*. In this year group a student would say they liked practical work primarily because of an affective reason, such as it was fun, as has been previously reported by Abrahams (2009). This affective reason would then be followed by a cognitive or behavioural reason, or indeed both. However, by Year 10, students were less positive about practical work in all three sciences and their reasons related more to the cognitive than the affective domain. Whilst their attitudes referred to *preferring* practical work, they were more concerned with issues relating to the ability to learn from it.

Overall this study has found that in response to what extent if at all, do students' attitudes to practical work in the three sciences differ within each year group:

- Students' attitudes to practical work are very positive in Year 7 across all three sciences with affective responses involving 'absolute' claims.
- By Year 8, students' attitudes to chemistry and physics practical work are seen more positively within the affective and cognitive domains than biology.
- By Year 9, students' attitudes to practical work in physics remains positive but reasons for enjoyment fall into the cognitive domain.
- By Year 10, students' attitudes are significantly lower for practical work in physics compared to the Year 7 and Year 9 with the cognitive value of practical work being an important factor in shaping their attitudes.

- For many students they *prefer* doing practical work to other non-practical work activities in the sciences, especially in the harder sciences like physics and chemistry.
- External factors such as GCSE examinations, do impact on students' attitudes to practical work in biology, chemistry and physics.
- In general, there is a decline of positive attitudes to practical work from Year 7 to Year 10 for chemistry and physics unlike biology.

7.3: An evaluation of the study and its findings

It is often valuable to look at a study with the benefit of hindsight, in order to evaluate the extent of which choices and decisions – in particular, in this case, the use of multi-site case studies employing a condensed fieldwork strategy – have affected the findings. It will focus in particular on the reliability, and validity – both internal and external – of the findings as well as the effect of external constraints on the type and quantity of data collected.

7.3.1: A critical reflection on the analytical framework

The analytical framework devised by Rosenberg and Hovland (1960) was an effective tool in analysing students' attitudes to practical work. Indeed, the reasons students provided for their attitudes to practical work all fell within the affective, behavioural and cognitive domains. The framework provided a useful tool for systematically evaluating attitudes in a way that facilitated the emergence of clear research findings about students' attitudes to practical work. The framework also provided a clear way of understanding changes to student attitudes across ear groups and sciences. In particular, the framework showed how the dominance of one domain gave way to the dominance of another as students moved from Key Stage 3 to Key Stage 4 with regards to biology, chemistry and physics practical work.

Using the affective, behavioural and cognitive aspects of an attitude, the framework provided an innovative approach to analysing attitudes to practical work which is applicable in a wide range of situations and that could facilitate a common approach to future studies in this area.

With regards to future research, the framework could be modified by addition of further sub-levels within the three domains. This approach would facilitate greater differentiation in terms of the three domains currently used. For example, within the affective domain, it may be useful to introduce additional sub-levels that would facilitate a clear understanding of specific preferences rather than looking at preferences per se.

7.3.2: The internal validity of the findings

The internal validity of the findings in quantitative and qualitative research, "seeks to demonstrate that the explanation of a particular event, issue or set of data which a piece of research provides can actually be sustained by the data. ... The findings must describe accurately the phenomena being researched" (Cohen et al., 2007, p. 135). So in this study it relates to the confidence in the results of the study in accurately portraying that those are students' attitudes to practical work. According to Ary, Jacobs, Sorensen and Razavieh (2009), internal validity is about designing appropriate controls to "eliminate extraneous variables that could lead to alternative interpretations and hence lower internal validity. Anything that contributes to the control of a design contributes to internal validity" (p. 272). In this study, the development of the questionnaire, the conduct of the questionnaires, observations and focus groups all involved varied degrees of controls to their design to restrict lowering the internal validity of the study. Whilst the quantitative results were internally validated by statistical methods seen throughout Chapter 5 and Chapter 6, the qualitative results were internally validated by means of triangulation.

One aspect to increase validity of the data involved reducing the Hawthorn effect. Within the distribution and collection of the questionnaires that were carried out by the researcher, students were assured of the study being anonymous and that their teachers would not be aware of who answered the questionnaire in a particular way. They were informed to select the option they *most* agreed with and/or write their thoughts on the paper. Whilst they were completing the questionnaire, the researcher stayed with the students to reduce the number of wasted questionnaires as well as ensuring students did not copy or select answers to match their peers. To prevent instrumentation threats to the internal validity (Ary et al., 2009), all three observations and focus groups were carried out by the same researcher. Furthermore to avoid maturation which refers to "changes (biological or psychological) that may occur within the subjects simply as a function of the passage of time" (Ary et al., 2009, p. 274) the students were questioned, observed and interviewed within the same time period of the school calendar. Data was collected from Year 8 to Year 10 at the end of the school year and Year 7 at the start of the academic year to reflect the research on students' attitudes in the first year of secondary school (Turner et al., 2010).

In this study, the decision to use the components of an attitude as an analytical framework meant students' reasons for liking or not liking practical work could be explored and the thought processes that they went through to formulate their attitudes could be better understood. The analytical framework did not pre-empt the results of the study but rather enabled the findings to be explored and probed in a more systematic manner.

A weakness in terms of internal validity is the fact that it was not possible to observe, or carry out, a focus group with a Year 8 class. Indeed, had it been possible to gain access in one of the three schools to observe a practical work lesson it would have meant the findings in this year group would have been further corroborated with the findings from the questionnaires. In addition the small sample size of the focus groups and observations meant that clearly the views are those of a relatively small group of students and that caution must be exercised in inferring too much from only three focus groups and three observations. Yet, given the access constraints for the research to be conducted, it was simply not possible to construct more of these in the schools. However, the views in the three focus groups and during the observations appeared to be very similar and with regards to the questionnaire data as well. This suggested that, in terms of external validity, it might - with caution - be possible to see these are reflective of a larger body of students in similar schools in England. Increasing the number of students involved could therefore have further enriched the data collected in those focus groups on students' attitudes to practical work.

Within the design of the instrument, the internal validity was checked throughout the instrument development stage and pilot stage in the study, a similar approach as was taken by Bennett and Hogarth (2005). Students not only completed written questionnaires but the contents of them were validated through group interviews, focus groups and individual interviews. Through the use of matching what was said and written in the questionnaires showed that the percentage of concordance was acceptable.

The use of a mixed methods approach of data collection was selected to improve the study's internal validity. Indeed, according to Meijer, Verloop and Beijaard (2002), for qualitative data collection, "multi-method triangulation is a worthwhile procedure to enhance the internal validity" (p. 145). The fact that the use of questionnaires, observations with semi-structured interviews and focus groups produced similar data on students' attitudes towards practical work makes it reasonable to assume that internal validity was achieved.

7.3.3: The external validity of the findings

The external validity refers to the "degree to which the results can be generalized to the wider population, cases or situations" (Cohen et al., 2007, p. 136.). Whilst the schools in this study were selected to ensure a "naturalistic coverage" (Ball, 1984, p. 75) of the schools that represent the vast majority of schools in England - comprehensive schools were used rather than independent or grammar- no single school can be truly representative or reflective of the Local Authority (LAs) no statistical difference was found between the data collected from the three schools. So although the three schools were drawn from three separate LAs, in three different counties, there was no LA or county bias. As such there appears to be no reason to assume that the results obtained in this study could not be seen as being applicable to other similar schools.

7.3.4: The reliability of the findings

According to Hammersley (1987), there is no widely agreed definition of reliability. However, Bell (1987) refers to reliability as "the extent to which a test or procedure produces similar results under constant conditions on all occasions...A factual question which may produce one type of answer on one occasion but a different answer on another is ...unreliable." (pp 50-51). In this study, data was collected from three different schools, across three different LAs and at different periods in the academic year. When statistical tests were carried out on this data, no significant difference was found between the schools. This suggests that neither the school, nor the LA, nor the time that the data was collected in the academic year had any significant impact on the findings. This suggests that the responses to the questionnaires – and the broad themes to emerge from the focus groups – would, in terms of reliability, be likely to be the same if collected from other schools that were broadly similar in the sense envisaged by Ball (1984).

Alongside this, the researcher distributed and conducted the questionnaires so as to ensure that there was minimal response bias that might influence the results (Peer & Gamliel, 2011). Also, by using a mixed methods approach – which entailed data triangulation - meant the “credibility and trustworthiness” (Johnson & Christensen, 2012, p. 439) of the research findings were increased.

Given the consistency of the data obtained within this study, the findings appear to provide reliable measure students’ attitudes to practical work as observed in the representative sample of schools.

7.3.5: External constraints on the design of the study

There were a number of external constraints which impacted on the design of the study. One of the key issues was access to schools at times when students were preparing for their GCSEs and other examinations. Schools were undeniably under pressure both due to the everyday aspects of teaching but also pressures associated with examination performance and league tables. This meant that access to students was difficult to obtain as schools were keen to ensure that students were not overly disrupted so as to avoid any negative impact on their study. Gaining access into schools meant fitting in around those times when schools were willing to have students observed, free to carry out a questionnaire or to be interviewed. This placed constraints on the year groups that were available to contribute to the study. Whilst it would have provided a more complete view of secondary school students' attitudes had it been possible to include students from all year groups, the timing of the study and the timing of the GCSE examinations clashed and so head teachers were not willing to grant access to Year 11 students.

That said, other than examination year groups (Year 11), teachers and head teachers involved in the study were happy to participate in a study about their students' attitudes to practical work. Indeed they were keen to find out what their students thought and so, once times were arranged with the schools for the visits, they were willing to help in any way they could to ensure the data was collected effectively. However, the limitations meant it was not possible to observe all year groups from Year 7 to Year 10 in all schools which would have strengthened the study's internal validity. Teachers were willing to offer a single observation but it was made clear that there was no opportunity for any further follow-up observations. For this reason, it was not possible to explicitly select which year group that was to be observed; this did mean the researcher was limited to one in each school and not one of each year group or particular science.

7.3.6: Changes to the study design

Due to the process of the questionnaire design, changes were being made right through to the final distribution in the three secondary schools. Indeed, it was necessary that the questionnaires were unambiguous, simple and not time consuming to complete as well as ensuring anonymity throughout. This approach benefitted response rate (Wellington,

2000) as students could access the questions and teachers were able to provide the required time out of their lessons for the questionnaires to be carried out.

Whilst the design of the questionnaire was useful for understanding students' attitudes to practical work, the benefit of questioning students directly during observations and focus groups was enlightening and provided richer data. Therefore, if the study was to be replicated, increasing the number of focus groups and observations with semi-structured interviews could provide more opportunity to collect this richer data. Certainly the decision in this study to add the observational semi-structured questions and focus group questions provided a stimulus for students as well as ensuring the researcher stayed focussed on discussing their attitudes to practical work.

Another area that could benefit from further research would be to broaden the number of schools in the study. This could include more schools not only from across more local educational authorities but also different types of schools (for example grammar, all boys, all girls). As well as the schools, more students could also be included, not only Year 7 to Year 10 but if possible, Year 11 as well with students of different academic abilities to see if that has an impact on their attitudes to practical work. With the current changes in England with regards to qualifications for Year 10 to Year 11 students, further research into the impact of the variety of GCSE and equivalent qualifications could provide further findings on the effects of a particular syllabus on students' attitudes to practical work.

7.4: Contribution of the findings to knowledge and understanding

This thesis has contributed to knowledge in three ways. First, it has resulted in a validated instrument that can be used to collect secondary school students' attitudes to practical work in the three main branches of science (biology, chemistry, and physics). Second, the use of the instrument has shown students' attitudes to practical work do differ between the three sciences and as they progress through secondary school. Third, the instrument has explored further and probed deeper into students' attitudes to practical work in science that go beyond the anecdotal claims made by students that practical work is enjoyable.

This study has contributed understanding of students' attitudes to practical work in biology, chemistry and physics. First, this study has found that students' attitudes to practical work whilst are generally speaking positive, do decline not only across the three sciences but as students progress through their secondary school education. This study has found that the reason for students' attitudes to practical work to decline is due to the relative importance of the cognitive, affective and behavioural domains. Indeed, students move away form the focus of the affective aspects such as enjoyment to one that focuses on the cognitive issues such as preparation for examinations. This study asks the question, should students' attitudes be looked at in terms of their attitudes to biology, chemistry or physics as opposed to science in general when for practical work, these attitudes are significantly different?

The findings of this study suggest it is important that we consider how, why and when practical work is used in biology, chemistry and physics to make it more effective in those lessons in benefitting students' attitudes. It is also important that consideration is taken as to when practical work is most effective at promoting positive attitudes in students.

7.5: Implications for practice

> Science teaching must take place in a laboratory; about that at least there is no controversy. Science simply belongs there as naturally as cooking belongs in a kitchen and gardening in a garden. Books of recipes or gardening manuals can be read anywhere, but the smells, taste, labour and atmosphere can only be evoked in those who already know the reality.
>
> (Solomon, 1994, p. 7)

What Solomon (1994) refers to here is that whilst science can, and is in some places in the world, taught without, or with relatively little, use of practical work, it seems that this would be a greatly missed opportunity to enhance students' experiences in science. Indeed, few can doubt that practical work will remain in science. Whilst this study has suggested that for most of the students, most of the time, practical work can engage them it has emerged that this tends to be short-term situational interest (Hidi & Harackiewicz, 2000) rather than an enduring personal interest (Krapp et al., 1992). The main implications for practice that have arisen from this study have impacts on teachers, future researchers and educational policy makers. It is to these three areas that will now be addressed.

7.5.1: Implications for teachers

The implications of the findings for teachers from this study, suggest that teachers need to be aware of how astute students' are in terms of their attitudes towards biology, chemistry and physics practical work. As many students do acknowledge and appreciate the importance of GCSE examinations - and with this the need to understand and know the theory - their attitudes to practical work become increasingly negative as they focus ever more on developing their conceptual understanding .

Also, the study's findings now question whether it is sensible for teachers use practical work in the same way for every year group, especially when students' think differently in each year group. Certainly, when students’ attitudes are becoming more negative by the end of Year 9 and Year 10 students are claiming that theory work is more important for examinations.

One area that this study set out to address was the issue of student motivation and the uptake of science in the post compulsory stage of their education. What this study has shown is that students’ attitudes to practical work undergo a significant change between Key Stage 3 and 4 and that designing teaching lessons that take account of these changes might increase uptake post compulsion. For example what has been found in this study is that practical work across all three sciences generate substantial enthusiasm in Key Stage 3 but that this enthusiasm is slowly eroded away throughout Key Stage 4 where students resent practical work seeing it as a barrier to their academic achievement in the subject. It might therefore be advisable to have more practical work in Key Stage 3 as a means of further engaging students with the subject of school science before reducing it below the current amount in Key Stage 4 enabling students to focus more effectively on achieving high examination results.

Another emerging finding which has implications for teachers is how students’ attitudes become negative by the end of Key Stage 3 in physics. The issue here is whether teachers should be using the same approach to practical work for each science. If students’ show that their attitudes to practical work are different according to the three sciences, then should biology practical work be delivered in the same way physics practical work is delivered? This study would suggest that this would need addressing and that further research into how they could be effectively delivered in the attempt to maintain positive students’ attitudes to practical work and ultimately science.

7.5.2: Implications for educational policy makers

The implications of the study for educational policy makers, suggest that policies need to consider the sciences as biology, chemistry and physics rather than one entity. There is a need for educational policy makers to consider students' attitudes not to *science* practical work but to *biology*, *chemistry* or *physics* practical work as this study has found that their attitudes are specific to the science they are studying. Indeed, this study has shown that that their attitudes are already compartmentalised to the particular science they are studying and therefore there is a need to treat the sciences as separate sciences with *separate* demands and expectations. Instead of considering what enjoyable practical work in science is, it should be a matter of considering what enjoyable practical work in biology, chemistry or physics is. This study has found that reasons for students' attitudes to practical work in biology are not necessarily the same for practical work in chemistry or physics. It is this difference in students' attitudes that educational policy makers need to consider when devising curricula that educates and is enjoyable.

Further to this, students' attitudes to practical work in physics dropped substantially by Key Stage 4, to the point that students were suggesting they felt less positive towards it. With this in mind, it may be worth considering the purpose and aims for doing practical work at this level. Certainly with the cost of resources, for equipment and science technicians, there is a growing concern as to the effects of the school science budgets impacting on practical work by teachers (SCORE, 2008). Therefore, it seems necessary to consider the reasons for why practical work is carried out, especially in Year 9 and Year 10. If practical work is carried out at this Key Stage to arouse and maintain interest in the sciences, this study suggests that for physics especially, the resources could be better distributed. Indeed, these resources could be used more so in Key Stage 3 so they have improved resources to promote a more realistic science. It may also mean that practical work is better implemented, so to arouse interest and try to better engage students with practical work in each of the sciences – potentially impacting on their attitudes for post compulsion.

7.5.3: Implications for future researchers

The implications of the findings to future researchers is that it illustrates that it is important to consider students' attitudes to practical work in biology, chemistry and, physics separately. It seems reasonable to think that if students' attitudes to practical work are different according to the science being studied; their attitudes to science should also be considered in terms of biology, chemistry and physics as these too could show differences. Certainly, research could investigate further students' attitudes to a science in comparison to the practical work in that particular science. Indeed, with more students currently studying the sciences separately from Year 7 and taking up triple science at GCSE level, their attitudes will become more distinct to the particular subject they are studying. Furthermore, if schools are starting to teach GCSE syllabi to students in Year 9 as was reported by Elwood (2012), then it may be that their attitudes start to change earlier. More research will need to be carried out to assess the effects of such changes on students' attitudes to practical work in biology, chemistry and physics.

Another implication to educational researchers is the importance of considering the impact of the particular science and the year group of the students. Not all students, in all year groups, think the same to biology, chemistry or physics practical work. Furthermore, their attitudes to biology practical work are not the same to chemistry or physics in each year group.

7.6: Final thoughts

Few can doubt that practical work will remain a part of science lessons in English schools and that this study has shown that students can, and do, hold positive attitudes to practical work which can be influenced by both their age and the particular science they are studying. This study has found that students' attitudes to practical work in biology, chemistry, and physics, will change over their time in secondary school. This concurs with the findings that their attitudes change with regards to biology, chemistry and physics as subjects, depending on the "historical, social and political context" (Wellington, 1998, p. xv). By understanding how students formulate their attitudes and what can impact on their attitudes is integral to effectively enhancing their school science experience. This study has shown that it is no longer realistic to discuss students' attitudes to *science* practical work per se since students hold different attitudes to biology, chemistry and physics practical work and these attitudes differ according to particular times in their academic life. Whilst researching and finding out about students' attitudes to practical work is beneficial, it is what happens with that knowledge that will directly impact on students and influence their attitudes.

Appendices

Appendix 1: Biology pilot questionnaire

<table>
<tr><th colspan="6">Biology Questionnaire</th></tr>
<tr><th colspan="6">1. I enjoy doing practical work in Biology lessons</th></tr>
<tr><td colspan="2">I agree because</td><td colspan="2">I neither agree nor disagree because</td><td colspan="2">I disagree because</td></tr>
<tr><td>A</td><td>I like working and talking with friends, sharing answers rather than writing</td><td>H</td><td>I have not done a practical in a biology lesson</td><td>P</td><td>It takes up most of the lesson</td></tr>
<tr><td>B</td><td>It is not something you do everyday</td><td>I</td><td>I prefer it more to chemistry or physics but I do find it quite boring because some of it I do not understand</td><td>Q</td><td>It is hard to understand</td></tr>
<tr><td>C</td><td>I get to investigate different things and explore with different experiments</td><td>J</td><td>I do not really like science in general because I've never been good at it</td><td>R</td><td>It can be difficult to do the practical work</td></tr>
<tr><td>D</td><td>It is also a good time to take control of my learning</td><td>K</td><td>Doing practicals are ok but it is not something I look forward to doing unless I have not done one for a while</td><td>S</td><td>I get limited to the (safe) things I can do</td></tr>
<tr><td>E</td><td>I learn more when I actually experience the experiment happening</td><td></td><td></td><td>T</td><td>It is too short</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>X</td><td>Another reason - Please explain</td><td>Y</td><td>Another reason - Please explain</td><td>Z</td><td>Another reason - Please explain</td></tr>
</table>

Appendix 1: Biology pilot questionnaire continued

2. I am able to learn from practical work in Biology lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I can see for myself how everything works rather than just being told what happens	H	I have not done a practical yet but if I did then I would learn more	P	I just follow instructions
B	If I am more into the lesson I am going to learn more than if I was bored writing	I	I think I learn from my practical lessons but not as much as I think I could doing written work	Q	Not every practical in biology teaches me something new
C	I learn a lot from making mistakes and learning how things work in the actual practical activity	J	It depends on what practical work it is as to whether I learn anything, some I can but some I can not	R	I do not always understand it
D	I am more involved in the lesson so I learn more	K	At times, the teacher does not explain it well	S	Using the equipment can be hard so I do not see what I am are learning
E	When I experience it I learn the smaller facts as well	L	I do not like biology that much really		
F	It is more independent work, so I can control my learning				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

3. I prefer practical work to non-practical work in Biology lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I get to develop my knowledge on practical work	H	I think if I did some practicals then I would prefer them	P	I have not had any practical lessons yet
B	I tend to concentrate and behave a lot more than if I am just sitting down not doing practical			Q	I just want to know the answers for the exams so non-practical is better for this
C	I remember it better than written work because I remember things that are fun			R	There are more dangerous risks from doing practical work
D	I get to do the experiment myself which is an easier way to learn				
E	I would rather be experimenting and exploring than with a work sheet				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

4. Doing practical work is my favourite part of Biology lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I get to do it myself instead of the teacher just explaining it	H	Sometimes they can be fun and other times they can be quite boring	P	It is too difficult to be my favourite part
B	I get to explore more and sometimes learn new skills	I	It is not my favourite part of biology	Q	Written work is quicker to complete
C	It shows that I can be independent and trusted to do something	J	It could get boring and I could struggle but they are sometimes enjoyable	R	I rarely do practical lessons
D	I do not get to do practical in every lessons so it is something different	K	Even though I have not had a practical lesson, I still like to do something practical rather than writing	S	I like doing writing anyway
E	I do not sit in a seat all lesson				
F	It gives me more of a chance to do more in a lesson				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

5. Practical work helps me understand Biology					
I agree because		I neither agree nor disagree because		I disagree because	
A	I can see what happens myself whereas when someone tells me something or I read it, I can not understand it as well	H	I think doing practical would help me understand	P	It is just another way of learning
B	It involves you having to think for yourself a lot more than writing	I	Written works helps me understand it better but I learn things doing practical that I would not learn from written work	Q	We are just understanding how to use the equipment
C	It makes me more enthusiastic	J	I see biology as testing things, like biologists would, not about understanding		
D	You can share results with people and not all get the same answers				
E	Have a chance to learn from your mistakes				
F	It is clearer and easier to understand				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

6. I find practical work in Biology easy

I agree because		I neither agree nor disagree because		I disagree because	
A	There is not a lot of writing or work to do really	H	Some of the things I do in biology is easy but some of it can be hard	P	I do not do enough for it to be easy
B	It just is	I	It depends if I understand the topic or not in the first place	Q	I have to work out what to do myself which is hard
C	It helps me understand	J	It depends on what I am doing in the practical lesson	R	The practical instructions are never easy to follow
D	The teacher explains it then I just do what I feel is correct	K	It can at times be challenging but it is good to be challenged		
E	I can not really do much in biology practicals	L	I struggle sometimes because it is not the easiest of subjects but some topics are quite easy		
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

7. What I do in Biology practical work will be useful when I leave school					
I agree because		I neither agree nor disagree because		I disagree because	
A	It will help me remember the information more so it will help me to pass my exams	H	It depends what I am going to do, some things will and other things will not	P	I do not want to be a biologist
B	I will know safety features	I	I think it would because I would know what happens	Q	Unless I want to be a biology teacher it will not be useful in any way
C	Everything I do will be useful when I leave school	J	I think it is pointless because I copy out of a book then do a practical at the end when I have learnt everything	R	It is nothing to do with the career I would like to do
D	It encourages people to work as a team and be careful around other people in a busy area				
E	There is no point learning it if I can not experience what I have learnt in lessons				
F	It gives me more experience				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

8. What I learn from Biology practical work is always useful for when I leave school					
I agree because		I neither agree nor disagree because		I disagree because	
A	I have to rely on myself when I get older so I have to physically do it	H	It depends on the job I want to do when I leave school, whether it involves biology or not	P	It is not always useful
B	I need to use biology to get a job in the future	I	The job I want to do does not involve it but I could need it in later life	Q	It depends on my job and what I want to do
C	I might want to work somewhere where I need to do biology practical work	J	I sometimes need to know things for the future and I sometimes do not		
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

9. I find practical work a way of seeing how Biologists work in the real world					
I agree because		I neither agree nor disagree because		I disagree because	
A	I get the understanding of the animal and the human body	H	I doubt I will see a biologist work in the real world	P	I do not really understand what biologists do in the real world
B	It is easier for me to watch someone do something and explain while they do it, than just listening to someone or reading a book	I	I can see how they work without doing practical work	Q	I do not take any notice of how they work in the real world
C	It shows how it would be like if I was a biologist	J	All the teacher will do is show me then I get on with it, it is not real	R	It is just a way of learning for the exams
D	I learn the same things because they must have done what I do to find things out too	K	I can not really imagine having to do science practical everyday, I guess if I liked it but I do not		
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

10. I think we should do more practical work in Biology lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	Then I learn what things are in more detail	H	If I need it for the topic then that is ok, but only if I need to	P	I need to know the theory more for the exams
B	It makes it more fun than just reading, and this means I am more likely to learn and work			Q	I can learn both ways
C	I do not do much of this so I do not understand stuff as much as I should do			R	If the practical work does not tell me the answer I still need to do the theory to understand the biology
D	It enables me to be more involved			S	It is not easy to do practical work unlike written work
E	Even if it will not be useful, I enjoy it				
F	I listen more as it is more interesting				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

11. For me to learn in Biology lessons, I need to do practical work					
I agree because		I neither agree nor disagree because		I disagree because	
A	I find it more interesting so I pay more attention	H	I find both ways comfortable to learn biology	P	I do not need a practical to learn things but it does make it easier to understand
B	I take more information in and I listen more	I	I am still able to learn without doing practical, it just makes it more interesting	Q	It is just free time to chat to friends not learn biology
C	If I do not do practical work how will I know what to expect in real life	J	Learning is learning	R	I can learn both ways
D	It is easier because if I do something wrong I remember I did it wrong whereas if I write it down wrong I may forget			S	Worksheets are more helpful to me
E	I do not concentrate as well when I just write in my book			T	Practical is just there for fun, written work is for learning biology
F	It gets my attention more then just having it explained				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

12. I prefer the freedom I have during practical work in Biology lessons							
I agree because			I neither agree nor disagree because			I disagree because	
A	I can learn independently and at my own pace		H	I am still working but it is more fun		P	I do not get freedom in practical work, too many rules to follow
B	When I am given freedom I take that privilege and enhance it to learn more		I	I like to work with other people because I can share opinions but I sometimes like to work with independence		Q	The teacher does not help so I never know what to do
C	I can help and get help from others and work together with friends					R	The teacher is constantly stopping me to tell me what to do
D	It helps my learning but then if it is wrong the teacher can always correct me and help me to understand without taking over or doing it for me					S	I do not get to explore by myself
E	I can explore new ideas						
F	I do not feel under pressure or constantly looked at						
X	Another reason - Please explain		Y	Another reason - Please explain		Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

13. My school science environment makes doing practical work difficult in my Biology lessons

I agree because		I neither agree nor disagree because		I disagree because	
A	Health and safety issues have gone to far in English schools and they are restricting me in what I can do in practical work	H	Sometimes it is difficult but not always	P	It is fine to do practical work in my biology lessons
B	I have not done practicals because of this	I	The environment does not effect my biology practical lessons	Q	I have a set area to work on my practical other than my desk
C		J	It makes it quite easy to do practical work in my biology lessons	R	I do not find it hard
D				S	I have everything I need to learn
E					
F					
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 1: Biology pilot questionnaire continued

14. I do find practical work helps my learning in Biology					
I agree because		I neither agree nor disagree because		I disagree because	
A	I find it more interesting which helps us learn	H	It depends what we are doing in our biology lessons	P	It just helps my memory for tests but I don’t learn from it
B	I learn more from it because I see it for myself			Q	
C	It helps my learning because then I know how something in biology really works			R	
D	It makes the lessons easier for me to be in and school more fun			S	
E	It helps me understand biology better				
F	It lets us try out new ideas				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire

Chemistry Questionnaire

1. I enjoy doing practical work in Chemistry lessons

I agree because		I neither agree nor disagree because		I disagree because	
A	The teacher makes it enjoyable	H	I enjoy everything about chemistry	P	I am always scared of the safety aspects when using chemicals
B	I learn from doing it, not just writing	I	I do not enjoy anything about chemistry	Q	It is sometimes difficult to work in groups or with people I do not like
C	I am bad at chemistry so participating in the practical will expand my skills in the subject			R	I find chemistry practicals always go wrong with me
D	I engage more with something I enjoy doing				
E	I enjoy working with other people and other equipment				
F	I like to visually see the reaction				
G	I remember what I did and learn the information better				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

2. I am able to learn from practical work in Chemistry lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I can see for myself how everything works rather than just being told what happens	H	Sometimes I go wrong and do not learn anything from it	P	I get distracted easily by everything so I do not focus on the practical
B	I understand what is happening when I do them	I	I think I learn from my practical lessons but not as much as I think I could doing written work	Q	I just use the time to chat with friends
C	I learn a lot from making mistakes and learning how things work in the actual practical activity			R	I do not learn from practical work, only learn from the teacher
D	I am more involved in the lesson so I learn more				
E	I usually do a table and a graph so I know the answers to questions for the exams				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

3. I prefer practical work to non-practical work in Chemistry lessons

I agree because		I neither agree nor disagree because		I disagree because	
A	I get very bored and less interested when a teacher is just telling me what to memorise rather than doing it myself	H	It is nice to vary what/how I get taught so it does not get boring	P	I do not learn as much in practical as I think I would do in a written work lesson
B	It is more enjoyable so I am more likely to pay attention	I	It is good to have experience but it is easier to memorise things in writing like taking notes	Q	I prefer discussions with my teacher
C	It can make me think about what I have to do instead of doing questions out of a book	J	Learning from textbooks gives me knowledge about chemistry I can not do via practicals	R	It is hard to get the results from practical
D	I get to interact and talk with other people	K	The non-practical work has to be done and I accept that and enjoy it		
E	I get to see what I am being taught				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

4. Doing practical work is my favourite part of Chemistry lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	Practical work requires skill and is a challenge, which I like	H	Sometimes they can be fun and other times they can be quite boring	P	I do not prefer practical work to written work because I do not feel I learn more with the written work because I do not really remember it all
B	It is easier to look at something happening and learn from it	I	It is good to learn and expand my knowledge	Q	I get distracted easily
C	It boasts my confidence if I get something right and gives me a sense of achievement	J	Doing lots of practical work is good but you still need to write up about it	R	The teacher never gets round to everyone to help me
D	It shows that I can be independent and trusted to do something				
E	I do not get to do practical in every lessons so it is something different				
F	Being young, I like being hands on				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

5. Practical work helps me understand Chemistry					
I agree because		I neither agree nor disagree because		I disagree because	
A	I can see what happens myself whereas when someone tells me something or I read it, I can not understand it as well	H	Sometimes it can but other times it just helps with my practical skills	P	I do not understand chemistry practicals because the results do not always appear
B	I am involved and I remember information	I	Written works helps me understand it better but I learn things doing practical that I would not learn from written work	Q	Chemistry practicals are too complicated to understand
C	I find it engages my learning and concentration			R	The teacher explains it better for me to understand unlike a practical
D	It is better to understand the process it goes through with instructions			S	The non-practical may be easier for me to understand
E	It is better because it is something different to do and I am actually doing the stuff I am learning				
F	Some situations it could be very dangerous if I do something wrong, so I pay more attention				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

6. I find practical work in Chemistry easy					
I agree because		I neither agree nor disagree because		I disagree because	
A	I am confident at doing practical	H	Some of the things I do in chemistry is easy but some of it can be hard	P	It always takes a long time to set the practical up and put away
B	The teacher tells me everything I need to do and I just do it	I	I am good at Bunsen Burners but I am not good at pouring chemicals as I often spill them	Q	There are far to many safety issues to remember during the practical
C	I get a chance to explore the way I want to	J	Sometimes it is hard to know what to do if I am not confident about practicals but it is fun when I am confident	R	There is a lot to do in a practical in a short time
D	I can work with a partner so I share the work	K	Most is easy but when I am learning a new skill it becomes difficult		
E	It does not matter if I do not see the results so I do not need to focus as much	L	The written and practical work is the same really		
		M	Some experiments are hard to understand but that is part of learning		
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

7. What I do in Chemistry practical work will be useful when I leave school					
I agree because		I neither agree nor disagree because		I disagree because	
A	Chemistry explains everything and the skills, although it may not be relevant to someone's future job, it teaches control	H	I might use it when I leave school, I might not	P	I do not want to be a chemist
B	I may go into the chemistry profession and it opens a big range of jobs and options for the future	I	Although I know what I want to do, I do not know if it will help or not	Q	I think some of the things I do in chemistry I will never use outside of school again unless I get a job which is very focussed on chemistry practical
C	It teaches me what is wrong and right about what happens in life and the skills I will keep forever	J	I do not know what I am doing after school		
D	It encourages people to work as a team and be careful around other people in a busy area	K	I am not sure what I am interested in within chemistry		
E	I can get a grade from practical work	L	It might help me in my job because I might want to be a chemist, but the individual skills are helpful		
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

8. What I learn from Chemistry practical work is always useful for when I leave school					
I agree because		I neither agree nor disagree because		I disagree because	
A	It helps me work as a team and to be conscious of other people	H	I think it depends what I want to do with my life, if I want to be a doctor then it would help but I am not sure what else it would help	P	There are not many jobs that involve burning stuff or mixing hazardous chemicals
B	I can get a mark in my end test and I can boast my grade	I	It depends on the A-levels I take	Q	I do not want to study chemistry when I leave school so I do not need to know it
C	It shows me what can go wrong and when I get things wrong	J	It is hard to answer as I have not left school yet so I would not know	R	The job I want to do will not involve chemistry practical work
D	I might want to work somewhere where I need to do chemistry practical work	K	It is only necessary if I am going to be a chemist		
		M	It is hard to answer but I do most definitely learn and gain more of an understanding from practicals		
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

9. I find practical work a way of seeing how Chemists work in the real world					
I agree because		I neither agree nor disagree because		I disagree because	
A	I use lots of chemistry equipment	H	I am unsure what a chemist does in the real world	P	I am only doing little experiments, things that chemists already know, whereas chemists will be doing large experiments trying to discover new things
B	It may not be as complex as what chemists do but it is like a beginners course			Q	Nothing I do in chemistry is what chemists do
C	It shows how it would be like if I was a chemist			R	It is just a way of learning for the exams
D	The practical work involved links in with some experiments real chemists carry out				
E	Chemists normally do experiments to find out information not just read out of a text book				
F	I would like to be a chemist				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

10. I think I should do more practical work in Chemistry lessons

I agree because		I neither agree nor disagree because		I disagree because	
A	It helps my learning and understanding of chemistry	H	I do one a week at the moment and I would like to do more but I need to do more written work	P	I need to know the theory more for the exams
B	It makes me experience the learning instead of watching it on a computer or off a sheet	I	Sometimes when I just repeat a practical it just gets boring but some things I do not learn by practicals alone	Q	I do enough as it is
C	I understand more through experiencing it rather than just hearing about it	J	I think I have a good balance of practical skills and writing already	R	Chemistry practicals take too long for me to learn anything
D	I do not do enough practical work	K	I think I do practicals when it is appropriate and relevant to the topic being covered but also I do enough written work to learn		
E	I learn more doing practical than if I answer questions from a textbook	L	It is good for the class who do not like book work but some, like me, are nervous around the practical equipment		
F	I remember it better if I do it than if I just read it in a book	M	I think practical work is good but the written work helps me towards my exams		
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

<table>
<tr><th colspan="6">11. For me to learn in Chemistry lessons, I need to do practical work</th></tr>
<tr><td colspan="2">I agree because</td><td colspan="2">I neither agree nor disagree because</td><td colspan="2">I disagree because</td></tr>
<tr><td>A</td><td>I find the lessons more engaging</td><td>H</td><td>I have to see what happens and what I need to do in the practical but I need to know the theory behind the practical for the exam</td><td>P</td><td>I do not need a practical to learn things but it does make it easier to understand</td></tr>
<tr><td>B</td><td>I take more information in and I listen more</td><td>I</td><td>I can still learn from looking at books but practicals extend my learning</td><td>Q</td><td>I learn just as much from books</td></tr>
<tr><td>C</td><td>I understand it more because just hearing about it can be confusing</td><td>J</td><td>I learn a lot from my written work but remember specific things, e.g. names of elements, when doing practical work</td><td>R</td><td>I definitely do not need to do it but it does make it more interesting</td></tr>
<tr><td>D</td><td>It is easier because if I do something wrong I remember I did it wrong whereas if I write it down wrong I may forget</td><td>K</td><td>I need to do some written work as well as some practical work</td><td></td><td></td></tr>
<tr><td>E</td><td>I do not concentrate as well when I just write in my book</td><td></td><td></td><td></td><td></td></tr>
<tr><td>F</td><td>I have to really concentrate and I am more likely to remember what I did</td><td></td><td></td><td></td><td></td></tr>
<tr><td>X</td><td>Another reason - Please explain</td><td>Y</td><td>Another reason - Please explain</td><td>Z</td><td>Another reason - Please explain</td></tr>
</table>

Appendix 2: Chemistry pilot questionnaire continued

12. I prefer the freedom I have during practical work in Chemistry lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I like to get on with what I want to do and how I want to do it	H	I like to have freedom at times but then I like to know what I am meant to be doing	P	I just want to know what to do for the exams
B	Just sitting and writing or watching a demonstration is boring	I	I prefer working in groups or pairs as I am not as confident as others however I enjoy finding things out and how they work without being told	Q	I prefer being told exactly what to do, step by step
C	I can experiment myself although sometimes it has to be controlled to be safe	J	I can do things for myself in the practical and when I am doing revision	R	Practicals in chemistry are too dangerous for me to be given freedom
D	It helps my learning but then if it is wrong the teacher can always correct me and help me to understand without taking over or doing it for me	K	I think I get just as much freedom, I have to stick to the task and I am still free to ask for help		
E	It gives me time and space to think	L	I sometimes have freedom to use what I want		
F	I like to work things out myself rather than the teacher telling me the answer all the time				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

13. My school science environment makes doing practical work difficult in my Chemistry lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	It is an enclosed space and so not much room	H	It depends on what I am doing	P	My school has plenty of space for practical lessons and this helps a lot
B	Sometimes I do not have enough space so people get in my way or I get in their way	I	There is enough space but sometimes there are too many people in one area to get an ingredient and end up knocking each other	Q	It is really easy as everyone is doing the same as me and it is really easy to ask for help if I need it
				R	I have a lot of space and good equipment
				S	The instructions given by my teacher are also clear enough to carry out an experiment safely and with the correct equipment
				T	I do not think it makes any difference
				U	I feel I have access to the facilities I need
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 2: Chemistry pilot questionnaire continued

14. I do find practical work helps my learning in Chemistry					
I agree because		I neither agree nor disagree because		I disagree because	
A	When I actually get involved it helps me understand it more than just hearing or writing about it	H	Sometimes it can and sometimes it doesn't	P	It does help me learn but sometimes it is better to be taught by a teacher so that I know everything that I need to know
B	It can help as it can go wrong and you can learn from your mistakes			Q	I need the theory to learn chemistry, like balancing chemical equations
C	It helps a lot to discover and make new substances			R	It just shows us what I am told in textbooks
D	Practical work and written work for me are best ways to learn as I can remember facts and look back in my book, but in practicals I can remember the chemicals and elements and what they make			S	I learn from textbooks quicker
E	It helps me remember what happened in the lesson and the whole of chemistry				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire

<table>
<tr><th colspan="6">Physics Questionnaire</th></tr>
<tr><th colspan="6">1. I enjoy doing practical work in Physics lessons</th></tr>
<tr><td colspan="2">I agree because</td><td colspan="2">I neither agree nor disagree because</td><td colspan="2">I disagree because</td></tr>
<tr><td>A</td><td>I like working and talking with friends, sharing answers rather than writing</td><td>H</td><td>Some physics topics I like, some I don't</td><td>P</td><td>It takes up most of the lesson</td></tr>
<tr><td>B</td><td>I learn from doing it, not just writing</td><td>I</td><td>I'm not bothered about some of the topics</td><td>Q</td><td>It takes times to pack away and carry on with the lesson</td></tr>
<tr><td>C</td><td>We get to investigate different things and explore with different experiments</td><td></td><td></td><td>R</td><td>It can be difficult to do the practical work</td></tr>
<tr><td>D</td><td>I engage more with something I enjoy doing</td><td></td><td></td><td>S</td><td>We have to complete follow up written work, like graphs of the results</td></tr>
<tr><td>E</td><td>You gain a better understanding for the topic</td><td></td><td></td><td>T</td><td>Other people in the class mess around or distract me from the practical work</td></tr>
<tr><td>F</td><td>If the teacher doesn't communicate well, it helps me understand</td><td></td><td></td><td>U</td><td>Most of the practical work we do is the same</td></tr>
<tr><td>X</td><td>Another reason - Please explain</td><td>Y</td><td>Another reason - Please explain</td><td>Z</td><td>Another reason - Please explain</td></tr>
</table>

Appendix 3: Physics pilot questionnaire continued

2. I am able to learn from practical work in Physics lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I can see for myself how everything works rather than just being told what happens	H	I have not done a practical yet but if I did then I would learn more	P	I get distracted easily by everything so I do not focus on the practical
B	If I am more into the lesson I am going to learn more than if I was bored writing	I	It depends on what practical work it is as to whether I learn anything, some I can but some I can not	Q	If the work is hard I do not work to my full potential
C	I learn a lot from making mistakes and learning how things work in the actual practical activity			R	If I do it wrong or get the wrong results, I do not learn
D	I am able to explore for myself what I am learning and I am able to interact			S	The teacher can not help me during the practical to check I am doing it right to learn from it
E	It is easier to concentrate than writing or listening to the teacher			T	I do not need to know the practical work for the exam
F	It is more interesting			U	Sometimes I do not get a go when working in a group, so I can not get involved to learn
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

3. I prefer practical work to non-practical work in Physics lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I get very bored and less interested when a teacher is just telling me what to memorise rather than doing it myself	H	It is nice to vary what/how I get taught so it does not get boring	P	I do not learn as much in practical as I think I would do in a written work lesson
B	I would not understand the work as well as I could if I did not do practical	I	I like doing practicals more than written work but some written work I learn more from	Q	I just want to know the answers for the exams so non-practical is better for this
C	I am more focussed and active			R	Information is easier to learn out of a textbook
D	I learn how stuff works in more depth than I ever would from a book			S	Practical work takes too much time out of the lesson
E	It is always easier than non-practical work			T	It can be difficult to do the practical work
F	Non-practical work is boring				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

4. Doing practical work is my favourite part of Physics lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	It makes the lesson go quicker as I am able to communicate with more people	H	It is my favourite but I do not hate non-practical work	P	I may not always find it interesting
B	I get a chance to use science equipment			Q	I do not feel confident at it
C	I get to work with who I want to			R	I do not like to work with practical equipment
D	It is a change from writing for the whole time			S	The practical can confuse me
E	I am doing something physically so I remember what I learn more effectively			T	I understand more from the teacher
F	It is more enjoyable and interesting				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

5. Practical work helps me understand Physics					
I agree because		I neither agree nor disagree because		I disagree because	
A	I can see what happens myself whereas when someone tells me something or I read it, I can not understand it as well	H	I do not know if practical work helps me in physics because we have not done any physics practicals	P	I do not always get the practical work to show me the right results
B	When I am doing practical, I am not bored and take it in better	I	Written works helps me understand it better but I learn things doing practical that I would not learn from written work	Q	It can be a really long process
C	I would switch off and forget it all if I did not do it	J	Sometimes it does and sometimes it does not	R	The teacher explains it better for me to understand unlike a practical
D	I find it engages my learning and concentration			S	The non-practical may be easier for me to understand
				T	I find it hard to explain my observations
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

6. I find practical work in Physics easy					
I agree because		I neither agree nor disagree because		I disagree because	
A	It is always easier than copying out of a book	H	Some of the things I do in physics is easy but some of it can be hard	P	It always takes a long time to set the practical up and put away
B	The teacher tells me everything I need to do and I just do it	I	It depends if I understand the topic or not in the first place	Q	I struggle to understand what to do
C	It is fun	J	It depends on what I am doing in the practical lesson	R	It confuses my original thoughts
D	I can work with a partner so I share the work	K	I do not understand it	S	It takes such a long time to do
E	The teacher is always around to help me	L	It depends on what I am doing but normally if I get the basic idea it challenges me	T	Sometimes it can go wrong
		M	I still have to memorise what I am learning but I find it more fun	U	It can be too complicated to complete
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

7. What I do in Physics practical work will be useful when I leave school					
I agree because		I neither agree nor disagree because		I disagree because	
A	Physics is a major part of life	H	It depends what I am going to do, some things will and other things will not	P	I do not want to be a physicist
B	I may go into the physics profession and it opens a big range of jobs and options for the future	I	I do not want to work in physics when I am older	Q	I think some of the things I do in physics I will never use outside of school again unless I get a job which is very focussed on physics practical
C	It is a form of learning and what I learn will help me in later life	J	I do not know what I am doing after school	R	Most jobs do not involve physics
D	It encourages people to work as a team and be careful around other people in a busy area			S	I do not learn from physics so I forget what I have done
E	It is a good experience for later life and I get a better understanding of why and how certain things happen/ work, for example gravity				
F	I want to be a physicist				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

8. What I learn from Physics practical work is always useful for when I leave school

I agree because		I neither agree nor disagree because		I disagree because	
A	I have to rely on myself when I get older so I have to physically do it	H	It depends on the job I want to do when I leave school, whether it involves physics or not	P	I will not have the equipment when I leave
B	If I need to know or even explain to others about the practical then I will know	I	Not everyone wants to be a scientist when they leave school	Q	In life people do not come across that many everyday situation where physics practical is needed
C	I can educate others from my own knowledge that I was taught at school	J	I sometimes need to know things for the future and I sometimes do not	R	The job I want to do will not involve physics practical work
D	I need to do practical work and not always be sat down writing	K	It is only necessary if I am going to be a physicist		
E	I might want to work somewhere where I need to do physics practical work	L	I may need it, I may not		
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

9. I find practical work a way of seeing how Physicists work in the real world

I agree because		I neither agree nor disagree because		I disagree because	
A	It is easier for me to watch someone do something and explain while they do it, than just listening to someone or reading a book	H	I am unsure what a physicist does in the real world	P	My teacher can not show me everything that happens
B	It may not be as complex as what physcists do but it is like a beginners course	I	Everybody does things differently	Q	Nothing I do in physics is what physicists do
C	It shows how it would be like if I was a physicist	J	Not all work is about seeing how physicists work in the real world	R	I am only a child and I am not able to do the experiments that a qualified physicist can do
D	It gives me an idea of the real world and helps me with choices I may have to make in the future			S	I do not think I will ever need those skills
E	If I have never done anything then I will not know how it works				
F	I always learn from practical as I am doing it				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

10. I think we should do more practical work in Physics lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I personally take in and engage more with practical work			P	I need to know the theory more for the exams
B	It becomes boring not doing practical so teachers have to do something else			Q	Most of it is boring and does not educate me very well
C	I can see for real what happens ourselves				
D	Hardly anyone likes writing a lot				
E	I learn more doing practical than if I answer questions from a textbook				
F	I need to be actively doing something to learn				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

11. For me to learn in Physics lessons, I need to do practical work

I agree because		I neither agree nor disagree because		I disagree because	
A	I find it more interesting so I pay more attention	H	I do not need to but it helps me a lot more	P	I can learn just as much from written work
B	I learn more because I enjoy it more	I	I can not do practical work for all the things you learn in physics	Q	I prefer to write things down
C	I get distracted easily so practical gets me to focus	J	Sometimes it is fun but I do not always write things down so can not refer back to them		
D	It shows physics in more detail	K	I need to do some written work as well as some practical work		
E	I do not concentrate as well when I just write in my book				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

12. I prefer the freedom I have during practical work in Physics lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	I can learn independently and at my own pace	H	I like to have freedom at times but then I like to know what I am meant to be doing	P	I do not need freedom to learn in school
B	When I am given freedom I take that privilege and enhance it to learn more	I	It is good to have freedom but if I have too much then there is chaos	Q	If I write it I am more focussed about what I am doing
C	I can help and get help from others and work together with friends				
D	It makes me feel like an adult, taking control of my learning				
E	It makes me feel that the teacher trusts me to use physics equipment				
F	I can experiment and see things for myself				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

13. My school science environment makes doing practical work difficult in my Physics lessons					
I agree because		I neither agree nor disagree because		I disagree because	
A	A lot is expected of me in the environment	H	It is alright, it is not the best or the worst	P	I enjoy working in this environment, I feel confident around my friends and people I know
B	I get bored in the physics environment	I	I enjoy physics in the environment as it is	Q	I have a good environment to work
				R	I have a lot of space and good equipment
				S	I find it easy doing practical work at school
				T	The practical work is designed for me to be able to do it
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 3: Physics pilot questionnaire continued

14. I do find practical work helps my learning in Physics

	I agree because		I neither agree nor disagree because		I disagree because
A	It helps my knowledge with my module exams	H	Sometimes it can and sometimes it doesn't	P	It can confuse what I already know
B	Book work is secondary learning but practical is first hand so I learn more	I	I think you can learn through practical work but I just like writing it	Q	The teacher explains it better
C	It helps my learning because then I know how something in physics really works	J	I can learn from both written and practical work	R	It takes too long to get the results
D	I learn faster by doing than writing			S	I learn from textbooks quicker
E	If I do not do practical I get bored so people mess around whereas I do practical I listen and take part and I get on better			T	It complicates things for me
F	It helps me understand physics better				
X	Another reason - Please explain	Y	Another reason - Please explain	Z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study

Student questionnaire: Your views on practical work in biology

This questionnaire is looking into **your** views on practical work in **your** biology lessons.
The questionnaire involves **14 statements.**
Your responses are anonymous, so **do not write your name** anywhere on the questionnaire.

What you need to do to complete the questionnaire:

1. Read the statement.
2. Decide if you **agree** or **neither agree nor disagree** or **disagree** with the statement and **tick the one square box** which **you** agree with.
3. Then **circle ONE letter** underneath **your ticked square box** which shows your **MAIN** reason for your position towards the statement.
4. If you do not agree with any of the reasons given, do write your own reason in the 'another reason' box in that same section.

Example:

EXAMPLE: I love practical work in biology lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☑	
a	It is fun	h	I like practical and non-practical	[✓ n]	I hate it
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Firstly, please circle your gender and year group:

I am: **Male** **Female**

I am in: **Year 7** **Year 8** **Year 9** **Year 10**

Now continue to complete the entire questionnaire and thank you for your help with this research.

Appendix 4: Biology final questionnaire for main study continued

1. I enjoy doing practical work in biology lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I like working and talking with friends sharing answers, rather than writing	h	Some biology topics I like, some I do not	n	It takes times to pack away and carry on with the lesson
b	I learn from doing it, not just writing	i	I have not done a practical in a biology lesson	o	It can be difficult to do and understand the practical work
c	I get to investigate different things and explore with different experiments	j	I do not enjoy anything about biology because I have never been good at it	p	I have to complete follow up written work, like graphs of the results
d	It is a good time to take control of my learning	k	It is not something I look forward to unless I have not done one for a while	q	It is difficult to do the work in groups or with people I do not like as they mess around or distract me from the practical work
e	It is not something I do everyday	l	I prefer biology more to chemistry or physics but I do find it quite boring because some of it I do not understand	r	I get limited to the safe things I can do, so most of the practicals are the same
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

2. I am able to learn from practical work in biology lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
A	I can see for myself how everything works rather than just being told what happens	h	I have not done a practical yet, but if I did then I would learn more	n	I do not need to know the practical work for the exam so I just follow the instructions
B	If I am more into the lesson I am going to learn more than if I was bored writing	i	It depends on what practical work it is as to whether I learn anything, some I can but some I cannot	o	I only learn from the teacher
C	I am able to explore for myself what I am learning and I am able to interact more	j	I think I learn from my practical lessons but not as much as I think I could doing written work	p	I just chat with friends
D	I usually complete a table and a graph from it, so I know the answers to questions for the exam	k	At times the teacher does not explain it well	q	Not every practical in biology teaches me something new
		l	I do not like biology that much	r	Sometimes I do not get a go when working in a group, so I cannot get involved to learn
X	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

3. I prefer practical work to non-practical work in biology lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I get very bored and less interested when a teacher is just telling me what to memorise rather than doing it myself	h	It is nice to vary what/how I get taught so it does not get boring	n	I do not learn as much in practical as I think I would do in a written work lesson
b	I get to understand and improve my knowledge by doing practical work	i	I like doing practicals more than written work but some written work I learn more from	o	I just want to know the answers for the exams so non-practical is better for this
c	It is always easier than non-practical work	j	I think if I did some practicals then I would prefer them	p	Practical work takes too much time out of the lesson
d	I can interact and talk with people	k	Learning from textbooks gives me knowledge about biology I cannot get via practicals	q	I prefer discussions with my teacher
e	I tend to concentrate and behave a lot more than if I am just sitting down not doing practical	l	The non-practical work has to be done, I accept that and enjoy it	r	I have not had any practical lessons yet
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

4. Doing practical work is my favourite part of biology lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It makes the lesson go quicker as I am able to communicate with more people and use science equipment	h	Sometimes they can be fun and other times they can be quite boring	n	I do not like to work with practical equipment
b	It is better because it is something different to do and involves me having to think for myself	i	It is good to learn and expand my knowledge	o	The practical can be difficult and confuse me
c	It shows that I can be independent and trusted to do something	j	Doing lots of practical work is good but you still need to write up about it	p	I get distracted and bored easily
d	I do not get to do practical in every lesson so it is something different			q	I rarely do practical lessons
e	I get to explore more and sometimes learn new skills			r	Written work is quicker to complete
f	It boosts my confidence if I get something right and gives me a sense of achievement			s	It is not my favourite part of biology
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

5. Practical work helps me understand biology

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I can see what happens myself whereas when someone tells me something or I read it, I cannot understand it as well	h	I do not know if practical work helps me in biology because we have not done any biology practicals	n	I do not always get the practical work to show me the right results
b	When I am doing practical, I am not bored and take it in better	i	Written work helps me understand it better but I learn things doing practical that I would not learn from written work	o	The non-practical may be easier for me to understand
c	I am doing something physically so I remember what I learn more effectively	j	I see biology as testing things, like biologists would, not about understanding	p	It is just another way of learning
d	Some situations it could be very dangerous if I do something wrong, so I pay more attention and concentrate more			q	We are just understanding how to use the equipment
e	I can share results with people and not all get the same results				
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

6. I find practical work in biology easy to do					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It is always easier than copying out of a book	h	Some of the things I do in biology is easy but some of it can be hard	n	It always takes a long time to set the practical up and put away
b	The teacher tells me everything I need to do and I just do it	i	I still have to memorise what I am learning but I find it more fun	o	I struggle to understand what to do
c	I can work with a partner so I share the work	j	Most is easy but when I am learning a new skill it becomes difficult	p	It confuses my original thoughts
d	It does not matter if I do not see the results so I do not need to focus as much	k	The written and practical work is the same really	q	There are far too many safety issues to remember during the practical
				r	I do not do enough for it to be easy
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

7. What I do in biology practical work will be useful when I leave school					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I may go into the biology profession and it opens a big range of jobs and options for the future	h	I do not want to work in biology when I am older	n	I do not want to be a biologist
b	It encourages people to work as a team and be careful around other people in a busy area	i	I am not sure what I am interested in within biology	o	I do not learn from biology so I forget what I have done
c	It is a good experience for later life and I get a better understanding of why and how certain things happen/work			p	Unless I want to be a biology teacher it will not be useful in any way
d	I want to be a biologist			q	It just helps me remember the information to pass my exams
				r	I think it is pointless because I copy out of a book then do a practical at the end when I have learnt everything
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

8. What I learn from biology practical work is always useful for when I leave school

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	If I need to know or even explain to others about the practical then I will know	h	It depends on the job I want to do when I leave school, whether it involves biology or not	n	I will not have the equipment when I leave
b	I might want to work somewhere where I need to do biology practical work	i	It is hard to answer as I have not left yet but I do most definitely learn and gain more of an understanding from practical work	o	The job I want to do will not involve biology practical work
c	It helps me work as a team and to be conscious of other people			p	It depends on my job and what I want to do
d	I can get a mark in my end test and I can improve my grade				
e	I need to use biology to get a job in the future				
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

9. I find practical work a way of seeing how biologists work in the real world

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It may not be as complex as what biologist do but it is like a beginners' course	h	I am unsure what a biologist does in the real world	n	My teacher cannot show me everything that happens
b	It shows how it would be like if I was a biologist	i	Not all work I do in the lesson is about seeing how biologists work in the real world	o	It is just a way of learning for the exams
c	It gives me an idea of the real world and helps me decide if I like what they do			p	I do not take any notice of how they work in the real world
d	If I have never done anything then I will not know how they work			q	I can see how they work without doing practical work
e	If I do not do practical work how will I know what to expect in real life?			r	I am only doing little experiments, things that biologists already know, whereas they will be doing large experiments trying to discover new things
f	I get the understanding of the animal and the human body				
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

10. I think we should do more practical work in biology lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I personally take in and engage more with practical work	h	If I need it for the topic then that is ok, but only if I need to	n	I need to know the theory more for the exams
b	I learn and remember more doing practical than if I answer questions from a textbook	i	Sometimes when I just repeat a practical it just gets boring but some things I do not learn by practicals alone	o	Most of it is boring and does not educate me very well
c	Even if it will not be useful, I enjoy it	j	I think I have a good balance of practical skills and writing already	p	Biology practicals take too long for me to learn anything
d	I need to be actively doing something to learn	k	I think I do practicals when it is appropriate and relevant to the topic being covered but also I do enough written work to learn	q	If the practical work does not tell me the answer I still need to do the theory to understand the biology
e	I do not do enough practical work	l	It is good for the class who do not like book work but some, like me, are nervous around the practical equipment		
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

11. For me to learn in biology lessons, I need to do practical work

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I find it more interesting so I pay more attention	h	I cannot do practical work for all the things I learn in biology	n	I can learn just as much from written work
b	It shows biology in more detail	i	Sometimes it is fun but I do not always write things down so cannot refer back to them	o	I prefer to write things down
c	I understand it more because just hearing about it can be confusing	j	I have to see what happens and what I need to do in the practical but I need to know the theory behind the practical for the exam	p	I do not need a practical to learn things but it does make it easier to understand
d	It is easier because if I do something wrong I remember I did it wrong, whereas if I write it down wrong I may forget it	k	I am still able to learn without doing practical, it just makes it more interesting	q	Practical is just there for fun, written work is for learning biology
				r	It is just free time to chat to friends not learn biology
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

12. I prefer the freedom I have during practical work in biology lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I can learn independently and at my own pace	h	I like to have freedom at times but then I like to know what I am meant to be doing	n	I do not need freedom to learn in school
b	I can help, and get help, and work together with friends	i	I prefer working in groups or pairs as I am not as confident as others, however I enjoy finding things out and how they work without being told	o	If I write it I am more focussed on what I am doing
c	It makes me feel that the teacher trusts me to use biology equipment	j	I can do things for myself in the practical and when I am doing revision	p	I just want to know exactly what to do for the exams
d	It helps my learning but then if it is wrong the teacher can always correct me and help me to understand without taking over or doing it for me	k	I think I get just as much freedom, I have to stick to the task and I am still free to ask for help	q	I do not get freedom in practical work as there are too many rules to follow
e	I can experiment and see things for myself although it has to be controlled to be safe			r	The teacher does not help and constantly stops me so I never know what to do
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

13. My school science environment makes doing practical work easy in my biology lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I enjoy working in this environment, I feel confident with my class and can ask for help if I need it	h	I do not think it makes any difference	n	A lot is expected of me in the environment
b	I have a good environment to work	i	I enjoy biology practical in my environment	o	I get bored in the biology environment
c	The practical work is designed for me to be able to do it	j	It depends on what I am doing	p	Sometimes I do not have enough space so people get in my way or I get in their way
d	The instructions given by my teacher are also clear enough to carry out an experiment safely and with the correct equipment	k	The environment does not effect my biology practical lessons	q	Health and safety issues have gone too far in English schools and they are restricting me in what I can do in practical work
e	It makes it quite easy to do practical work in my biology lessons			r	I have not done practicals because of this
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 4: Biology final questionnaire for main study continued

14. I do find practical work helps my learning in biology					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It helps my knowledge with my module exams	h	I think you can learn through practical work but I just like writing it	n	It can confuse and complicate what I already know
b	Book work is secondary learning but practical is first hand so I learn more and see it for myself	i	I can learn from both written and practical work	o	The teacher explains it better
c	If I do not do practical I get bored so people mess around whereas I do practical I listen and take part and I get on better	j	It depends on what I am doing in the lesson	p	It takes too long to get the results
d	It can help as it can go wrong and you can learn from your mistakes			q	I learn from textbooks quicker
e	It lets us try out new ideas			r	It just helps my memory for tests but I do not learn from it
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Thank you for completing the questionnaire

Appendix 5: Chemistry final questionnaire for main study

Student questionnaire: Your views on practical work in chemistry

This questionnaire is looking into **your** views on practical work in **your** chemistry lessons.
The questionnaire involves **14 statements.**
Your responses are anonymous, so **do not write your name** anywhere on the questionnaire.

What you need to do to complete the questionnaire:

1. Read the statement.
2. Decide if you **agree** or **neither agree nor disagree** or **disagree** with the statement and **tick the one square box** which **you** agree with.
3. Then **circle ONE letter** underneath **your ticked square box** which shows your **MAIN** reason for your position towards the statement.
4. If you do not agree with any of the reasons given, do write your own reason in the 'another reason' box in that same section.

Example:

EXAMPLE: I love practical work in chemistry lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☑	
a	It is fun	h	I like practical and non-practical	[✓ n]	I hate it
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Firstly, please circle your gender and year group:

I am: **Male** **Female**

I am in: **Year 7** **Year 8** **Year 9** **Year 10**

Now continue to complete the entire questionnaire and thank you for your help with this research.

Appendix 5: Chemistry final questionnaire for main study continued

1. I enjoy doing practical work in chemistry lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I like working and talking with friends sharing answers, rather than writing	h	Some chemistry topics I like, some I do not	n	It takes times to pack away and carry on with the lesson
b	I learn from doing it, not just writing	i	I have not done a practical in a chemistry lesson	o	It can be difficult to do and understand the practical work
c	I get to investigate different things and explore with different experiments	j	I do not enjoy anything about chemistry because I have never been good at it	p	I have to complete follow up written work, like graphs of the results
d	It is a good time to take control of my learning	k	It is not something I look forward to unless I have not done one for a while	q	It is difficult to do the work in groups or with people I do not like as they mess around or distract me from the practical work
e	It is not something I do everyday	l	I prefer chemistry more to biology or physics but I do find it quite boring because some of it I do not understand	r	I get limited to the safe things I can do, so most of the practicals are the same
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

2. I am able to learn from practical work in chemistry lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
A	I can see for myself how everything works rather than just being told what happens	h	I have not done a practical yet, but if I did then I would learn more	n	I do not need to know the practical work for the exam so I just follow the instructions
B	If I am more into the lesson I am going to learn more than if I was bored writing	i	It depends on what practical work it is as to whether I learn anything, some I can but some I cannot	o	I only learn from the teacher
C	I am able to explore for myself what I am learning and I am able to interact more	j	I think I learn from my practical lessons but not as much as I think I could doing written work	p	I just chat with friends
d	I usually complete a table and a graph from it, so I know the answers to questions for the exam	k	At times the teacher does not explain it well	q	Not every practical in chemistry teaches me something new
		l	I do not like chemistry that much	r	Sometimes I do not get a go when working in a group, so I cannot get involved to learn
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

3. I prefer practical work to non-practical work in chemistry lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
A	I get very bored and less interested when a teacher is just telling me what to memorise rather than doing it myself	h	It is nice to vary what/how I get taught so it does not get boring	n	I do not learn as much in practical as I think I would do in a written work lesson
B	I get to understand and improve my knowledge by doing practical work	i	I like doing practicals more than written work but some written work I learn more from	o	I just want to know the answers for the exams so non-practical is better for this
C	It is always easier than non-practical work	j	I think if I did some practicals then I would prefer them	p	Practical work takes too much time out of the lesson
D	I can interact and talk with people	k	Learning from textbooks gives me knowledge about chemistry I cannot get via practicals	q	I prefer discussions with my teacher
e	I tend to concentrate and behave a lot more than if I am just sitting down not doing practical	l	The non-practical work has to be done, I accept that and enjoy it	r	I have not had any practical lessons yet
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

4. Doing practical work is my favourite part of chemistry lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It makes the lesson go quicker as I am able to communicate with more people and use science equipment	h	Sometimes they can be fun and other times they can be quite boring	n	I do not like to work with practical equipment
b	It is better because it is something different to do and involves me having to think for myself	i	It is good to learn and expand my knowledge	o	The practical can be difficult and confuse me
c	It shows that I can be independent and trusted to do something	j	Doing lots of practical work is good but you still need to write up about it	p	I get distracted and bored easily
d	I do not get to do practical in every lesson so it is something different			q	I rarely do practical lessons
e	I get to explore more and sometimes learn new skills			r	Written work is quicker to complete
f	It boosts my confidence if I get something right and gives me a sense of achievement			s	It is not my favourite part of chemistry
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

5. Practical work helps me understand chemistry

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I can see what happens myself whereas when someone tells me something or I read it, I cannot understand it as well	h	I do not know if practical work helps me in chemistry because we have not done any chemistry practicals	n	I do not always get the practical work to show me the right results
b	When I am doing practical, I am not bored and take it in better	i	Written work helps me understand it better but I learn things doing practical that I would not learn from written work	o	The non-practical may be easier for me to understand
c	I am doing something physically so I remember what I learn more effectively	j	I see chemistry as testing things, like chemists would, not about understanding	p	It is just another way of learning
d	Some situations it could be very dangerous if I do something wrong, so I pay more attention and concentrate more			q	We are just understanding how to use the equipment
e	I can share results with people and not all get the same results			r	I do not understand chemistry practicals because the results do not always appear
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

6. I find practical work in chemistry easy to do

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It is always easier than copying out of a book	h	Some of the things I do in chemistry is easy but some of it can be hard	n	It always takes a long time to set the practical up and put away
b	The teacher tells me everything I need to do and I just do it	i	I still have to memorise what I am learning but I find it more fun	o	I struggle to understand what to do
c	I can work with a partner so I share the work	j	Most is easy but when I am learning a new skill it becomes difficult	p	It confuses my original thoughts
d	It does not matter if I do not see the results so I do not need to focus as much	k	The written and practical work is the same really	q	There are far too many safety issues to remember during the practical
		l	I am good at Bunsen Burners but I am not good at pouring chemicals as I often spill them	r	I do not do enough for it to be easy
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

7. What I do in chemistry practical work will be useful when I leave school

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
A	I may go into the chemistry profession and it opens a big range of jobs and options for the future	h	I do not want to work in chemistry when I am older	n	I do not want to be a chemist
B	It encourages people to work as a team and be careful around other people in a busy area	i	I am not sure what I am interested in within chemistry	o	I do not learn from chemistry so I forget what I have done
C	It is a good experience for later life and I get a better understanding of why and how certain things happen/work			p	Unless I want to be a chemistry teacher it will not be useful in any way
D	I want to be a chemist			q	It just helps me remember the information to pass my exams
				r	I think it is pointless because I copy out of a book then do a practical at the end when I have learnt everything
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

8. What I learn from chemistry practical work is always useful for when I leave school

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	If I need to know or even explain to others about the practical then I will know	h	It depends on the job I want to do when I leave school, whether it involves chemistry or not	n	I will not have the equipment when I leave
b	I might want to work somewhere where I need to do chemistry practical work	i	It is hard to answer as I have not left yet but I do most definitely learn and gain more of an understanding from practical work	o	The job I want to do will not involve chemistry practical work
c	It helps me work as a team and to be conscious of other people	j	I think it depends what I want to do with my life, if I want to be a doctor then it would help but I am not sure what else it would help	p	It depends on my job and what I want to do
d	I can get a mark in my end test and I can improve my grade			q	There are not many jobs that involve burning stuff or mixing hazardous chemicals
e	I need to use chemistry to get a job in the future				
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

9. I find practical work a way of seeing how chemists work in the real world

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It may not be as complex as what chemists do but it is like a beginners' course	h	I am unsure what a chemist does in the real world	n	My teacher cannot show me everything that happens
b	It shows how it would be like if I was a chemist	i	Not all work I do in the lesson is about seeing how chemists work in the real world	o	It is just a way of learning for the exams
c	It gives me an idea of the real world and helps me decide if I like what they do			p	I do not take any notice of how they work in the real world
d	If I have never done anything then I will not know how they work			q	I can see how they work without doing practical work
e	If I do not do practical work how will I know what to expect in real life?			r	I am only doing little experiments, things that chemists already know, whereas they will be doing large experiments trying to discover new things
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

10. I think we should do more practical work in chemistry lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
A	I personally take in and engage more with practical work	h	If I need it for the topic then that is ok, but only if I need to	n	I need to know the theory more for the exams
B	I learn and remember more doing practical than if I answer questions from a textbook	i	Sometimes when I just repeat a practical it just gets boring but some things I do not learn by practicals alone	o	Most of it is boring and does not educate me very well
C	Even if it will not be useful, I enjoy it	j	I think I have a good balance of practical skills and writing already	p	Chemistry practicals take too long for me to learn anything
D	I need to be actively doing something to learn	k	I think I do practicals when it is appropriate and relevant to the topic being covered but also I do enough written work to learn	q	If the practical work does not tell me the answer I still need to do the theory to understand the chemistry
E	I do not do enough practical work	l	It is good for the class who do not like book work but some, like me, are nervous around the practical equipment		
X	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

11. For me to learn in chemistry lessons, I need to do practical work

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I find it more interesting so I pay more attention	h	I cannot do practical work for all the things I learn in chemistry	n	I can learn just as much from written work
b	It shows chemistry in more detail	i	Sometimes it is fun but I do not always write things down so cannot refer back to them	o	I prefer to write things down
c	I understand it more because just hearing about it can be confusing	j	I have to see what happens and what I need to do in the practical but I need to know the theory behind the practical for the exam	p	I do not need a practical to learn things but it does make it easier to understand
d	It is easier because if I do something wrong I remember I did it wrong, whereas if I write it down wrong I may forget it	k	I am still able to learn without doing practical, it just makes it more interesting	q	Practical is just there for fun, written work is for learning chemistry
		l	I learn a lot from my written work but remember specific things, e.g. names of elements, when doing practical work	r	It is just free time to chat to friends not learn chemistry
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

12. I prefer the freedom I have during practical work in chemistry lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I can learn independently and at my own pace	h	I like to have freedom at times but then I like to know what I am meant to be doing	n	I do not need freedom to learn in school
b	I can help, and get help, and work together with friends	i	I prefer working in groups or pairs as I am not as confident as others, however I enjoy finding things out and how they work without being told	o	If I write it I am more focussed on what I am doing
c	It makes me feel that the teacher trusts me to use chemistry equipment	j	I can do things for myself in the practical and when I am doing revision	p	I just want to know exactly what to do for the exams
d	It helps my learning but then if it is wrong the teacher can always correct me and help me to understand without taking over or doing it for me	k	I think I get just as much freedom, I have to stick to the task and I am still free to ask for help	q	I do not get freedom in practical work as there are too many rules to follow
e	I can experiment and see things for myself although it has to be controlled to be safe			r	The teacher does not help and constantly stops me so I never know what to do
				s	Practicals in chemistry are too dangerous for me to be given freedom
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

13. My school science environment makes doing practical work easy in my chemistry lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I enjoy working in this environment, I feel confident with my class and can ask for help if I need it	h	I do not think it makes any difference	n	A lot is expected of me in the environment
b	I have a good environment to work	i	I enjoy chemistry practical in my environment	o	I get bored in the chemistry environment
c	The practical work is designed for me to be able to do it	j	It depends on what I am doing	p	Sometimes I do not have enough space so people get in my way or I get in their way
d	The instructions given by my teacher are also clear enough to carry out an experiment safely and with the correct equipment	k	The environment does not effect my chemistry practical lessons	q	Health and safety issues have gone too far in English schools and they are restricting me in what I can do in practical work
e	It makes it quite easy to do practical work in my chemistry lessons	l	There is enough space but sometimes there are too many people in one area to get an ingredient and end up knocking each other	r	I have not done practicals because of this
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 5: Chemistry final questionnaire for main study continued

14. I do find practical work helps my learning in chemistry

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It helps my knowledge with my module exams	h	I think you can learn through practical work but I just like writing it	n	It can confuse and complicate what I already know
b	Book work is secondary learning but practical is first hand so I learn more and see it for myself	i	I can learn from both written and practical work	o	The teacher explains it better
c	If I do not do practical I get bored so people mess around whereas I do practical I listen and take part and I get on better	j	It depends on what I am doing in the lesson	p	It takes too long to get the results
d	It can help as it can go wrong and you can learn from your mistakes			q	I learn from textbooks quicker
e	It lets us try out new ideas			r	It just helps my memory for tests but I do not learn from it
f	It helps a lot to discover and make new substances			s	I need the theory to learn chemistry, like balancing chemical equations
g	Practical work and written work for me are best ways to learn as I can remember facts and look back in my book, but in practicals I can remember the chemicals and elements and what they make				
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Thank you for completing the questionnaire

Appendix 6: Physics final questionnaires for main study

Student questionnaire: Your views on practical work in physics

This questionnaire is looking into **your** views on practical work in **your** physics lessons.
The questionnaire involves **14 statements.**
Your responses are anonymous, so **do not write your name** anywhere on the questionnaire.

What you need to do to complete the questionnaire:

1. Read the statement.
2. Decide if you **agree** or **neither agree nor disagree** or **disagree** with the statement and **tick the one square box** which **you** agree with.
3. Then **circle ONE letter** underneath **your ticked square box** which shows your **MAIN** reason for your position towards the statement.
4. If you do not agree with any of the reasons given, do write your own reason in the ‘another reason’ box in that same section.

Example:

EXAMPLE: I love practical work in physics lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☑	
a	It is fun	h	I like practical and non-practical	[✓ n]	I hate it
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Firstly, please circle your gender and year group:

I am: **Male** **Female**

I am in: **Year 7** **Year 8** **Year 9** **Year 10**

Now continue to complete the entire questionnaire and thank you for your help with this research.

Appendix 6: Physics final questionnaires for main study continued

1. I enjoy doing practical work in physics lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I like working and talking with friends sharing answers, rather than writing	h	Some physics topics I like, some I do not	n	It takes times to pack away and carry on with the lesson
b	I learn from doing it, not just writing	i	I have not done a practical in a physics lesson	o	It can be difficult to do and understand the practical work
c	I get to investigate different things and explore with different experiments	j	I do not enjoy anything about physics because I have never been good at it	p	I have to complete follow up written work, like graphs of the results
d	It is a good time to take control of my learning	k	It is not something I look forward to unless I have not done one for a while	q	It is difficult to do the work in groups or with people I do not like as they mess around or distract me from the practical work
e	It is not something I do everyday	l	I prefer physics more to biology or chemistry but I do find it quite boring because some of it I do not understand	r	I get limited to the safe things I can do, so most of the practicals are the same
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

2. I am able to learn from practical work in physics lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I can see for myself how everything works rather than just being told what happens	h	I have not done a practical yet, but if I did then I would learn more	n	I do not need to know the practical work for the exam so I just follow the instructions
b	If I am more into the lesson I am going to learn more than if I was bored writing	i	It depends on what practical work it is as to whether I learn anything, some I can but some I cannot	o	I only learn from the teacher
c	I am able to explore for myself what I am learning and I am able to interact more	j	I think I learn from my practical lessons but not as much as I think I could doing written work	p	I just chat with friends
d	I usually complete a table and a graph from it, so I know the answers to questions for the exam	k	At times the teacher does not explain it well	q	Not every practical in physics teaches me something new
		l	I do not like physics that much	r	Sometimes I do not get a go when working in a group, so I cannot get involved to learn
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

3. I prefer practical work to non-practical work in physics lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I get very bored and less interested when a teacher is just telling me what to memorise rather than doing it myself	h	It is nice to vary what/how I get taught so it does not get boring	n	I do not learn as much in practical as I think I would do in a written work lesson
b	I get to understand and improve my knowledge by doing practical work	i	I like doing practicals more than written work but some written work I learn more from	o	I just want to know the answers for the exams so non-practical is better for this
c	It is always easier than non-practical work	j	I think if I did some practicals then I would prefer them	p	Practical work takes too much time out of the lesson
d	I can interact and talk with people	k	Learning from textbooks gives me knowledge about physics I cannot get via practicals	q	I prefer discussions with my teacher
e	I tend to concentrate and behave a lot more than if I am just sitting down not doing practical	l	The non-practical work has to be done, I accept that and enjoy it	r	I have not had any practical lessons yet
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

4. Doing practical work is my favourite part of physics lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It makes the lesson go quicker as I am able to communicate with more people and use science equipment	h	Sometimes they can be fun and other times they can be quite boring	n	I do not like to work with practical equipment
b	It is better because it is something different to do and involves me having to think for myself	i	It is good to learn and expand my knowledge	o	The practical can be difficult and confuse me
c	It shows that I can be independent and trusted to do something	j	Doing lots of practical work is good but you still need to write up about it	p	I get distracted and bored easily
d	I do not get to do practical in every lesson so it is something different			q	I rarely do practical lessons
e	I get to explore more and sometimes learn new skills			r	Written work is quicker to complete
f	It boosts my confidence if I get something right and gives me a sense of achievement			s	It is not my favourite part of physics
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

5. Practical work helps me understand physics

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I can see what happens myself whereas when someone tells me something or I read it, I cannot understand it as well	h	I do not know if practical work helps me in physics because we have not done any physics practicals	n	I do not always get the practical work to show me the right results
b	When I am doing practical, I am not bored and take it in better	i	Written work helps me understand it better but I learn things doing practical that I would not learn from written work	o	The non-practical may be easier for me to understand
c	I am doing something physically so I remember what I learn more effectively	j	I see physics as testing things, like physicists would, not about understanding	p	It is just another way of learning
d	Some situations it could be very dangerous if I do something wrong, so I pay more attention and concentrate more			q	We are just understanding how to use the equipment
e	I can share results with people and not all get the same results				
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

6. I find practical work in physics easy to do					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It is always easier than copying out of a book	h	Some of the things I do in physics is easy but some of it can be hard	n	It always takes a long time to set the practical up and put away
b	The teacher tells me everything I need to do and I just do it	i	I still have to memorise what I am learning but I find it more fun	o	I struggle to understand what to do
c	I can work with a partner so I share the work	j	Most is easy but when I am learning a new skill it becomes difficult	p	It confuses my original thoughts
d	It does not matter if I do not see the results so I do not need to focus as much	k	The written and practical work is the same really	q	There are far too many safety issues to remember during the practical
				r	I do not do enough for it to be easy
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

7. What I do in physics practical work will be useful when I leave school

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I may go into the physics profession and it opens a big range of jobs and options for the future	h	I do not want to work in physics when I am older	n	I do not want to be a physicist
b	It encourages people to work as a team and be careful around other people in a busy area	i	I am not sure what I am interested in within physics	o	I do not learn from physics so I forget what I have done
c	It is a good experience for later life and I get a better understanding of why and how certain things happen/work			p	Unless I want to be a physics teacher it will not be useful in any way
d	I want to be a physicist			q	It just helps me remember the information to pass my exams
				r	I think it is pointless because I copy out of a book then do a practical at the end when I have learnt everything
				s	Most jobs do not involve physics
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

<table>
<tr><th colspan="6">8. What I learn from physics practical work is always useful for when I leave school</th></tr>
<tr><td colspan="2">I agree because ☐</td><td colspan="2">I neither agree nor disagree because ☐</td><td colspan="2">I disagree because ☐</td></tr>
<tr><td>a</td><td>If I need to know or even explain to others about the practical then I will know</td><td>h</td><td>It depends on the job I want to do when I leave school, whether it involves physics or not</td><td>n</td><td>I will not have the equipment when I leave</td></tr>
<tr><td>b</td><td>I might want to work somewhere where I need to do physics practical work</td><td>i</td><td>It is hard to answer as I have not left yet but I do most definitely learn and gain more of an understanding from practical work</td><td>o</td><td>The job I want to do will not involve physics practical work</td></tr>
<tr><td>c</td><td>It helps me work as a team and to be conscious of other people</td><td></td><td></td><td>p</td><td>It depends on my job and what I want to do</td></tr>
<tr><td>d</td><td>I can get a mark in my end test and I can improve my grade</td><td></td><td></td><td>q</td><td>In life people do not come across that many everyday situation where physics practical is needed</td></tr>
<tr><td>e</td><td>I need to use physics to get a job in the future</td><td></td><td></td><td></td><td></td></tr>
<tr><td>x</td><td>Another reason - Please explain</td><td>y</td><td>Another reason - Please explain</td><td>z</td><td>Another reason - Please explain</td></tr>
</table>

Appendix 6: Physics final questionnaires for main study continued

9. I find practical work a way of seeing how physicists work in the real world

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It may not be as complex as what physicist do but it is like a beginners' course	h	I am unsure what a physicist does in the real world	n	My teacher cannot show me everything that happens
b	It shows how it would be like if I was a physicist	i	Not all work I do in the lesson is about seeing how physicists work in the real world	o	It is just a way of learning for the exams
c	It gives me an idea of the real world and helps me decide if I like what they do			p	I do not take any notice of how they work in the real world
d	If I have never done anything then I will not know how they work			q	I can see how they work without doing practical work
e	If I do not do practical work how will I know what to expect in real life?			r	I am only doing little experiments, things that physicists already know, whereas they will be doing large experiments trying to discover new things
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

10. I think we should do more practical work in physics lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I personally take in and engage more with practical work	h	If I need it for the topic then that is ok, but only if I need to	n	I need to know the theory more for the exams
b	I learn and remember more doing practical than if I answer questions from a textbook	i	Sometimes when I just repeat a practical it just gets boring but some things I do not learn by practicals alone	o	Most of it is boring and does not educate me very well
c	Even if it will not be useful, I enjoy it	j	I think I have a good balance of practical skills and writing already	p	Physics practicals take too long for me to learn anything
d	I need to be actively doing something to learn	k	I think I do practicals when it is appropriate and relevant to the topic being covered but also I do enough written work to learn	q	If the practical work does not tell me the answer I still need to do the theory to understand the physics
e	I do not do enough practical work	l	It is good for the class who do not like book work but some, like me, are nervous around the practical equipment		
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

11. For me to learn in physics lessons, I need to do practical work

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I find it more interesting so I pay more attention	h	I cannot do practical work for all the things I learn in physics	n	I can learn just as much from written work
b	It shows physics in more detail	i	Sometimes it is fun but I do not always write things down so cannot refer back to them	o	I prefer to write things down
c	I understand it more because just hearing about it can be confusing	j	I have to see what happens and what I need to do in the practical but I need to know the theory behind the practical for the exam	p	I do not need a practical to learn things but it does make it easier to understand
d	It is easier because if I do something wrong I remember I did it wrong, whereas if I write it down wrong I may forget it	k	I am still able to learn without doing practical, it just makes it more interesting	q	Practical is just there for fun, written work is for learning physics
				r	It is just free time to chat to friends not learn physics
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

12. I prefer the freedom I have during practical work in physics lessons					
I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I can learn independently and at my own pace	h	I like to have freedom at times but then I like to know what I am meant to be doing	n	I do not need freedom to learn in school
b	I can help, and get help, and work together with friends	i	I prefer working in groups or pairs as I am not as confident as others, however I enjoy finding things out and how they work without being told	o	If I write it I am more focussed on what I am doing
c	It makes me feel that the teacher trusts me to use physics equipment	j	I can do things for myself in the practical and when I am doing revision	p	I just want to know exactly what to do for the exams
d	It helps my learning but then if it is wrong the teacher can always correct me and help me to understand without taking over or doing it for me	k	I think I get just as much freedom, I have to stick to the task and I am still free to ask for help	q	I do not get freedom in practical work as there are too many rules to follow
e	I can experiment and see things for myself although it has to be controlled to be safe			r	The teacher does not help and constantly stops me so I never know what to do
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Appendix 6: Physics final questionnaires for main study continued

13. My school science environment makes doing practical work easy in my physics lessons

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	I enjoy working in this environment, I feel confident with my class and can ask for help if I need it	h	I do not think it makes any difference	n	A lot is expected of me in the environment
b	I have a good environment to work	i	I enjoy physics practical in my environment	o	I get bored in the physics environment
c	The practical work is designed for me to be able to do it	j	It depends on what I am doing	p	Sometimes I do not have enough space so people get in my way or I get in their way
d	The instructions given by my teacher are also clear enough to carry out an experiment safely and with the correct equipment	k	The environment does not effect my physics practical lessons	q	Health and safety issues have gone too far in English schools and they are restricting me in what I can do in practical work
e	It makes it quite easy to do practical work in my physics lessons			r	I have not done practicals because of this
x	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

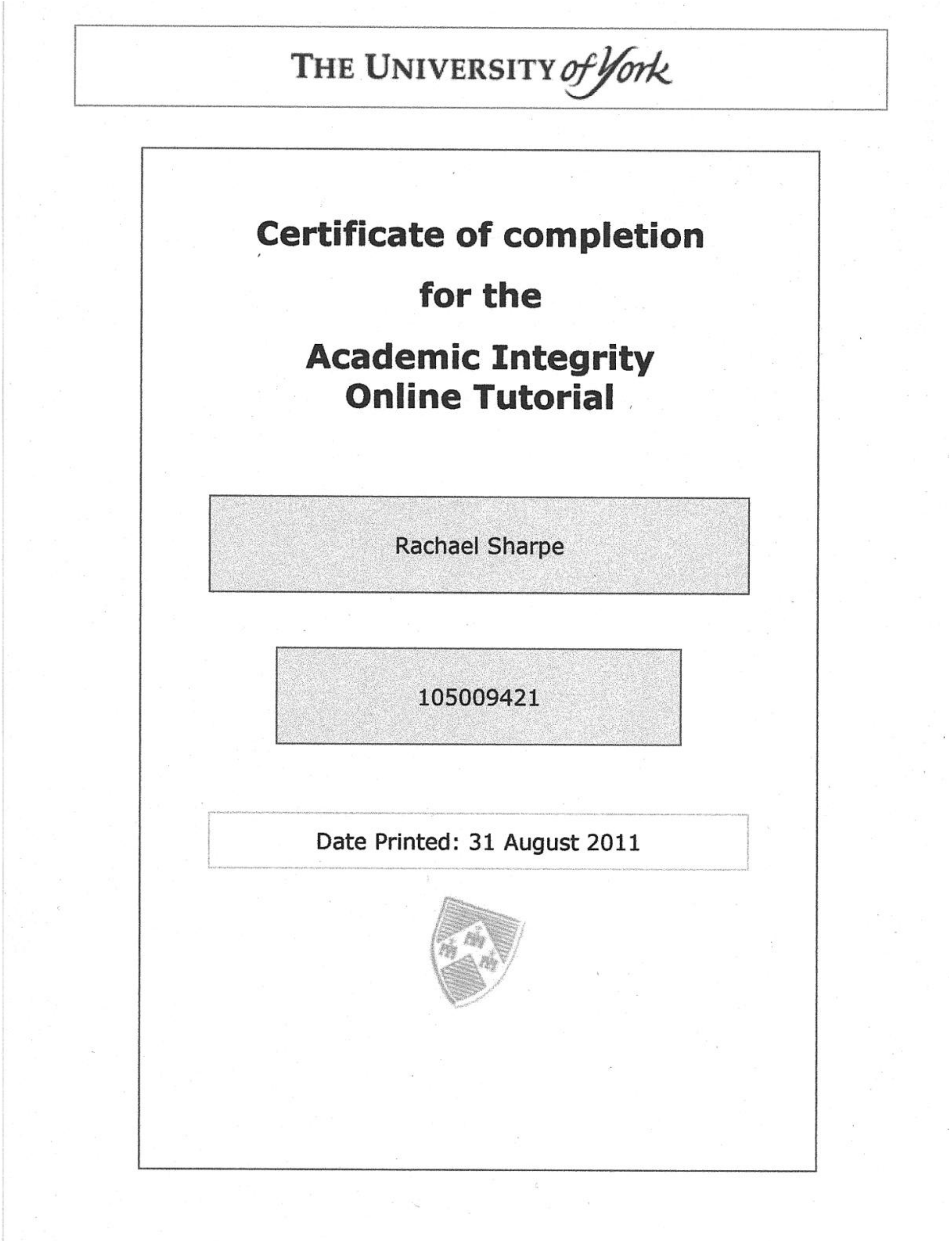
Appendix 6: Physics final questionnaires for main study continued

14. I do find practical work helps my learning in physics

I agree because ☐		I neither agree nor disagree because ☐		I disagree because ☐	
a	It helps my knowledge with my module exams	h	I think you can learn through practical work but I just like writing it	n	It can confuse and complicate what I already know
b	Book work is secondary learning but practical is first hand so I learn more and see it for myself	i	I can learn from both written and practical work	o	The teacher explains it better
c	If I do not do practical I get bored so people mess around whereas I do practical I listen and take part and I get on better	j	It depends on what I am doing in the lesson	p	It takes too long to get the results
d	It can help as it can go wrong and you can learn from your mistakes			q	I learn from textbooks quicker
e	It lets us try out new ideas			r	It just helps my memory for tests but I do not learn from it
X	Another reason - Please explain	y	Another reason - Please explain	z	Another reason - Please explain

Thank you for completing the questionnaire

Appendix 7: Certificate of completion for the academic integrity online tutorial



THE UNIVERSITY of York

Certificate of completion

for the

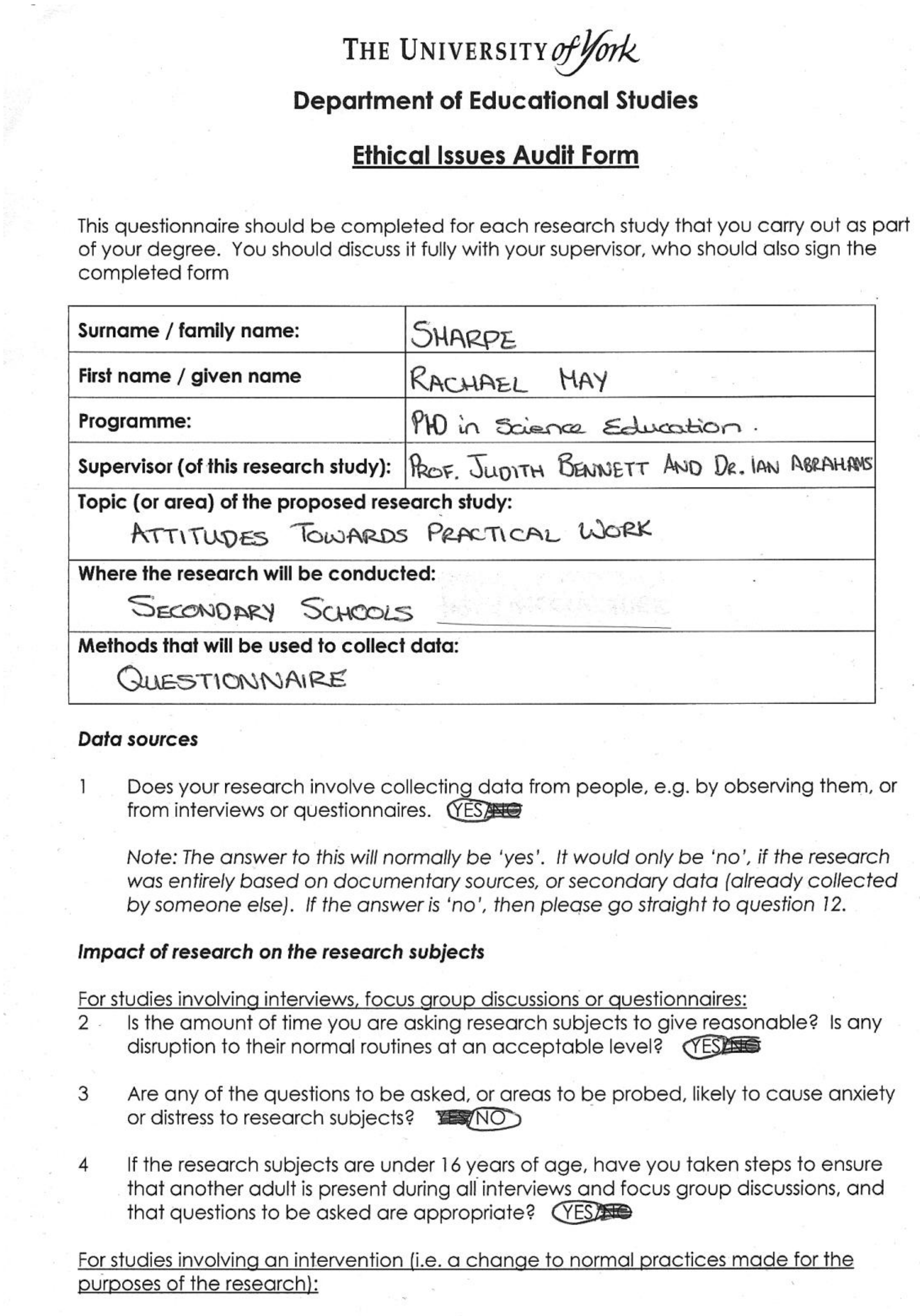
Academic Integrity
Online Tutorial

Rachael Sharpe

105009421

Date Printed: 31 August 2011

Appendix 8: Ethical issues audit form



THE UNIVERSITY *of York*

Department of Educational Studies

Ethical Issues Audit Form

This questionnaire should be completed for each research study that you carry out as part of your degree. You should discuss it fully with your supervisor, who should also sign the completed form

Surname / family name:	SHARPE
First name / given name	RACHAEL MAY
Programme:	PhD in Science Education.
Supervisor (of this research study):	PROF. JUDITH BENNETT AND DR. IAN ABRAHAMS
Topic (or area) of the proposed research study:	ATTITUDES TOWARDS PRACTICAL WORK
Where the research will be conducted:	SECONDARY SCHOOLS
Methods that will be used to collect data:	QUESTIONNAIRE

Data sources

1 Does your research involve collecting data from people, e.g. by observing them, or from interviews or questionnaires. [✓ YES]/~~NO~~

Note: The answer to this will normally be 'yes'. It would only be 'no', if the research was entirely based on documentary sources, or secondary data (already collected by someone else). If the answer is 'no', then please go straight to question 12.

Impact of research on the research subjects

For studies involving interviews, focus group discussions or questionnaires:

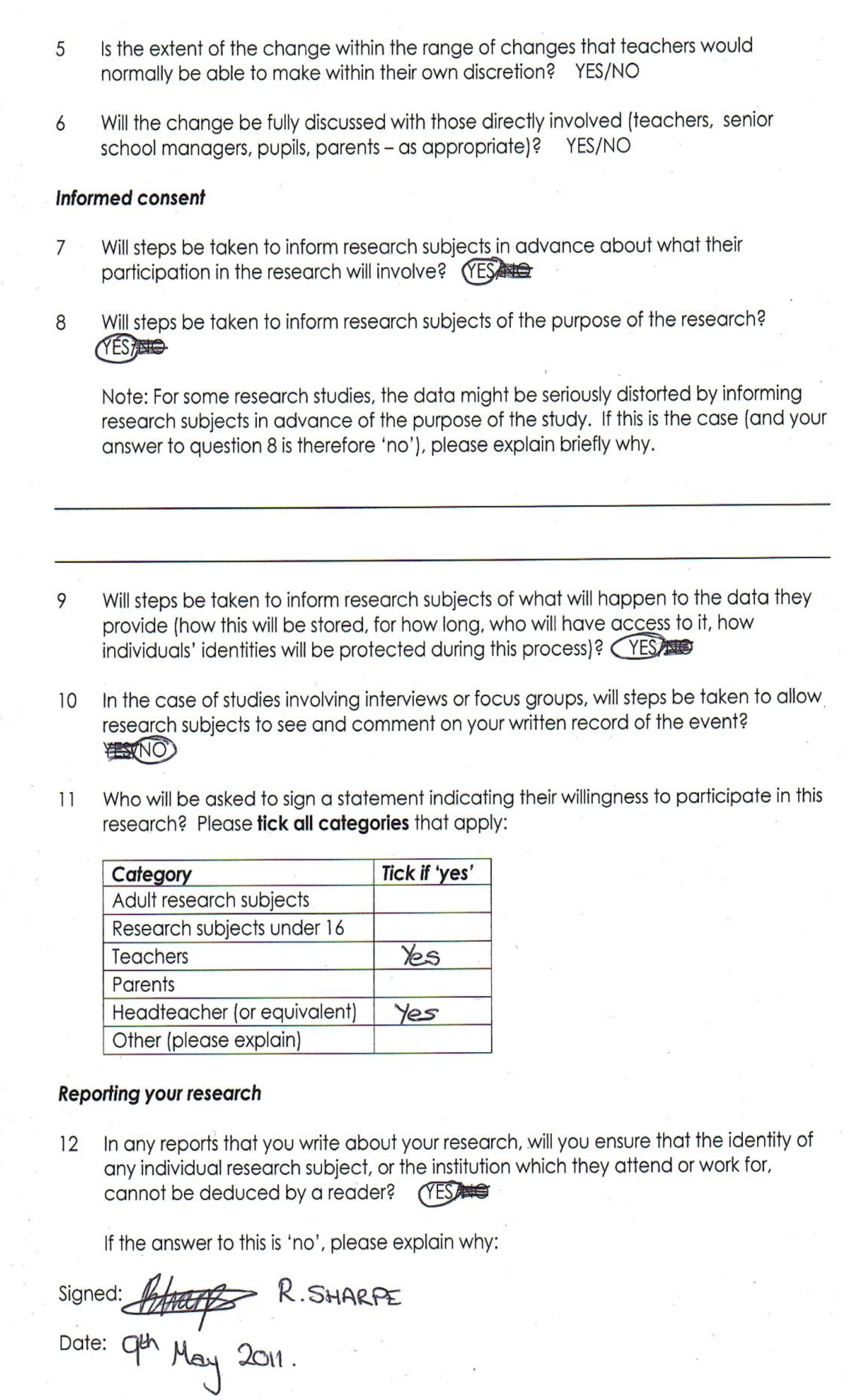
2 Is the amount of time you are asking research subjects to give reasonable? Is any disruption to their normal routines at an acceptable level? [✓ YES]/~~NO~~

3 Are any of the questions to be asked, or areas to be probed, likely to cause anxiety or distress to research subjects? ~~YES~~/[✓ NO]

4 If the research subjects are under 16 years of age, have you taken steps to ensure that another adult is present during all interviews and focus group discussions, and that questions to be asked are appropriate? [✓ YES]/~~NO~~

For studies involving an intervention (i.e. a change to normal practices made for the purposes of the research):

Appendix 8: Ethical issues audit form continued



5 Is the extent of the change within the range of changes that teachers would normally be able to make within their own discretion? YES/NO

6 Will the change be fully discussed with those directly involved (teachers, senior school managers, pupils, parents – as appropriate)? YES/NO

Informed consent

7 Will steps be taken to inform research subjects in advance about what their participation in the research will involve? [✓ YES]/~~NO~~

8 Will steps be taken to inform research subjects of the purpose of the research? [✓ YES]/~~NO~~

Note: For some research studies, the data might be seriously distorted by informing research subjects in advance of the purpose of the study. If this is the case (and your answer to question 8 is therefore 'no'), please explain briefly why.

9 Will steps be taken to inform research subjects of what will happen to the data they provide (how this will be stored, for how long, who will have access to it, how individuals' identities will be protected during this process)? [✓ YES]/~~NO~~

10 In the case of studies involving interviews or focus groups, will steps be taken to allow research subjects to see and comment on your written record of the event? ~~YES~~/[✓ NO]

11 Who will be asked to sign a statement indicating their willingness to participate in this research? Please **tick all categories** that apply:

Category	***Tick if 'yes'***
Adult research subjects	
Research subjects under 16	
Teachers	Yes
Parents	
Headteacher (or equivalent)	Yes
Other (please explain)	

Reporting your research

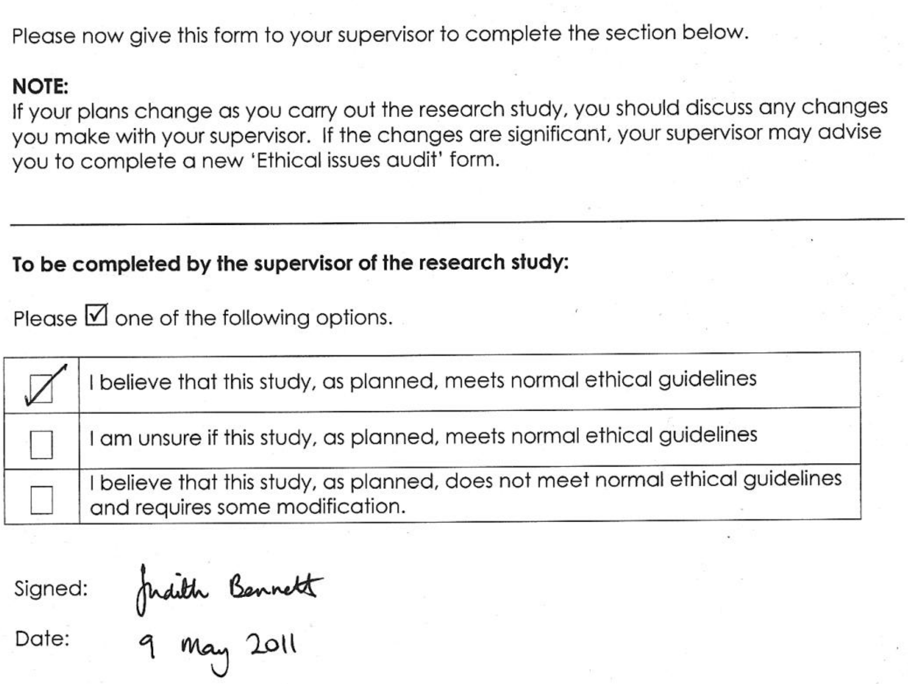
12 In any reports that you write about your research, will you ensure that the identity of any individual research subject, or the institution which they attend or work for, cannot be deduced by a reader? [✓ YES]/~~NO~~

If the answer to this is 'no', please explain why:

Signed: R.SHARPE

Date: 9th May 2011.

Appendix 8: Ethical issues audit form continued



Please now give this form to your supervisor to complete the section below.

NOTE:
If your plans change as you carry out the research study, you should discuss any changes you make with your supervisor. If the changes are significant, your supervisor may advise you to complete a new 'Ethical issues audit' form.

To be completed by the supervisor of the research study:

Please ☑ one of the following options.

☑	I believe that this study, as planned, meets normal ethical guidelines
☐	I am unsure if this study, as planned, meets normal ethical guidelines
☐	I believe that this study, as planned, does not meet normal ethical guidelines and requires some modification.

Signed: Judith Bennett

Date: 9 May 2011

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