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Developing Scientific Literacy through Cooperative Learning in School Science: One Science Department's Effort to Implement Curriculum for Excellence.

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This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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Abstract.

In Scotland, the current Science curriculum reform under a Curriculum for Excellence (*CfE*) has reoriented the aims of Scottish Science education, with its primary aim being to enable young people to develop as scientifically literate citizens, able to hold and defend informed views on social, moral, ethical, economic and environmental issues related to science, with a secondary aim of preparing young people for further, more specialised learning in Science (Scottish Executive Education Department, 2006). However, these reforms give little practical guidance as to how Science teachers should develop scientific literacy. Research suggests that increased use of discussion of controversial socio-scientific issues can be useful in the development of scientific literacy. However, it also suggests that Science teachers feel uncomfortable handling such discussion and tend to shy away from it (Bryce & Gray, 2004), and when they do engage in it, it is often short in duration, of poor quality and teacher-dominated (Osborne, Duschl, & Fairbrother, 2002).

This study presents a rich picture of how one secondary school Science department implemented increased use of discussion of controversial socio-scientific issues into practice using cooperative learning. This study shows that Science teachers hold equally complex conceptual models of discussion when compared with Humanities teachers, but that their focus lies towards the development of social, communication and listening skills whereas Humanities teachers' focus lies towards the development of reasoning skills, for the exposure of multiple perspectives. The use of cooperative learning during socio-scientific discussion helped shift the classroom discourse away from an autocratic, teacher-dominated recitation-style towards an open-ended, pupil-centred discussion. Some issues arose over the development of teaching materials, increased planning and preparation time for individual teachers and technical problems relating to internet access and website availability. In terms of developing scientific literacy, this study indicates that at present, 13/14 year old pupils have difficulties with literacy and numeracy tasks which are vitally linked to the development of scientific literacy.

Contents.

Tables.

Figures.

Abbreviations.

AAAS	American Association for the Advancement of Science
ATQ	Additional Teaching Qualification
BA	Bachelor of Arts
BEd	Bachelor of Education
BSc	Bachelor of Science
CfE	Curriculum for Excellence
CO_2	Carbon dioxide
CP7	Curriculum paper No7
CPD	Continuing Professional Development
ExHT	Experienced Humanities Teacher
ExST	Experienced Science Teacher
GCSE	General Certificate in Secondary Education
Inv	Investigator
IRE	Initiation, Response, Evaluation
IRF	Initiation, Response, Feedback
IVF	*in vitro* Fertilisation
KWL	What you ***Know,*** what you ***Want*** to know**,** what you have ***Learnt***
LEA	Local Education Authority
LTS	Learning and Teaching Scotland
MEd	Master of Education
MP	Member of Parliament
MSc	Master of Science
NQST	Newly Qualified Science Teacher
NRC	National Research Council
OECD	Organisation for Economic Cooperation and Development
P	Pupil
PGCE	Post-graduate Certificate in Education
PGDE	Professional Graduate Diploma in Education
PhD	Doctor of Philosophy
PIGS	Pre-implantation Genetic Screening

PSHE	Personal, Social and Health Education
ROSE	Relevance of Science Education
S2	Second year
SA	Structural Approach
SASI	Statements about Science Instrument
SCCC	Scottish Consultative Council on the Curriculum
SFAA	Science for All Americans
SPU	Science for Public Understanding
STAD	Student Team-Achievement Division
STL	Student Team Learning
STS	Science, Technology and Society
UK	United Kingdom
ZPD	Zone of Proximal Development

Chapter 1. Context and Significance of the Study.

1.1 Introduction.

This thesis examines the practical application of teaching through discussion of controversial socio-scientific issues using cooperative learning, in response to the reform of the Scottish science curriculum under the auspices of Curriculum for Excellence (*CfE*). The thesis focuses particularly on the implementation of the Topical Science strand of the new science curriculum. Reform of the science curriculum has resulted in a shift of emphasis in the main aims for science education in Scotland, the science rationale of the new science curriculum states that the aims of the new curriculum are to:

- enable young people to develop as scientifically literate citizens, able to hold and defend informed views on social, moral, ethical, economic and environmental issues related to science;
- and prepare them for further, more specialised, learning by developing their secure understanding of the 'big ideas' and concepts of science. (Scottish Executive Education Department, 2006)

This rationale places the main emphasis of science education on the development of pupils as scientifically literate citizens, with teaching for science specialisation as a secondary aim. However, traditionally the emphasis of science education in Scotland is on preparing of pupils for specialisation in the sciences. This has been described as the 'pipeline' (Aikenhead, 2006; Kind & Taber, 2005); indicating that school science education functions as a filtering mechanism which feeds pupils through the system to become the next generation of scientists, clinicians, and engineers.

This shift in emphasis in the new science curriculum marks the latest attempt to reform the Scottish education system, which has been in a relatively constant state of flux over the last thirty years but, *what has led us to this change now?* This question requires a closer look at the historical context of the Scottish education system over these years to see how this chain of reform has brought us to this point.

1.2 The Historical Context of Curricular change in Scotland.

The question posed in the introduction requires us to reflect upon a number of changes to the Scottish education system in order to gain a clear image of how the system has arrived at *CfE*. The state of flux began with the publication of two influential reports on the state of secondary education and the examination system in 1977, the Dunning Report on Assessment for All (Scottish Education Department, 1977a) and the Munn Report on The Structure of the Curriculum in Third and Fourth Years of the Scottish Secondary School (Scottish Education Department, 1977b). It could be argued that both of these reports arose as consequence of the raising of the school leaving age from fifteen to sixteen in 1973.

The Munn Report redefined the aims and objectives of the Scottish secondary curriculum from a curriculum already biased towards cognitive development, to one with a more holistic view placing academic attainment within the context of social and affective development. The Dunning Report dealt with aspects of the assessment system by introducing ideas for broadening the scope of assessment to include the use of diagnostic assessment to establish baseline data as well as considering assessment which encompassed affective characteristics, practical skills and social competence as well as academic attainment (Francis, 1986).

Both of these reports aimed to deal with the concern that the curricular structure of the day was inflexible and unable to respond sufficiently to the needs of the less-able pupil, which in turn resulted in a lack of motivation and interest in the learning process, and which ultimately led to poor exam performance and low levels of attainment nationally. These reports led to the replacement of the Ordinary or 'O' Grades, which had been in operation since 1962, with Standard Grades. Ordinary Grades were only ever designed for the top 30% of the school population. However, by 1985 up to 75% of the pupil population took at least one 'O' Grade.

The 'O' Grade exam was designed to be taken by the more-able pupil but was being taken by average and less-able pupils resulting in poor pass rates. In addition, it became increasingly clear that 'O' Grade was not stretching the more-able pupils enough to enable them to make the jump in intellectual demand to Higher Grade at the end of S5. The aim of Standard Grade was to provide a form of assessment which would meet the recommendations of the Dunning report (Scottish Education Department, 1977a), in that there should be awards at separate levels, for the less-able, average and more-able pupil.

Standard Grade was designed to be taken by the whole school population where the exams would be assessed using grade related criteria having Foundation level for less-able pupils, General Level for the majority and Credit Level for the more-able pupils, thereby creating "certification for all". However, while these changes were far reaching they were slowed down by industrial disputes between the Government of the day and the Teaching Unions since these changes had implications for both teacher workload and conditions of service. As a result, the implementation of the Standard Grade curriculum did not happen in full until 1993.

It should be noted that although the Standard Grade helped to solve the problem of certification for the less-able pupil, it failed to solve the problem of meeting the needs of the more-able pupils with regard to the gap in intellectual demand between the new Standard Grade Credit exam and the Revised Higher. In the opinion of most teachers this gap widened. This problem laid the foundations for the reform of the Higher Grade examinations under the auspices of *Higher Still*.

At the same time as these changes occurred in secondary education, the then Conservative government also fixed its sights on reforming Scottish Primary educational provision as well as improving the transition from primary to secondary. In 1987, the consultation paper, *Curriculum and Assessment - a Policy for the 90's* was issued arguing that there was a lack of consistency in experience as well as a lack of cohesion and precision within the primary sector, consequently there was a lack of continuity between primary and secondary (Roger & Hartley, 1987). This was highlighted by Her Majesty's Inspectorate of Education (Scotland) who had long complained that Primary schools had little direction about what to teach, resulting in inspectors not being able to assess Primary schools against a set framework. The Scottish Consultative Council on the Curriculum (SCCC) was therefore asked to draw up guidelines, with priority for English, Mathematics and Environmental Studies which would include Science.

In 1993, the 5-14 curriculum guidelines as they came to be known were published and contained five areas - English; Mathematics; Environmental Studies (which included History, Geography, Science and Technology); Expressive Arts (including PE); and Religious and Moral Education. The implementation of the 5-14 guidelines within primaries are broadly described as successful in that most of the guidelines had been broadly implemented by 1997 but within Secondary Education the implementation was poor since most secondary schools had not began implementing 5-14 until 2003, almost 10 years after the first publication of the guidelines. The reasons for this were varied and context-dependent but the main concern, particularly within science, was that most secondary science teachers could tell from their pupils' lack of content knowledge on a particular topic which was supposedly covered at primary school, that there were considerable gaps in pupils' knowledge and experience of science. This situation led to a lack of confidence in the 5 -14 environmental studies coverage by Primary schools. In addition, there was a major revision of the 5-14 guidelines in 1999-2000, therefore most science departments chose to wait and see before implementing the 5-14 science guidelines into their S1/S2 Science courses.

In 1996, the Scottish Office Education Department began a wide ranging reform of the Higher Grade examination system called *Higher Still,* in a bid to both update the curriculum and to increase pupil choice and attainment. These reforms were viewed at the time by the teaching profession as an opportunity to refine and improve the S5 and S6 exam system. The *Higher Still* reforms saw the replacement of the Certificate of Sixth Year Studies exam with the new Advanced Higher exam and the gain of a new suite of National Qualifications, three new examination levels i.e. Intermediate levels 1, 2 and Advanced Higher as well as the introduction of Access 3 for less-able pupils. The Higher Grade syllabi in all subject areas were reformed. These changes were predominantly led from the centre with most course material and resources being produced and disseminated to schools prior to implementation. In addition, there was extensive consultation with the profession at national and local levels.

The consultation with the profession is commonly regarded as the main reason for the successful implementation of the Higher Still reforms since from inception to implementation the whole process took four years with the first examinations at all levels taking place in 2000. These reforms also helped to solve the problem of the gap between Credit level and Higher by introducing an Intermediate 2 examination for those pupils unable to cope with the jump from Credit to Higher at the end of S4. The subsequent uptake of the new National Qualification courses, particularly Intermediate 2 at present, is good and steadily increasing. However, in science the Intermediate 1 course has not been implemented in S5, instead it has been used as a replacement for Standard Grade Science in S3/S4.

In 2002, the Scottish Executive initiated an extensive consultation exercise on the state of the Scottish Education system: The National Debate on Education. This debate brought together the views of all the main stakeholders including, pupils, parents, teachers and employers. At the close of the debate in 2003, these stakeholders indicated that they valued and wished to retain many aspects of the current Scottish curriculum. However, an argument for change to the curriculum emerged from the feedback which pressed for changes to ensure that all pupils achieved success and were equipped to contribute effectively to the Scottish economy and society for both the present and the future.

The main thrust of the changes which emerged from The National Debate was that people felt that the present curriculum was overcrowded and that this was a potential barrier to pupils' enjoyment of the learning and teaching process. In addition, the respondents felt that a better balance between 'academic' and more 'vocational' subjects should be struck to provide a wider range of experiences. Furthermore, a stronger emphasis on equipping young people with skills was required as well as an increased emphasis on pupil choice to meet the needs of individuals.

Against this backdrop, In November 2003, the Scottish Executive set up a review group to identify the purpose of Education from the ages of three to eighteen and to set out the defining principles for the design of the curriculum. The end result of the review group's deliberations was grandly entitled A Curriculum for Excellence

(*CfE*). In September 2004, *CfE* was launched by the Scottish Executive in a consultation paper which set out four themes which the curriculum designers would follow as well as outlining the thinking of the review group at that point. The four themes which were later termed capacities emanating from *CfE* relate in the main to elements of potential pupil development outcomes, since *CfE* ultimately aims to produce *successful learners, confident individuals, responsible citizens and effective contributors* (see Figure 1.1). However, the challenge posed by *CfE* to the curriculum planners was to design a curriculum that challenges pupils while simultaneously making the learning process a more enjoyable experience, as well as introducing breadth and depth. In addition, the new curriculum also needed to have a degree of personalisation and choice as well as being more relevant, coherent and staged in progression.

In November 2004, the curriculum review programme board of *CfE* began to look at the curriculum structure by grouping existing subjects under headings as follows;

- **Health and Wellbeing:** includes PSHE, PE, and elements of health from home economics and Biology.
- **Language:** includes English, Gaelic, Modern Languages and Classics to make a large contribution to Literacy.
- **Mathematics:** to make a large contribution to Numeracy.
- **Sciences:** including Biological, Chemical, Physical and Environmental science
- **Social Studies:** including Historical, Geographical, Social, Political, Economical and Business.
- **Expressive arts:** including Drama, Dance, Music, Visual arts
- **Technology:** including Technology Studies, Craft and Design, Graphics, Computing and Home Economics.
- **Religious and Moral Education:** including Philosophy.

Figure 1.1: *The four capacities for a curriculum for excellence.*

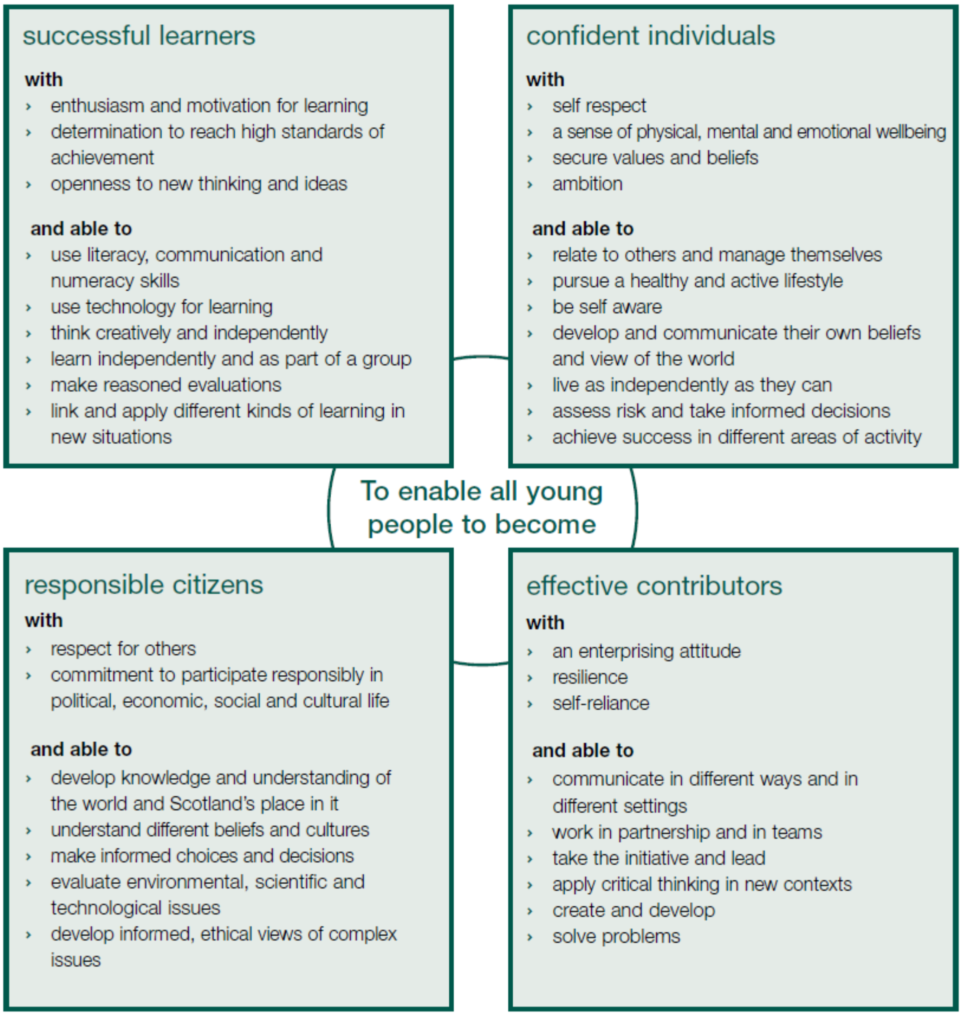
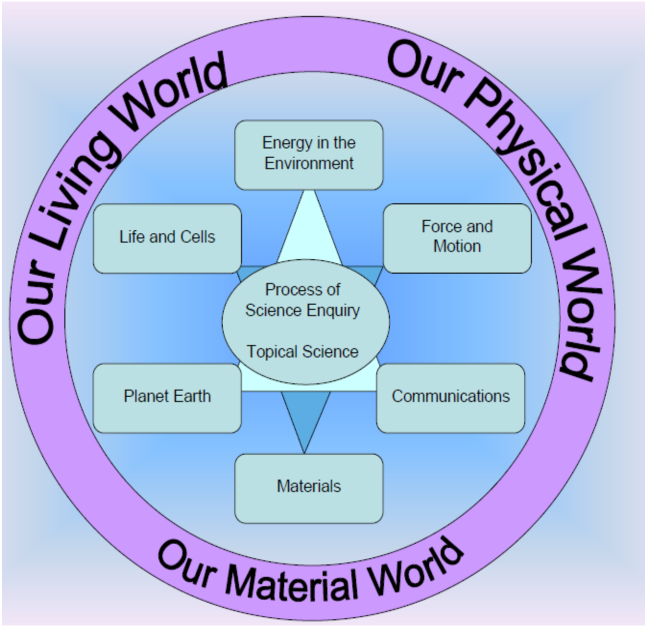


Figure 1.1 shows how the four capacities which emanate from CfE are defined (p.12) (Scottish Executive Education Department, 2004)

The first phase of this review looked at the areas of Language, Mathematics and Science. While this thesis concentrates on Science, one must not forget that Science contributes heavily to both Numeracy and Literacy across the curriculum. To help science teachers visualise how the new curriculum outcomes fit together, the *CfE* review group published through Learning and Teaching Scotland (LTS) a schematic diagram (See Figure 1.2) and draft learning outcomes for science under three major themes of science: The Physical World dealing with topics and concepts broadly thought of as Physics; The Material World dealing with topics and concepts broadly thought of as Chemistry; and The Living World dealing with topics and concepts broadly thought of as Biology.

Figure 1.2 *Science curriculum schematic diagram from CfE.*



It is interesting to note that Figure 1.2 places topical science and the process of scientific enquiry at the centre of the new curriculum. Furthermore, the draft learning outcomes for topical science clearly state that discussion of socio-scientific issues, particularly the issue of climate change must be covered. However, no guidance about how the topical science strand should be delivered is given in the outcomes. Are we to assume that the method of delivery is being left to the teachers' discretion?

The draft science outcomes and experiences from *CfE* were met by apathy from most science teachers and their professional associations. However, the Royal Society of Edinburgh was the main objector to the draft experiences and outcomes of the new science curriculum, arguing rightly in the view of this researcher that they lacked conceptual detail. Heated debate surrounded issues emerging from the draft outcomes over the consultation period, at all levels of science education. This debate resulted in a radical re-write of the experiences and outcomes for the new science curriculum by LTS prior to the launch of the final experiences and outcomes in April 2009.

The final experiences and outcomes retained the topical science strand and extended the use of discussion of controversial socio-scientific issues by embedding discussion of issues such as the therapeutic use of cells, relating to embryonic stem cell research as well as ethical discussions which emerge from the use of controversial biological procedures such as *in vitro* fertilisation (IVF) and pre-implantation genetic screening (PIGS). Each of the three sciences is represented within the new science experiences and outcomes both in terms of content knowledge and conceptual detail as well as discussion of socio-scientific issues relating to each area. However, it is important to note that the new science experiences and outcomes are not as radical in terms of content as they might have been. The question of how best to implement the Topical Science strands outcomes in terms of learning and teaching approaches which allow for pupil development towards becoming more scientifically literate citizens remains unanswered and open to further debate. The main body of this thesis is intended to help inform this debate and provide an insight into how science teachers might meet this challenge.

1.3 The professional relevance of the study.

This study explores issues related to teaching through discussion of controversial socio-scientific issues using cooperative learning as a pedagogical approach within secondary school science. As such, it describes one science department's attempt to develop a model of discussion which could be applied to the teaching of the topical science strand of the new science curriculum. This study is a rich picture of the reality of educational development in response to reform and as such, provides a prism through which we can unpack the reality of change and understand how science teachers across Scotland might cope with the curricular changes required in response to *CfE*. The pupil group chosen for this study ranged in age from 13 to 14 years in second year of their secondary education and in terms of age would be grouped in the new curriculum towards the third and fourth level of the new course.

Furthermore, this study describes a developmental process which will be substantially duplicated in some shape or form by every science department across Scotland over the next few years and as such provides some insights into the challenge and opportunities likely to be faced. This study provides a view of change which might be used by other science departments as they face up to their own circumstances.

The professional relevance of the work presented in the thesis serve four aims:

1. To define the concept of 'scientific literacy' and set it within a framework which science teachers can access, identifying the characteristic components of scientific literacy and outlining how these characteristics might be developed in secondary science education.
2. To determine pupils' views on science and in particular in relation to teaching through the discussion of climate change and global warming and to evaluate how pupils' attitudes to science impact on their engagement with the issues.
3. To outline a working model of cooperative learning which science teachers can use when managing the discussion of controversial socio-scientific issues.
4. To identify areas of difficulty with the delivery of teaching towards the topical science strand of *CfE*, and highlight potential issues which arise from the development of learning and teaching materials to be used in discussion within the topical science strand of the new science curriculum.

With the change in emphasis of science education discussed earlier in mind, working from the draft science learning outcomes emanating from *CfE*, the Science department within the author's school agreed to run an action research project to help develop learning and teaching materials and to evaluate how implementation of the new curricular outcomes contained within the topical science strand would impact on the management and delivery of the new science curriculum. This study is particularly relevant to the current educational context as implementation of the new curriculum is scheduled to begin in August 2009 with full implementation to have commenced nationwide by August 2010.

The significance of this study lies within the context of secondary school science and science education for citizenship within a modern techno-centric society. Some science educators (Cross & Price, 1996; Irwin, 2001; Kolsto, 2001; Roth & McGinn, 1997) emphasise the importance of decision making on controversial socio-scientific issues as an important element of citizenship and as such call for the inclusion of discussion of them within modern science curricula. This study suggests that discussion of socio-scientific issues can be used to bridge the relevance gap between what pupils perceive science to be and the science that they are taught.

1.4 The research questions.

The research questions which are derived from the aims of the action research were as follows:

1. What is ‘scientific literacy’ and what are the characteristic elements which define it as a concept which can be developed within secondary school science education?
2. What conceptual models of discussion do science teachers hold and do they differ from those held by humanities teachers?
3. How useful is cooperative learning as a pedagogical approach for the teaching of discussion within the science classroom setting?
4. What are the pupils’ attitudes towards Science & Technology and School Science and how does pupil attitude to science impacts on their engagement with socio-scientific issue?
5. What issues arise from teaching the Topical Science strand of the new science curriculum in terms of the development of teaching materials, time to deliver, teacher CPD and management of resources?

How each of these questions was tackled by the research described in this thesis is outlined in section 1.5.

1.5 Outline of the thesis.

The research findings presented in this thesis provide an insight in to how a science department in a large non-denominational comprehensive secondary school have coped with change to the S1 and S2 science curriculum. It also offers guidance to science teachers elsewhere as they face up to change in their own situation. The thesis comprises nine chapters. The following outline gives an overview of each chapter.

Chapter one provides a rationale for the present study as well as an overview of the contextual background from an historical perspective on educational reform in Scotland. In addition it provides an outline of the research objectives.

Chapter two is a review of the relevant literature in science education. It begins by reviewing the historical context of reform within Scottish science education in the lead up to *CfE*. This sets the reform in science education in context. The review then looks specifically at the concept of scientific literacy in terms of its meaning and how the characteristics of scientific literacy may be developed within the science curriculum. It then examines the research literature on discussion in general and more specifically on discussion of controversial socio-scientific issues and the promotion of scientific literacy. The review then focuses on the use of cooperative learning as a method for the promotion of small group discussion and as a teaching model for the promotion of the development of scientific literacy among Scottish pupils.

Chapter three describes the research methodology and design of the investigation. This chapter begins by setting out the rationale for using Educational Action Research as a methodology. It sets the research paradigm in the context of the research literature, before outlining how the mixed method (quantitative and qualitative) approach was applied to the action research cycles. It also describes the data collection strategies used in the study and how the data was analysed. An outline of the issues of validity and reliability within the research is given to qualify these terms in the context of the present study.

Chapter four examines the findings from the semi-structured teacher interviews. This chapter begins by setting the problem of teaching through discussion in context with reference to the literature. It then relates the findings to the teachers' conceptual models of discussion, their comfort levels leading discussions of socio-scientific issues, and their views on cooperative learning as a pedagogical approach to the teaching of discussion.

Chapter five outlines the findings from the S2 pupil questionnaire. This chapter begins by describing the S2 study cohort characteristics such as ability in English reading and writing, Mathematics and Science. It then goes on to describe the pupils' views on the environment, science and technology, school science and what they would like to learn. The chapter concludes with a summary of the key findings.

Chapter six outlines findings from the series of teacher post-lesson semi-structured interviews; classroom observations; pupil post-lesson questionnaire data; and from pupil-group semi-structured interviews from all three rounds of the action research project. The chapter concludes with a summary of the key findings.

Chapter seven outlines findings from pupil work carried out during the cooperative learning approach to teaching through discussion of the climate change and global warming topic as a controversial socio-scientific issue from all three rounds of the action research project. The chapter concludes with a summary of the key findings.

Chapter eight discusses the findings of the research by inter-relating the findings presented in chapters four, five, six and seven of the thesis and considers their implications for teachers, departmental managers and teacher educators, with reference to the research questions and the existing literature.

Chapter nine presents the main conclusions, examines the implications of the study, and provides suggestions for further research.

Chapter 2: Literature Review.

2.1: Introduction.

This literature review examines theoretical perspectives that form the basis for *Curriculum for Excellence* (*CfE*) in the context of science education. The main aims of science education as stated in the Science rationale of *CfE* are improved scientific literacy with increased discussion of contemporary scientific issues within secondary science classrooms. First, a brief historical overview of reform in Scottish science education is presented as a background narrative to the reform of the science curriculum under the auspices of *CfE*. Second, a philosophical perspective on scientific literacy to help define the concept and the teaching of scientific literacy is then explored. Third, an outline of the use of classroom discussion of controversial socio-scientific issues as an approach to promoting the acquisition of knowledge, skills and attitudes is provided. Fourth, the use of cooperative learning as a pedagogical approach to promote increased discussion within small groups is then explored. Fifth, the connections between these differing perspectives are drawn together to provide (a) a theoretical insight into the teaching of controversial socio-scientific issues within secondary school science for the promotion of scientific literacy, and (b) a basis for the research conducted with fellow teachers in the author's school.

2.2: Curricular change in Scottish Science Education: 1945 to 2009.

For a relatively small country, Scotland's impact in the fields of Science and Engineering has been immense. Many eminent scientists and engineers such as Joseph Black, Alexander Fleming, Lord Kelvin, John Logie Baird, Thomas Telford, James Watt, Alexander Graham Bell and John Loudon McAdam have made discoveries and inventions which arguably define the modern world. However, it is rather surprising to note that formal science education was only introduced to the Scottish Secondary School Curriculum in 1947 with the publication of the influential report, *Secondary Education: A report of the Advisory Council on Education Scotland* in which science education was set as part of every school student's education.

> We propose that science should be studied by every pupil throughout the four years of the School Certificate course. To justify such a policy we do not point to the technological needs of the country, nor do we lay the primary emphasis on that exactitude of observation, measurement and thought which is the characteristic virtue of the trained scientist. Science claims this place in the education of every boy and girl because of its immense cultural significance. It is far more than a subject or group of subjects; it is a whole vast world of human thought, feeling and endeavour.
> (Advisory Council on Education in Scotland, 1947)

As Wynne Harlen notes, the main emphasis of this document was not to justify Science's place in the curriculum on the basis of national priorities or economic imperatives rather its emphasis was on the need for pupils to think more scientifically and to become more aware of the role that science plays in modern society (Harlen, 1995). However, with the benefit of hindsight, it could be argued that this document was interpreted by science teachers to mean that pupils should learn more scientific facts in the hope that more knowledge might lead to improved thinking and perhaps by implication, a greater appreciation of how science impacts on society.

The consequent translation of this policy document into practice was very slow. Indeed, it could be argued that in terms of implementation of a balanced science course throughout secondary school, this was never fulfilled. Since its incorporation into the Secondary curriculum, Science is currently studied by all pupils in Scotland in some form or another i.e. any one of the individual disciplines biology, physics, and chemistry or as science. Indeed, an Inspectorate report from 1994 found that 50% of pupils in S3 and S4 take only one of the separate sciences and thus 'are not experiencing a broadly based science course' (Scottish Office Education Department, 1994). This situation had worsened by 2005 due to increased uptake of pupils into the new Intermediate 1 course in the discrete sciences (Her Majesty's Inspectorate of Education Scotland, 2005). The uptake of Intermediate 1 in S3/S4 has effectively relegated Standard Grade Science to the history books, the numbers of pupils sitting the Standard Grade Science exam having declined by 74.7% between 1996 and 2007 with most of the decline occurring after the introduction of National Qualification course (The Royal Society, 2008).

The nature of science education in the first two years of secondary school was set out by the Scottish Education Department through the publication of Curriculum Paper No 7(CP7) (Scottish Education Department, 1969). This laid the foundations for the *Scottish Integrated Science* course which covered S1/S2 Science in the secondary school. Scottish Integrated Science placed a strong emphasis on problem solving and communication skills. In addition, it was supposed to stress an awareness of the contribution that science makes to the welfare of man, and some of the potential dangers of the misuses of scientific knowledge as derived in response to CP7 (Scottish Consultative Council on the Curriculum, 1980).

> The Scottish Integrated Science course is designed to be part of the general education of all children. While specific items of content have been described in the published materials the intention has always been that the understanding of concepts and the development of "process" skills is of more importance than straight-forward rote-learning of facts. . . . The ability to solve problems depends more on one's development of skills of thinking (Curriculum Paper 7, page 12), i.e. process skills and one's capacity for marshalling the correct concepts, than on the ability to recall disconnected facts. Children can only be helped to develop this problem-solving capability by providing them with practice in solving problems. (SCCC, 1980)

However in reality, discussion of the impact of science on society was rarely if ever covered in schools. This was highlighted by Her Majesty's Inspectorate of Education (Scotland) in the report *Improving Achievement in Science in Primary and Secondary Schools* (2005) in reference to S1/S2 Science.

> Many schools were failing to develop students' understanding of key areas of contemporary science and were therefore failing to prepare them for the science they would encounter as citizens of the 21st century. (Her Majesty's Inspectorate of Education Scotland, 2005)

This situation sadly persists today. However, this issue ought to be addressed by the Topical Science strand within the new science curriculum emanating from *CfE*. What these curricular papers and HMIE reports clearly show is that in terms of curricular content in Secondary School Science, not much has changed from CP7 in 1969 even with the introduction of Standard Grade, the 5-14 reforms of the early 1990s and *Higher Still*. This is contrasted by the fact that over the same time period there has been an explosion in scientific knowledge in all of the sciences with the greatest proportion of this increasing knowledge emerging from the Biological Sciences. Furthermore, there has been an increase in interest from students particularly around knowledge linked to the growing fields of Forensics, Molecular Biology and Genetic Engineering. The problem is that the curriculum has failed to keep pace with these developments in science creating a relevance gap. It is important to note that these new fields of scientific endeavour have only grown relatively recently from humble beginnings in the late 1970s/early 1980s until their explosion in the mid-1990s.

Even with the *Higher Still* reforms in the late 1990s relatively little of this new science content found its way into the New Higher Sciences syllabi. In fact none appear in the Higher Grade Biology or Higher Human Biology syllabi. Furthermore, most of the new Advanced Higher Biology, Cell and Molecular Biology Unit contain knowledge of forensics and the uses of genetic engineering which was out of date by the time the new syllabus was introduced. In addition, this unit of the Advanced Higher lacks coherence since it is an amalgamation of very different fields in molecular and cellular biology each of which could fill a whole unit of work in their own right.

In March 2006, the curriculum review group published *CfE* Progress and Proposals. In appendix 2, they set out the Science rationale, Science 3 to 15. Contained within this rationale, the review group define the two main aims of Science Education as being to:

- enable young people to develop as scientifically literate citizens, able to hold and defend informed views on social, moral, ethical, economic and environmental issues related to science;
- and prepare them for further, more specialised, learning by developing their secure understanding of the 'big ideas' and concepts of science. (Scottish Executive Education Department, 2006)

This rationale places the main emphasis of science education on the development of pupils as scientifically literate citizens, with the production of science specialists as a secondary aim. To date, the review group has neither defined what scientific literacy is or what a scientifically literate person should be capable of doing or what should be taught in order to develop pupils' scientific literacy.

Worryingly, the final experiences and outcomes are vague and so wide-ranging that interpretation of the outcomes, by different interested groups, leads to differing emphases, thus there is a danger that consistency of pupil experience within Scottish science education could be compromised, depending on how individual schools choose to interpret and subsequently implement the new curriculum. These issues have yet to be addressed. However, if science teachers are to be expected to develop their pupils' scientific literacy, one must first define what scientific literacy is and what the components of scientific literacy are before the developmental process can begin. In addition, science teachers must also decide which pedagogical approaches could be used within the different stages of education in order to facilitate the development of scientific literacy within all pupils.

2.3 Summary.

The Scottish education system has been in a state of flux for the best part of thirty years. During this time there have been a number of changes to both the primary and secondary sectors, with major change occurring in the structure of the middle and upper school of secondary, coupled with changes to the examination systems which assess attainment at the end of S4 and S5/6. However, since the turn of the Century, there has been a growing recognition that the curriculum content was in need of radical reform since it had essentially remained static since Curriculum Paper 7 issued in 1969. This led in 2002 to the National Debate on Education which brought the views of all the main stakeholders in education together. The response to this consultation provided the catalyst for the government's proposed reform of the whole curriculum from 3-18 years which is now known as Curriculum for Excellence (*CfE*). The main aims of these reforms are to provide a better connection between the primary and secondary curriculum as well as to update and modernise curricular content. In addition, a secondary aim is to reduce the gap in relevance between the secondary curriculum and pupils' life experiences.

These reforms have led to the introduction of four capacities; responsible citizens; confident individuals; effective contributors and successful learner. In terms of the structure of the curriculum, the Standard Grade, Intermediate One and Two courses are to be dropped to be replaced with a National Qualification at two levels and Literacy and Numeracy examinations are to be added from 2013-2014. In addition, the curricular content of the Higher courses is to be de-cluttered and modernised and a new Scottish Baccalaureate is to be introduced. For science these reforms mark an intended change in focus towards science education for citizenship from science education for specialisation. In addition, they formalise the discussion of contemporary science issues into the curriculum under the topical science strand of the new curricular outcomes.

2.4: Scientific Literacy: Concept, slogan or a curricular outcome?

2.4.1: Introduction.

In this section of the literature review the philosophy behind the term 'scientific literacy' will be explored, noting the historical origins of the phrase and its use in the educational literature associated with several curricular reforms. A critical perspective will then be outlined and the implications for Scottish educational reform today discussed.

2.4.2: Scientific Literacy: Origins in Educational Reform.

Over the last 20 years the research literature on scientific literacy has mushroomed. As a concept, scientific literacy has come to be used more extensively in many Western Countries to express what constitutes science education for all students. However, it is well known within the science education community that there is no real consensus as to the definition of the term. The phrase 'scientific literacy' is used in many research studies, in discussion and analyses of science educational aims and in assessment programmes. It has also been widely used in curriculum policy documents such as *A Curriculum for Excellence.*

The literature on Public Understanding of Science, a phrase commonly used in the United Kingdom, as well as Scientific Culture (or for the French *la culture scientifique*) is highly significant in the context of scientific literacy. Furthermore, one must not forget the contribution to the concept of scientific literacy made by the literature on Science Education for Citizenship. Looking across these various fields of study, it is not difficult to grasp why the science education community has failed to settle upon a reasonably tight definition for scientific literacy.

In the United States there has been an unhelpful change in the term itself. In the curricular reform documents emanating from Project 2061, in particular *Science for all Americans* (SFAA) published in 1989 on behalf of the American Association for the Advancement of Science, the phrase scientific literacy was used, but when the Oxford University Press edition was subsequent published in 1990 the phrase science literacy replaced scientific literacy (Rutherford & Ahlgern, 1990). This change in phrase albeit a subtle one, is for some writers unimportant (Carson, 1998; Hurd, 1998; Shen, 1975), while for others it is significant (Marshall, Scheppler, & Palmisano, 2003; Mayer, 2002).

In 1996 The American National Research Council (NRC) published the *National Science Education Standards* (National Research Council, 1996), in which they use the term scientific rather than science. So is there a difference in emphasis between science and scientific? The lead author of SFAA, F.J. Rutherford in reply to this query by Douglas Roberts states that;

> Science literacy refers to literacy with regard to science, while scientific literacy properly refers to properties of literacy, namely literacy that is scientifically sound no matter what content domain it focuses on. (Roberts, 2007)

Reading between the lines, it appears that, for Rutherford, there is no reason to assume that these terms are fundamentally different. That is unless you take the term literally to mean literacy through science i.e. using science to advance literacy in terms of reading and writing, which one could argue advances English literacy rather than scientific literacy and as such constitutes a different construct. However, it would be naïve to assume that literacy only refers to the ability to read and write. Lawrence Cremin (1988) describes literacy in terms of either inert or liberating, where inert literacy refers to the ability of people to read a passage or sign a document but, liberating literacy is defined as the ability to read freely and widely in search of whatever information and knowledge people chose. This means that literacy may serve a number of purposes. Liberating literacy provides access to materials that may open minds and introduces new ideas and aspirations (Cremin, 1988). This perspective on literacy comes close to the reformer intentions for scientific literacy since we all desire to open our students' minds to new ideas and perspectives.

In addition to this perspective, it is interesting to note that there is disagreement within the Scientific Literacy literature as to the origins of the phrase 'scientific literacy', with most commentators crediting Paul deHart Hurd with the term's inception in 1958 (Hurd, 1958). However, the term 'scientific literacy' was first introduced into the educational arena by the then President of Harvard University, James Bryant Conant (Kemp, 2000) in his foreword for General Education in Science (Cohen & Watson, 1952)

> Such a person might be called an expert on judging experts. Within the field of his experience, he would understand the modern world; in short, he would be well educated in applied science though his factual knowledge of mechanical, electrical, or chemical engineering might be relatively slight. He would be able to communicate intelligently with men who were advancing science and applying it, at least within certain boundaries. The wider his experience, the greater would be his scientific literacy (Conant, 1952).

It is clear that Conant saw scientific literacy as a matter of education and experience which results in the ability to "communicate intelligently" about scientific and technical issues.

As Kemp (2000) points out in his review of the scientific literacy literature, science education in the United States underwent a series of reforms as a result of several contextual factors. These factors included the post-war baby boom which called for an expansion in educational provision, a problem also seen in the United Kingdom at the same time, as well as criticisms of the progressive educational approach prevalent in the United States at that time. Central to the criticisms of the progressive educational approach was the concern of academics, scientists and professional associations that the progressive curriculum was not adequately preparing students in Mathematics and Science to provide the country with the number of scientists and engineers that, at the time, was perceived to be required to stay competitive with the Soviet Union (Bybee, 1997; Kemp, 2000; Shamos, 1995).

Then in 1957, the Soviet Union launched the *Sputnik* satellite. Suddenly the perceived post-war scientific advantage that the United States thought they enjoyed over the Soviet Union disappeared. There was a realisation on both sides of the Atlantic that science education was in need of reform. This realisation led to the publication of many articles and reports which discussed scientific literacy. One panel report for the "America at Mid-Century Series" project, funded by the Rockefeller Brothers, included a section on the 'crisis' in US science education which attributed this crisis to the movement of the US into a new technological era (Rockefeller Brothers Fund, 1958). The report noted that the technological prowess of the Soviet Union did not cause the crisis, but that it provided the stimulus which helped the United States to see the reality of the situation. This report called for better education of scientists and cautioned that there was a danger of training scientists so narrowly in their respective specialties that they were unprepared to shoulder the moral and civic responsibilities which the modern world thrusts upon them. However, this report went further by explicitly extrapolating this zeal to educate by stating;

> …just as we must insist that every scientist be broadly educated, so we must see to it that every educated person be literate in science. (p28)

However, the report did not go on to define the phrase "literate in science." At the same time Paul Hurd used the term "scientific literacy" in an article entitled *Scientific Literacy: Its Meaning for American Schools* in the October issue of Educational Leadership (Hurd, 1958). In that article Hurd noted that;

> Science with its applications in technology had become the most important characteristic feature of modern society (p13).

In addition, he suggested that American children should be able to cope with a society of expanding scientific and technological developments as well as to continue the accelerated momentum of science. Therefore,

> More than a casual acquaintance with scientific forces and phenomena is essential for effective citizenship today. Science instruction can no longer be regarded as an intellectual luxury for the select few. If education can no longer be regarded as sharing of the experiences of the culture, then science must have a significant place in modern curriculum from the first through the twelfth grade (Hurd, 1958, p13).

It should be noted that Hurd never explicitly defined what he meant by the term scientific literacy in the 1958 paper. However, he did imply that it had something to do with developing an understanding of science as a method of theoretical inquiry, as an appreciation of science as a human endeavour, and as a preparation for the changes in culture and world due to advances in science and technology.

The term ‘scientific literacy’ soon became an educational ideology with the idea of scientific literacy in the 1950s and early 1960s including the premise that all students, not just those destined to become the next generation of scientists and engineers, ought to have some understanding of science. However, while science educators recognised the need for all students to gain an appreciation for science, the main model for the acquisition of this appreciation was thought to be through letting students act like scientists by exploring and discovering in the lab. None of the early users of the term scientific literacy bothered to define it. From the early 1960s until 1983 there was a ‘period of interpretation’ through which a number of basic definitions emerged as well as numerous outline characteristics of a scientifically literate citizen, in addition to further justification for the need for greater scientific literacy.

Scientific literacy has become linked with science education's ultimate aim and in many ways it has become the criterion for assessing curriculum and pedagogy with new approaches being evaluated by the extent to which they promote scientific literacy. As a result, science education researchers have a tendency to conceptualise the construct in a manner which lends weight to their own aims for education. Consequently, this has left the field of science education with a plethora of distinct prescriptions of what scientific literacy encompasses. The majority of science teachers would agree that promoting scientific literacy is a primary aim of science education, but there is no real consensus as to the meaning of scientific literacy itself. Despite this, scientific literacy has become part of the educational landscape and more significantly the language of science education, where its meaning is 'mired in debate'(Sadler, 2004b).

Most of the multiple definitions of scientific literacy tend to focus on the areas of process, knowledge and attitude (Jenkins, 1990). Attempts to implement scientific literacy typically appeals, at the very least to one of these areas with the arguments usually proceeding along the following lines;

> The scientifically literate person accurately applies appropriate science concepts, principles, laws and theories in interacting with the universe (Rubba & Andersen, 1978).

In this example, the knowledge dimension is highlighted but equally viable statements can be made regarding the process of science as well as attitude towards science. In addition, some definitions delineate scientific literacy in combination with multiple aims as in the case of equating concepts with building "scientific habits of mind" which involve processes, epistemic considerations and attitudes (Zeidler & Keefer, 2003). It could be claimed that this is evidence that scientific literacy is an ill-defined concept with little practical utility (Shamos, 1995). However, since educators appropriate multiple meanings to the phrase it can still be useful in describing the aims of science education, so long as there are appropriate qualifiers and supporting views regarding the authors' conception of, and rationale for, their given perspective on scientific literacy.

Science for all Americans, defines scientific literacy as a multifaceted construct including the following elements,

> …being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes (Rutherford et al., 1990).

Whereas, PISA 2006 defines scientific literacy in terms of an individual's

- *Scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues*. For example, when individuals read about a health-related issue, can they separate scientific from non-scientific aspects of the text, and can they apply knowledge and justify personal decisions?
- *Understanding of the characteristic features of science as a form of human knowledge and enquiry*. For example, do individuals know the difference between evidence-based explanations and personal opinions?
- *Awareness of how science and technology shape our material, intellectual and cultural environments*. For example, can individuals recognise and explain the role of technologies as they influence a nation's economy, social organisation, and culture? Are individuals aware of environmental changes and the effects of those changes on economic and social stability?
- *Willingness to engage with science-related issues, and with the ideas of science, as a reflective citizen*. This addresses the value students place on science, both in terms of topics and in terms of the scientific approach to understanding the world and solving problems. Memorising and reproducing information does not necessarily mean students will select scientific careers or engage in science-related issues. Knowing about 15-year olds' interest in science, support for scientific enquiry, and responsibility for resolving environmental issues provides policy makers

> with early indicators of citizens' support of science as a force for social progress (OECD, 2006).

In yet another statement, the American *National Science Education Standards* defines a scientifically literate person as someone who is able to

> …use appropriate scientific processes and principles in making personal decisions [and] engage intelligently in public discourse and debate about matters of scientific and technological concern (National Research Council, 1996).

As Sadler (2004b) points out, these documents characterise scientific literacy as an active objective; they provide benchmarks for using scientific knowledge and processes. However, a logical question to ask in response to this analysis is *use of knowledge and processes towards what end?* For Sadler the answer is in the title of one, *Science for All* Americans (Rutherford et al., 1990) and the opening sentence of the other, "scientific literacy has become a necessity for everyone" (National Research Council, 1996, p.1).

Furthermore, this emphasis on scientific literacy for all forces us to recognise that scientific literacy is not a goal restricted to the academic elite or for those who show the promise of becoming tomorrow's scientists, doctors or engineers: scientific literacy is for every student. If this is so, scientific literacy cannot involve the level of technical sophistication required by professional scientists and engineers. In fact most students will not become professional scientists or engineers and, as a result, dont need to master the specifics of 'post-translational protein modification', or any number of other science discipline-specific information. Sadler (2004b) argues that most professional scientists probably do not even understand intra-discipline complexities beyond their own specialties. Thus, it seems ridiculous to expect student scientific literacy to eclipse that of practising scientists (Pool, 1991).

Looking more closely at curriculum reform from a United Kingdom perspective, two documents play a critical role in defining the aims of science education for the 21st Century in the United Kingdom. *Beyond 2000: science education for the future*

(Millar & Osborne, 1998) argues for a repositioning of the English Science curriculum in terms of *scientific literacy*, whereas *Science Education in Scottish Schools: Looking to the future* published two years previously*,* argues for a repositioning of the Scottish Science curriculum in terms of *scientific capability* (SCCC, 1996).

In *Beyond 2000*, Millar and Osborne (1998) argue that the science curriculum in England from 5 to 16 should primarily be seen as a course to enhance general 'scientific literacy'. They suggest that the structure of the English science curriculum had to differentiate more explicitly between elements designed to enhance 'scientific literacy', and those designed for the early stages of a specialist training in science, so that the requirement for one did not distort the other (since the situation, then as now, did not make a clear enough distinction between these two competing aims).

They also suggested that the science curriculum required a clear statement of its *aims* – making clear *why* it was considered valuable for all pupils to study science, and *what* it was that pupils would gain from the experience. In addition, they argued that these aims had to be clear, realistic, achievable and easily understood by teachers, pupils and parents. Further to this, they argued that the exploration of how aspects of technology and the applications of science (at the time omitted from the curriculum) should be incorporated within a science curriculum design in order to enhance 'scientific literacy'. The science curriculum should provide pupils with an understanding of the key ideas-about-science, in other words, ideas about the ways in which reliable knowledge of the natural world has been, and is being, obtained (p.20). They lamented that the current English science curriculum provided little scope for extended enquiry into aspects of the history of science, or to the assessment of media reports of socioscientific controversies and risk.

To this end, they proposed that the assessment approaches used to report on pupils' performance should encourage teachers to focus on pupils' ability to understand and interpret scientific information, and to discuss controversial issues, as well as on their knowledge and understanding of scientific ideas. In addition, the curriculum ought to be presented clearly and simply, with its content seen to follow from the statement of aims. Scientific knowledge should be presented as a number of key 'explanatory stories', with the curriculum being introduced to pupils as a number of important ideas-about-science.

As Millar and Osborne saw it, science education for the 21st Century should aim to produce both scientifically literate citizens while, at the same time, adequately prepare those pupils who wished to enter scientifically-related professions. Ultimately they suggested that the same curriculum could not achieve both aims simultaneously, that the early stages of science education should be balanced more towards the aim of producing scientifically literate citizens. In the intervening years from the publication of *Beyond 2000* to the present day, the English Science curriculum has undergone a staged transition towards the reorientation suggested by Millar and Osborne (1998). In this time a new General Certificate in Secondary Education (GCSE) in applied Science has been introduced. In addition, a New AS- and A2 -level course called *Science in Society* has been developed for pupils wishing to study the more social aspects of science rather than following on into specialist A-level courses in Science.

In Scotland, the Scottish Consultative Council on the Curriculum in their report *Science Education in Scottish Schools: Looking to the future,* chose to look at science education from a different angle by adopting the term *scientific capability* as opposed to *scientific literacy*. The authors of this report convey clearly a flavour of science education for action, enlightenment and satisfaction. They set out to describe 'scientific capability' in terms of five distinct but inter-related aspects; (1) scientific *curiosity* - an enquiring habit of mind; (2) scientific *competence* - an ability to investigate scientifically; (3) scientific *understanding* - understanding of scientific ideas and the way science works; (4) scientific *creativity* – the ability to think and act creatively; and (5) scientific *sensitivity* – critical awareness of the role of science in society, combined with a caring and responsible disposition. This suggests that becoming 'scientifically capable' involves more than the acquisition of scientific skills, knowledge and understanding: it also involves the development of personal qualities and attitudes, the ability to formulate one's own opinions on a variety of issues that have a scientific and/or technological dimension together with the ability to establish an underlying value position.

> A person who is scientifically capable is not only knowledgeable and skilled but is also able to draw together and apply his/her resources to an issue, problem or phenomena (SCCC, 1996).

For a document which purports to be action-orientated it disappointingly failed to include other aspects such as preparation of pupils for socio-political action. However, what this document implies is that a scientifically capable person should be able to discuss critically with others controversial issues with a scientific dimension.

In a sympathetic but nonetheless insightful critique of SCCC (1996), Bryce (1996) summed up his concerns about the situation in science education at that time by concluding that (1) Scientific *curiosity* wanes as pupils progress through school, largely due to inappropriate content and with diminishing focus upon problems which pupils find interesting; (2) Scientific *competence* is unacceptably patchy throughout school, with unconvincing outcomes for general education; (3) Scientific *understanding* is relatively over-emphasised with unjustified claims for the output of non-specialists in school; (4) Scientific *creativity* is usually sacrificed because project/investigative activity is subordinated to content coverage; and (5) Scientific *sensitivity* is still significantly under-emphasised at great cost to education (Bryce, 1996). With hindsight, his final comment was more prophetic than he could have imagined :-

> The arguments mounted in SCCC (1996) are therefore timely and much needs to be done, particularly at a point when a major overhaul of the upper secondary curriculum is underway (*Higher Still).* The signs are that changes in that quarter are unlikely to be spirited or radical in the ways so surely spelled out in the SCCC document (Bryce, 1996).

Since the publication of SCCC (1996), there has been a major revision of the 5-14 Science curriculum as well as radical reform of the entire post-16 curriculum in all subject areas under the auspices of the *Higher Still* reforms. Sadly and rather shortsightedly in this researcher's opinion, this reform of the science curriculum completely ignored the recommendations in *Science Education in Scottish Schools: Looking to the future*; it had no impact at all on the new National Qualifications in Science which emerged from *Higher Still*.

The Scottish emphasis on scientific capability rather than scientific literacy was perhaps unfortunate, since the word 'capable' conjures up an image of someone capable of doing science. Then, as now, the majority of Scottish citizens are far from scientifically competent. Furthermore, from the author's own experience, most BSc (Honours) project students are generally lacking in scientific competence in that they can barely be trusted to carry out simple tasks in the lab without considerable supervision. They generally lack the scientific sensitivity to see beyond the science of their project to the potential implications that their work might have for society at large.

This notwithstanding, the failure of the SCCC (1996) report to impact on the science *Higher Still* reforms was due in part to a lack of political will to take on board the recommendations in the report and force the issue with Scottish science teachers. The main problem faced by SCCC (1996) was, and still remains, the conservative/traditional views held by the large majority of Scottish science teachers on the nature of science and the content of the curriculum. It is clear from the grumblings surrounding *CfE* that, although teachers accept the need for reform of the science curriculum, they fail to accept that for that reform to be successful, it requires a change of view on their part as to which science education aims to achieve. A shift is required from an authoritative, certain body of knowledge designed for the production of future scientists towards a more inclusive, less elitist curriculum designed to produce scientifically literate citizens.

It is clear from the United Kingdom's experience of curriculum reform that interpretations of what constitutes a science curriculum suited to the needs of future citizens in the 21st Century are a little varied. Is the concept of scientific capability different from scientific literacy? When one compares the characteristic elements of scientific capability as set forth in SCCC (1996) against the characteristic elements of scientific literacy, it can be argued that the five aspects of capability may be narrower in their scope, but they are completely congruent with the characteristic elements of scientific literacy. However, one question remains to be answered: *What do students require to learn in order to become scientifically literate?* It has been argued that the ability to make informed decisions regarding socio-scientific issues is an integral part of teaching for scientific literacy (Kolsto, 2001; Ryder, 2001; Sadler, 2004b). However, while this justifies the inclusion of discussion on socio-scientific issues in the curriculum, it does not offer a complete pedagogy for teaching students to become more scientifically literate. We must look more closely at the literature on scientific literacy to find more detail concerning the characteristic elements and how teachers may be helped to frame what content knowledge and skills should be taught. The elements of scientific literacy shown in the Table 2.1 have been modified and extended from those discussed by Andrew Kemp (Kemp, 2000) to include more recent reform documents.

Table 2.1: *Summary of Studies which compare elements of scientific literacy.*

Element of Scientific Literacy	Intellectual Independence	Science Communication	Science and Society	Conceptual Knowledge	Science and Technology	Science in everyday life	Science Appreciation	Ethics of Science	Nature of Science	History of Science	Science in the Humanities	Science Skills	Science and Mathematics
Studies													
Conant 1952	●	●	●	●	●	●	●	○	○	○	○	○	○
Rockerfeller 1958	○	●	●	●	○	○	○	●	○	○	○	○	○
Hurd 1958	○	●	●	●	●	○	●	○	●	○	○	○	○
McCurdy 1958	○	○	○	●	○	●	●	○	○	●	○	○	○
Carleton 1963	○	●	○	●	○	○	○	○	●	○	○	○	○
Koelsche & Morgan 1964	●	●	●	●	○	●	○	○	○	○	○	○	○
Pella *et al* 1966	○	○	●	●	●	○	○	●	○	○	●	○	○
Hurd 1968	○	○	●	●	●	○	●	○	●	○	○	○	○
NSTA 1971	●	○	●	●	●	●	○	○	○	○	●	○	○
Agin 1974	○	○	●	●	●	○	○	●	●	○	●	○	○
Shen 1975	○	●	●	●	●	●	●	○	○	○	○	○	○
Gabel 1977	●	○	●	●	●	●	●	○	●	○	○	○	○
Miller 1983	●	●	●	●	○	○	○	○	●	○	○	○	○
Arons 1983	●	●	●	●	○	●	●	●	●	●	●	○	○
AAAS (Collins) 1989	●	●	○	●	○	●	●	○	●	○	○	●	○
SFAA (Rutherford *et al*) 1990	●	**I**	●	●	●	●	●	●	●	○	○	○	●
Shamos's "true" 1995	●	●	●	●	●	●	●	○	●	○	○	○	●
NRC 1996	●	●	●	●	●	●	●	●	●	●	○	●	●
SCCC 1996	**I**	○	●	●	●	●	●	○	●	●	○	●	○
Bryce 1996	**I**	○	●	●	●	●	●	●	●	○	○	●	○
Bybee 1997	○	●	●	●	●	●	●	●	●	○	○	○	○
Hurd 1998	●	●	●	●	●	●	○	●	●	○	○	○	○
Millar and Osborne 1998	**I**	●	●	●	●	●	●	●	●	●	○	●	●
OECD (PISA) 2006	●	●	●	●	●	●	●	○	○	○	○	○	○

Notes:
The symbols in Table 2.1 signify the following: ○ not referred to in study as an element of Scientific Literacy, ● referred to in the study as an element of Scientific Literacy, **I** means the element is implied but not stated.

The thirteen elements of scientific literacy shown in Table 2.1 can be described as follows:

1. **Intellectual Independence:** includes the capability of a student to find out information and make personal decisions about an issue involving science, being able to evaluate 'expert' advice, and the ability to continue to learn science after formal schooling ends.
2. **Science Communication:** the ability of the student to both interpret science and communicate through reading, listening and viewing as well as to encode such communications through writing, speaking and drawing either to non-scientists or science specialists.
3. **Science and Society:** includes the student's ability to understand the relationship between science and society, civic democracy, culture, national security and economics, as well as some understanding about how science is controlled/ influenced by society.
4. **Conceptual Knowledge:** refers to knowledge in terms of pertinent facts and conceptual understanding emerging from various science disciplines. In a broad sense holding some knowledge about an array of science disciplines, not just one or two.
5. **Science and Technology:** refers to the inter-relationship between the two enterprises.
6. **Science in everyday life:** this implies normal encounters with science or its products, including those which help people become more economically productive. It also includes statements such as 'understand the modern world'.
7. **Science appreciation:** includes a number of things such as support of basic and applied science, appreciation of science as a way of knowing and as a significant human endeavour and intellectual stimulus/satisfaction derived from using science to answer questions posed by oneself or others.
8. **Ethics of Science:** includes knowing and applying the values of science, such as objectivity and logic as well as the 'moral' and 'civic' responsibilities of science and scientists.
9. **Nature of Science:** includes understanding such things as hypothesis testing (variables and controls), the reliance on testable evidence to make

decisions, the tentative nature of scientific findings and the self-corrective nature of the scientific endeavour.

10. **History of science:** means a familiarity with the accomplishments of science and scientists, but not necessarily a deep or detailed knowledge of science history.
11. **Science in the humanities:** refers to the relationship of science to other disciplines in the curriculum, and the mutual influence that science and other disciplines might have had on one another.
12. **Science Skills:** means actually being able to do science, as opposed to just recognising or knowing about it. It sometimes implies being able to think like a scientist.
13. **Science and mathematics:** is made explicit in SFAA, whereas it had been assumed in earlier conceptions of scientific literacy (Agin, 1974; Arons, 1983; Bryce, 1996; Bybee, 1997; Carleton, 1963; Collins, 1989; Conant, 1952; Gabel, 1977; Hurd, 1958; Hurd, 1998; Koelsche & Morgan, 1964; McCurdy, 1958; Millar et al., 1998; Miller, 1983; National Research Council, 1996; National Science Teacher Association, 1971; OECD, 2006; Pella, O'Hearn, & Gale, 1966; Rockefeller Brothers Fund, 1958; Rutherford et al., 1990; SCCC, 1996; Shamos, 1995; Shen, 1975).

A quick glance across Table 2.1 shows that different commentators place different emphases on particular elements of scientific literacy. The characteristics can be ranked according to frequency of times mentioned in these studies. This ranking is shown in Table 2.2

Table 2.2: *Rank order of characteristic elements of scientific literacy as derived from Table 2.1*

Characteristic Element of Scientific Literacy	Rank Order	% Frequency
Conceptual Knowledge	1	100
Science and Society	2	88
Science and technology	3	71
Science in everyday life	3	71
Science Communication	4	67
Science Appreciation	4	67
Nature of Science	4	67
Intellectual Independence	5	63
Ethics of Science	6	42
History of Science	7	21
Science skills	7	21
Science in the Humanities	8	17
Science and Mathematics	8	17

Of the 24 papers reviewed in Table 2.1 the major characteristic of scientific literacy to emerge is conceptual knowledge as all the papers see this element as important. However, somewhat surprisingly, intellectual independence ranks fifth with a frequency of 63% and ethics of science ranks sixth with a frequency of 42%. So does the literature suggest that the teaching of ethics in science is less important? Or that teaching for intellectual independence is less important than conceptual knowledge? This is probably not so since the literature surveyed in Table 2.1 fleshes out the conceptual underpinning over a historical time frame. However, the relative ranking of the ethics of science element is echoed by the debate among science educators, particularly within the UK, as to whether ethics should be taught within the science curriculum.

> The view that science can be the source of ethical and moral values is rather like the character in a Punch and Judy show who pops up perkily from time to time and is soundly dispatched with a good drubbing, only to reappear with unabated confidence in subsequent acts. Epistemological imperialism (if you'll pardon the term) may be one reason for this persistence; that is, the tendency of subjects to claim credence and authority in domains outside their legitimate territory (Hall, 2004).

Hall does acknowledge that scientific knowledge does create problems which have a social dimension and that the present education system fails to provide teachers and pupils with the required skills to deal with such problems.

It is important to note from the analysis in Table 2.2 that science skills or the ability to do science is seen as relatively unimportant as it ranked joint 7th overall along with the history of science with 21% of the papers mentioning this element of scientific literacy. This implies that it is possible to be scientifically literate without necessarily being able to do science professionally.

The need to identify the characteristic elements of scientific literacy and to assess the relative merits of each, raises questions about levels or degrees of scientific literacy, since within any mixed ability class there will always be pupils who are cognitively more able to attain good grades. So would it follow that some pupils will be able to reach a higher level of scientific literacy? If so what would that level be and what determinants would specify such a level?

This thinking echoes the sub-division of scientific literacy into broad categories by Benjamin Shen (1975) where he suggested that scientific literacy could be categorised by (i) *practical science literacy* as possession of the kind of scientific knowledge that can be used to help solve problems (p.46). (ii) *Civic science literacy* as to enable the citizen to become more aware of science and science-related issues so that he/she and his/her representatives would bring common sense to bear on issues, and as a result participate more fully in the democratic process of an increasingly technological society. (iii) *Cultural science literacy*, to enable the citizen to become more motivated by a desire to know something about science as a major human achievement (Shen, 1975).

For Douglas Roberts, Shen's three categories of science literacy represent qualitatively different types of scientific literacy which are not intrinsically hierarchical (Roberts, 2007). However, Shamos (1995) and Bybee (1997) discuss types and levels of scientific literacy for learners as they advance through a curriculum.

In his book '*The myth of scientific literacy'*, Morris Shamos proposed that different amounts of science are required to achieve Shen's three types of scientific literacy, thereby converting them into levels in a hierarchy.

Shamos suggests that;

1. *Cultural scientific literacy* is the simplest form of literacy by which he means a grasp of certain background information that communicators must assume their audience must already have (Shamos 1995, p.87-88).
2. *Functional scientific literacy* is where the citizen has both a command of the lexicon of science and is able to read, write and converse coherently using such scientific terms in perhaps a non-technical but nevertheless meaningful context (Shamos 1995, p.88-89).
3. *True scientific literacy* being the level the individual actually knows something about the overall scientific enterprise… the major conceptual schemes of science, how they were arrived at, and why they are widely accepted, how science achieves order out of a random universe, and the role of experiment in science. This individual also appreciates the elements of scientific investigation, the importance of proper questioning, of analytical and deductive reasoning, of logical thought processes, and the reliance upon objective evidence (Shamos 1995, p.89-90).

For Shamos, true scientific literacy is a demanding objective asserting that "the term scientific literacy itself has been too loosely defined in the past and that, when viewed realistically, true scientific literacy as defined here, is unlikely to be achieved in the foreseeable future" (p.90). Shamos goes on to say that the number of individuals within the US and UK who are truly scientifically literate is approximately 7%, which is roughly the number of professional scientists and engineers in each country. By setting the bar for true scientific literacy so high, Shamos is suggesting that it is unattainable by ordinary citizens and that any attempt on the part of the scientific education community to achieve scientific literacy for all is futile and ultimately a waste of time, energy and resources. His attempt to sequester true scientific literacy as an appropriate educational goal for science-orientated students is unfortunate.

Later in his book he goes on to offer three guiding principles for presenting science to the general student (p.217) where he proposes that teachers should:

- Teach science mainly to develop appreciation and awareness of the enterprise, that is, as a cultural imperative and not primarily for content…
- Focus on technology as a practical imperative for the individual's personal health and safety, and on an awareness of both the natural and manmade environments…
- For the development of social (civic) literacy, emphasize the proper use of scientific experts, an emerging field that has not yet penetrated the science curriculum.

These three principles bare a remarkable similarity to Shen's three categories of practical, civic and cultural scientific literacy. The last of Shamos's principles suggests that the general public would be better served by listening to the appropriate experts in the field rather than being educated to come to an independent judgement of socio-scientific issues (Shamos, 1995). If these principles were to be followed, particularly the third, this would mean that the general public would have to rely on expert advice when making decisions in relation to issues of a scientific nature, a situation which in the UK context would be difficult, since over the last sixty years the relationship between science and society has shifted from a position of trust to one of scepticism (Hodson, 2003).

In today's climate, scientific activity is expensive and funding for research is becoming increasingly commercially driven or government led (Ravetz, 1995). Consequently questions have been raised as to the impartiality of the knowledge claims made by such research. In addition, evidence suggests that there is a lack of public confidence in scientists as effective problem-solvers, particularly those providing advice to the Government. The House of Lords Select Committee on

Science and Technology, in their Third Report, commented on a perceived 'crisis of trust':

> Society's relationship with science is in a critical phase . . . On the one hand, there has never been a time when the issues involving science were more exciting, the public more interested, or the opportunities more apparent. On the other hand, public confidence in scientific advice to Government has been rocked by a series of events, culminating in the BSE [Bovine Spongiform Encephalopathy] fiasco; and many people are deeply uneasy about the huge opportunities presented by areas of science including biotechnology and information technology, which seem to be advancing far ahead of their awareness and assent. In turn, public unease, mistrust and occasional outright hostility are breeding a climate of deep anxiety among scientists themselves (House of Lords Select committee, 2000).

This lack of public confidence in science would make the working out of Shomos's third principle extremely difficult, particularly in the current climate of distrust. Partly in response to Shamos, Rodger Bybee presents his framework for scientific and technological literacy as a continuum in which the individual will develop a greater and increasingly more sophisticated understanding of science and technology (Bybee, 1997). Bybee presents a four level framework where individuals move through the levels over a lifetime. The framework levels are;

1. *Nominal literacy:* the individual associates names with a general area of science and technology. However, the association may represent a misconception, naïve theory, or inaccurate concept. Using the basic definition of the nominal relationship between science and technology terms and acceptable definitions is small and insignificant. At best students demonstrate only a token understanding of scientific concepts, one that bears little or no relationship to real understanding (p.84).

2. *Functional Literacy:* individuals demonstrate a functional level of literacy, respond adequately and appropriately to vocabulary… they can read and write passages with simple scientific vocabulary… They may also associate

vocabulary with larger conceptual schemes… but have a token understanding of these associations (p.84-85).

3. *Conceptual and Procedural Literacy:* occurs when individuals demonstrate an understanding of both the part and the whole of science and technology as disciplines… At this level individuals understand the structure of disciplines and the procedures for developing new knowledge and techniques (p.85).

4. *Multidimensional Literacy:* consists of understanding the essential conceptual structures of science and technology as well as the features that make that understanding more complete, for example, the history and nature of science. In addition, individuals at this level understand the relationship of disciplines to the whole of science and technology and to society (p.85).

Bybee, unlike Shamos, does not distinguish between scientific literacy for science-bound students and non-science-bound students. Indeed, Bybee's framework and his entire discussion is about making scientific literacy for all students attainable even although he admits that "no one could possibly achieve full scientific and technological literacy" (p.85). He further suggests that "Some will develop further than others at all levels or within one, depending on their motivation, interests and experiences… Cognitive development varies, and an individual may be at different places within the framework at any time and for any given topic". Bybee sees the development of scientific literacy as a continuum of understanding about the natural and designed world, from nominal to functional, conceptual and procedural to multidimensional, and as such provides direction to those responsible for curriculum, assessment, research, professional development and teaching science to a broad range of students.

The idea which emanates from the *CfE* science rationale of developing scientific literate citizens, able to hold and defend informed views on social, moral, ethical, economic and environmental issues related to science is a bold statement of intent, and sets a tall order for the science education community in Scotland to achieve. This is particularly stark when one considers the fact that international research (Miller, 1998; Miller, Pardo, & Niwa, 1997; National Science Board, 2008) suggests that most efforts to develop significant levels of scientific literacy over the last twenty years have been disappointing at best. This bleak assessment of what can be achieved in terms of developing scientific literacy requires Scottish science teachers to reconceptualise what we mean when we say that we are to develop scientific literacy. Are we aiming to develop within our students multidimensional scientific literacy? Or are we aiming to instil a functional scientific literacy?

Furthermore, the functional scientific literacy described by Bybee differs from that described by other science educators, particularly that of Jim Ryder who suggests that functional scientific literacy has to do with the scientific knowledge required by individuals to enable them to function effectively in specific settings (Ryder, 2001). In his analysis of 31 published case studies of individuals not professionally involved with science but who interact either with scientific knowledge and/or scientific professionals, Ryder categorised six areas of scientific understanding that are required: subject matter knowledge; collecting and evaluating data; interpreting data; modelling in science; uncertainty in science; and science communication in the public domain as key components of functional scientific literacy. He further suggests that although an understanding of subject knowledge is necessary for individuals to engage in the many varied discussions which contain a high level of scientific understanding, overall, much of the science knowledge relevant to individuals in the case studies related to knowledge *about* science i.e. knowledge about the development and use of scientific knowledge rather than the scientific knowledge itself. This suggests that, in order to be a functional scientifically literate person, one must appreciate how the scientific knowledge is produced (nature of scientific investigation and its limitations) and used both in terms of the scientific and political arena as well as the social context.

The question of what level or type of scientific literacy we are developing needs to be answered prior to the implementation of the new Scottish science curriculum if consistent results are to be achieved nationally. These questions have not been addressed at all by the review group in charge of the development of the new science curriculum. In fact the draft learning outcomes only add further confusion to the situation. They neither inform teachers' thinking on what the curriculum planners conceptualisation of scientific literacy is, nor do they hint at which pedagogies would be most appropriate to use when developing students' scientific literacy. The situation has not changed with the publication of the final experiences and outcomes of the new science curriculum in April 2009.

The one thing that is apparent from both the draft learning outcomes and the final experiences and outcomes is that the curriculum planners see scientific literacy from a system point of view. This suggests that their justification for arguing for increased scientific literacy is policy-centred rather than student-centred. They justify the goal of developing scientific literacy from an all-inclusive collection of economic, utilitarian, citizenship and cultural literacy arguments. In this way the new science curriculum can incorporate many possibilities that accommodate all students regardless of their ability, interest, or future plans for their careers. However, it does not necessarily provide every student with the same exposure to scientific literacy (not when compared to a compulsory scientific literacy-orientated course).

In one sense this permits scientific literacy to permeate throughout the whole science curriculum, allowing for a rich and comprehensive policy which accommodates variation in the degree of development of scientific literacy by students with differing abilities, motivation and future plans. In another sense, one wonders if the curriculum planners know what they intend to achieve. If they do, why have they not set forth their vision? Why have they not discussed the issues with science teachers or their professional associations? Since they have failed to articulate what they envisage scientific literacy to be or how best to develop scientific literacy within students, there is a lack of direction from the centre which is a potential weakness in the new curriculum. Different groups of science teachers will be left to interpret what all of these interpretations mean in terms of practice. It is difficult to avoid the conclusion that this will lead to inconsistency of practice nationally and possibly even a failure to achieve the stated aim of scientific literacy.

In an attempt to answer the question of how science teachers might begin to develop scientific literacy within their classroom setting, the following sections explore the literature on discussion as a suitable pedagogical approach to use for the development of skills required to engage in the discourse of making democratic decisions at the interface between science and society. The argument will link the use of discussion of socio-scientific issues to the development of scientific literacy.

2.5: Summary.

Scientific literacy is a multifaceted, complex and difficult concept to define. It has become associated with reform of the science curriculum over the last fifty years and has become a "yard stick" by which most modern science curricula are assessed. So much so, that many of the current educational reforms proposed to science curricula place scientific literacy as a major aim of the secondary school science curriculum. Indeed, the Scottish Science Curriculum through *CfE* has been re-oriented to incorporate scientific literacy as its main aim. Achievement of adequate levels of scientific literacy by school students is justified on the grounds that increasingly we live in a society which is reliant on science and technology and that a clear understanding of how they influence our daily life is necessary for citizens to be able to make decisions based on issues which emanate from contemporary science and technology.

However, some commentators suggest that this drive to increase scientific literacy within the general population is futile, and a waste of taxpayers' money (Shamos, 1995). Others disagree, arguing that the new knowledge emerging from science can affect everyone at some point in their life and, as such, citizens need to be equipped to make informed decisions and hold reasoned opinions on how science operates in order for proper democratic decisions about such things as therapeutic cloning, genetically modified organisms and climate change (Bybee, 1997; Kolsto, 2001; Kolsto et al., 2006; Levinson, 2003; Marshall et al., 2003; Ratcliffe, 1997; Ratcliffe & Grace, 2003; Ravetz, 1995; Sadler, 2004b; Sadler, Zeidler, Simmons, & Howes, 2005c; Zeidler et al., 2003).

The reform of the Scottish Science curriculum under the auspices of *CfE* fail to outline what type or level of scientific literacy Scottish students are expected to attain by the time they leave compulsory science education. In addition, key decisions as to which pedagogical approaches are appropriate for the development of scientific literacy have not been discussed widely with teachers. The answers to these questions need to be found if the proposed reforms are successfully to achieve the aim of increasing scientific literacy.

2.6: Discussion as Pedagogy.

2.6.1. Introduction.

In this section of the review, the main points of the debate as to what constitutes discussion as a pedagogical approach will be explored. Why the ability to discuss is thought to be of primary importance to the education of children within a democracy and the key features which distinguish discussion from lecture and recitation lessons will be emphasised.

2.6.2: The importance of Discussion.

The importance of discussion was outlined by J.J Schwab in 1954 when he set forth his belief that classroom discussion was imperative for the development of the student's "intellectual arts", these being thinking and communication;

> In a curriculum concerned primarily with specific understandings of objects, discussion as a device of instruction may be defended as a particularly powerful teaching instrument… but it cannot be maintained that for a curriculum so orientated discussion is indispensable. It is merely one of several usable techniques. In a curriculum, however, which aims to impart intellectual arts, skills, habits and attitudes, as well as a body of information, discussion is not simply efficient or powerful but is indispensable. Discussion is an engagement in and a practice of the activities of thought and communication (Schwab, 1954).

Larson (2000) claims that the majority of classroom talk is synonymous with a recitation-style (Larson, 2000) but significant social and cognitive changes have been reported when classroom talk shifts towards adult "conversations" (Cazden, 1988). Recitation, the act of reciting text such as poetry is a form of performance that requires the individual to repeat a passage from memory. This differs from the pedagogical approach of recitation in that recitation as pedagogy is an act through which the teacher *initiate*s an interaction with pupils by asking a question; listens to the pupils' *response*; and then *evaluates* a pupil's response by providing that pupil with feedback. This approach is commonly termed Initiation, Response, Evaluation (IRE) or Initiation, Response, Feedback (IRF) and is particularly used as a method for the review of content covered either at the end of a lesson or from a previous lesson. However, recitation is a teacher dominated discourse that provides little scope for the pupil to challenge the teacher's evaluation of his/her response. In general terms, recitation is used to control the pace of a lesson, where the pupil engages in a game of *guess what the teacher is thinking* since the teacher generally is often looking for one correct response to any question.

Discussion differs from recitation in a variety of ways which shall be discussed later. However, for discussion to educate students there needs to be serious interactions where students support their ideas with evidence, where their opinions are subject to challenge by their peers and by the teacher, and where the teacher's ideas are equally open to criticism (Engle & Ochoa, 1988). It has been suggested that discussion contributes to a student's understanding of a topic by increasing each student's knowledge base on a topic with information gathered from their peers; it allows different perspectives on a topic to emerge; provides opportunities for students to criticise, accept, or reject alternative points of view; and can encourage mutual modifications among students' opinions to hopefully produce a consensus (Brookfield & Preskill, 2005).

Group interaction is crucial for discussion as it shapes and directs the exploration of a topic (Bridges, 1987). It can be argued that if you teach students how to discuss, the benefits of using discussion in the classroom can be extended to all areas of students' lives. However, research on how teachers 'teach discussion' is limited. Most of the available research is related to citizenship education because discussion provides one way for citizens to interact.

The classroom teacher plays a pivotal role in determining what, and how, curriculum content is delivered. Thus, examining teacher thinking about discussion is important because of the diverse types of classroom interactions that teachers label as discussion (Cazden, 1988; Dillon, 1990; Dillon, 1984). However, teachers often find themselves using the term discussion as an umbrella term which covers a multitude of classroom activities which involve interactive oral communication. In general, teachers rarely if ever stop to think what it is that they mean when they use the term. Is discussion talk between individuals or groups of individuals, back and forth? Or, is the term discussion more specific than that?

Teachers, like others, use the term as a rubric covering all manner of communicative interactions. It embraces exchange with other terms such as conversation, argument, debate, dialogue and recitation. This usage may also stretch to include interview and negotiation (Dillon, 1994).

Dillon (1994) describes discussion and its application in the following manner:

> In a discussion people talk back-and forth with one another. What they talk about is an issue, some topic that is in question for them. Their talk consists of advancing and examining different proposals over an issue. The proposal may be various understandings, facts, suggestions, opinions, perspectives, experiences and the like. These are examined for their contribution towards resolving the issue (p.7).

However, David Bridges describes the term as follows:

> Discussion is a word applied to an activity involving a number of people (e.g. in group talk) or a single person (in a disquisition upon a subject). It is also applied to a product such as a scholarly article or a newspaper editorial (Bridges, 1979).

A major problem with pinning down a working definition of discussion is the multiplicity of perspectives and views which teachers and philosophers have concerning the distinction between what constitutes a discussion, a dialogue or a conversation. The philosopher Matthew Lipman argues that conversation seeks equilibrium, with each person in turn taking opportunities to speak and then listen but where little or no movement occurs (Lipman, 1991). He claims that conversation is an exchange of thoughts and feeling in which genial cooperation prevails, whereas dialogue aims at disequilibrium in which each argument leads to a counterargument which pushes itself beyond the other and pushes the other beyond itself (Lipman, 1991). Thus for Lipman, dialogue is an inquiry in which the participants see themselves as collaborators intent on expeditiously solving a problem or issue which they face. The educational philosopher Nicholas Burbules suggests that conversation is more informal and less structured than dialogue and that dialogue focuses more on inquiry and increasing understanding and tends to lead participants to be more exploratory and questioning than does conversation (Burbules, 1993).

David Bridges (1979) suggests that discussion is different from conversation and other forms of group talk by its concern with the development of knowledge, understanding or judgment among those taking part (p.17). Bridges believes that discussion is more serious than conversation in that it requires the participants to be both “mutually responsive” to different points of view expressed and to be disposed to be “affected by the opinions one way or another in so far as they merit acceptance or approval” (p.15).

However, Richard Rorty believes that philosophy itself is a stimulus to a great and continuing conversation. For Rorty, keeping the conversation going is the most important thing. He remarked that ‘as long as the conversation lasts there is hope for agreement or at least, exciting and fruitful disagreement’ (Rorty, 1979). He sees bringing people together in conversation and challenging them to use their imaginations to create new meanings and to move towards greater human inclusiveness as a moral endeavour. For Rorty, conversation extends our sense of “we” to people whom we previously thought of as “they” (p.192) and provides a forum for acting on our obligation to achieve solidarity with others. Thus in effect Rorty is linking conversation in many ways to a democratic ideal which Bridges (1979) does for discussion when he asserts that;

> Discussion has been regarded in a long tradition of political writing as a central characteristic and valued procedure in democratic government… In more contemporary literature, the centrality of discussion to democratic decision-making was reiterated by Mills in *Representative government* and again by John Dewey (p.150).

Dewey wrote ‘the democratic method is persuasion through public discussion carried on not only in legislative halls but in the press, private conversations and public assemblies’ (Dewey, 1940b). Whereas Bridges (1979, p.151) quoting Benn and Peters (1959) account of democracy suggests that;

> Democracy has been called ‘government by discussion’. In a sense this is of course true of all government; for the most authoritarian of governments must have its committees to pool experience and coordinate departmental policies. But it is true of democracy in the special sense that the whole process presumes that give and take of criticism and justification, conducted within the framework of moral criteria. Freedom of discussion is thus not merely a safeguard against the abuse of authority in a democracy, but a condition for democracy itself (Benn & Peters, 1959).

The English philosopher Michael Oakeshott characterised group talk as an “unrehearsed” intellectual adventure in which as many participants as possible are invited to speak and acknowledge one another. Despite the inevitable and irreconcilable differences between them, the act of conversation allows them to emerge from the experience broadened and enriched (Oakeshott, 1962). For Oakeshott, participation in conversation is a distinctively human activity. Becoming skillful at this involves us in discerning how each voice reflects a different set of human interests.

It is easy to see from these few examples that it is not easy to define accurately what constitutes discussion; therefore one way of arriving at a workable definition may be to distinguish what it is not. As stated earlier, Larson (2000) has suggested that the predominant classroom discourse is recitation and this was independently corroborated by Alvermann *et al* (1990) who showed that the majority of discussions that they observed in classrooms were in fact recitation. Dillon (1994) suggests that one can observe the difference between recitation and discussion by looking at the characteristics of the talk, the perceptions of the participants and the concept of discussion.

2.6.3 Characteristics of Discussion as opposed to Recitation.

Firstly, when one looks at the characteristics of the talk, one can summarise the differences by looking at seven characteristics: the predominant speaker; the typical type of exchange; the predictable sequence of events; the overall pace of events; the questions asked; the answers given; and the evaluation of these exchanges. All these characteristics are drawn together in a comparison between recitation and discussion in Table 2.3

Table 2.3 *Comparison between the characteristics of Recitation versus Discussion*

Characteristics	Recitation	Discussion
1.Predominant speaker	Teacher two-thirds or more	Students half or more
2.Typical exchange	**Question & Answer** 1.Teacher question 2.Student answer 3.Teacher evaluation (plus next question)	**Not question & answer** A mixture of statements and questions by a mixture of teacher and students.
3. Predictable sequence	Teacher-student	A mixture of teacher-student, student teacher, student-student
4. Overall pace	Many, brief, fast exchanges (could be slower)	Fewer, longer, slower exchanges (could not be faster).
5. The question	Not the question itself as asked, but students showing knowledge of answer	The question itself as asked, and the student gaining or using knowledge about the matter in question.
6. The answer	1. Predetermined right/wrong 2. Same right answer for all students	1. Indeterminate, determinable, determined and not (but not predetermined). 2. Could be different answer for different students.
7. The evaluation	1. Right/wrong 2. By teacher only	1. Agree/disagree 2. By students and by teacher, also by student of teacher.

(This table is adapted from Dillon (1994, p.17)

The use of these seven characteristics of talk as observation criteria can give researchers a framework for observation of discussion in order to assess more accurately whether the lessons they observe are truly discussions. They also allow teachers a way to reflect on their teaching using discussion to allow for better self-evaluation in order that they can modify their approach to incorporate more discussion. Secondly, the perceptions of participants involved in a class can help us discriminate whether a lesson is a discussion or recitation. How do the participants see it? A first task is to ask the teacher what their purpose for the lesson might be i.e. was the lesson planned as a discussion? When teaching the lesson, was it their intention to conduct a discussion? Such questions could be put prior to the lesson. Following the lesson, one could check with the teacher what their intentions were during the actual process as it progressed. A second task would be to ask the students what they thought, since the teacher may well have intended a discussion but the students might not have perceived the lesson as such. This could be done by questionnaire or by interview.

Thirdly, the concepts involved in discussion are the most important but least observable features of discussion. These concepts are to-all-intents-and-purposes abstract ideas, notions and definitions, unlike the characteristics of talk which are observable and the perceptions of the participants which can be sought. The concepts of discussion can be inferred (and subsequently analysed) from interview transcripts in order to discover how these conceptions apply to the classroom situation. Understanding Science teachers' thinking about discussion in particular is required if we can assume that, as with all teachers, their thoughts underlie their classroom action (Clark & Peterson, 1986). However complex and articulated teachers' conceptions of discussion might be, one must bear in mind that they may not necessarily translate into proficient use in the classroom (Parker & Hess, 2001). Nevertheless, if discussion is to be used to help develop students' skills base in conjunction with knowledge and to help students learn how to go about the process of discussing, then teachers are a crucial variable in creating a relevant context. If teachers only think of discussion as a recitative interaction between teacher and student, then recommendations for using it are likely to fail. There is a need for additional insights into the uses of discussion in the classroom.

2.6.4 The educational purpose of discussion

Recent Scottish research into science teachers' thinking on discussion within secondary school science has highlighted that practising science teachers were uncomfortable with discussion and tend to shy away from using it with socio-scientific issues as much as possible. This was in part, due to a lack of confidence with handling discussion and a lack of clarity as to the purpose of such discussion in the research carried out by Bryce & Gray (2004).

Such research leads to the questions: *How can science teachers engage more with discussion in their classrooms? Which models of discussion can they use in order to become more comfortable when leading discussion?* Before science teachers will risk engaging in more open forms of discussion within their classes, they need to be convinced that discussion is of value in terms of measurable outcomes, and that there are clear aims for its use. In addition, they require a working model of discussion with which to apply to their practice.

It is fair to suggest that most pedagogical approaches have clear goals either in terms of student attainment and achievement or student behaviour and attitude. In that respect, discussion is no different. However, questions about the effectiveness and efficiency of discussion with respect to other pedagogical approaches remain the focus of many teachers.

2.6.5 Educational and Psychological Research on Discussion.

According to Bligh (2000), there have been many educational and psychological studies into the effectiveness, efficacy and efficiency of discussion but these studies are mostly old with only a few recent studies. However, what the research does show is that discussion methods can achieve several objectives at the same time and as such this is a major advantage for their use. A number of studies have shown that group discussion is more effective than individual learning in terms of retention of information and the pace of learning (Bligh, 2000; Smith, Johnson, & Johnson, 1982; Yuker, 1955). For example, Smith *et al* (1982) compared discussion and individual learning and found that discussion not only resulted in better retention of information and higher levels of achievement among a range of ability groups, but also resulted in greater motivation to learning and enhanced self-esteem. In addition, Yuker (1955) showed that recall scores for those who learned in groups were better on average (38 out of 40) than those of individual learners (29 out of 40). These studies are supported by psychological research which suggests that learning in groups (G) is better than learning individually (I) in other words, G then I and that students who previously learned individually then in groups (I then G) perform equally as well as those who first learned in groups (Perlmutter & De Montmollin, 1952). In a classic experiment using a series of mazes, Gurnee (1937) found that groups made fewer errors and worked quicker (Gurnee, 1937; Gurnee, 1939). What these studies suggest is that, if this is generally true for group discussion, then group discussion could be useful in an educational context and by extension could be true in the case of discussion within science. A series of questions arise from this research such as: What if the superiority of groups is an additive effect rather than indicating that individuals learn better in groups and that faster learning could be the result of practice rather than anything to do with group interactions? What if these effects are the result of pooled knowledge rather than superior learning?

A later experiment by Perlmutter implies that a group product is partly due to additive effects and partly a result of interaction (Perlmutter, 1953). Perlmutter observed that the style of the group's product (recall of a story) was not obviously related to the product of the individuals who made up the group; while some of what was recalled seemed to be the product of the groups, but also bore characteristics of the individuals who made up the group. Psychological research evidence suggests that discussion can help people recall information when they want it for other purposes such as problem-solving and decision-making (Adams, 1985; McDaniel, 1986; van Dam, Brinkerink-Carlier, & Kok, 1985; Zimmer, 1985). If so, discussion may be useful when teachers have more than one type of objective for their lesson. These studies indicate that, in terms of recall, acquisition of thinking skills and 'democratic' habits such as listening and communication, discussion is an effective approach.

To gain some insights into how such discussions can be useful in science, it is first necessary to explore the research literature surrounding the discussion of controversial socio-scientific issues in order to place such discussions within the context of developing scientific literacy.

2.7: Summary.

Discussion is used by most teachers as an umbrella term to describe a multitude of types of oral discourse including dialogue, debate, conversation and argumentation. However, discussion in the pedagogical sense being developed here is concerned with solving a problem; it has purpose and is not aimless like conversation. Discussion is persuasive and involves participants in being open to different perspectives and willing to accommodate or assimilate ideas as they are presented. Therefore, discussion is far more than simply conversation.

Discussion has been described as an essential element of a curriculum which seeks to develop "intellectual" habits, attitudes and thinking skills as well as a means of delivering information (Schwab, 1954). However, while discussion is effective at developing such intellectual arts, it is not as efficient as other methods. Furthermore, teachers' conceptual models of discussion have been shown to differ both qualitatively and in terms of how discussion is enacted within their classrooms (Alvermann, O'Brien, & Dillon, 1990). While it is possible to distinguish discussion from other modes of delivery such as recitation and lecture, teachers find it difficult to enact within their practice (Parker et al., 2001). Thus, for discussion to work as a pedagogical approach, teachers need to develop their practice carefully against a model in order to evaluate whether they are practising discussion or enacting a form of recitation. Dillon (1994) sets out a useful method for teachers to use in evaluating their teaching with discussion which involves observation of lessons, professional reflection and questioning of students.

When asked about using discussion in science, teachers described an element of discomfort, citing a lack of confidence in handling discussion and a lack of clarity as to the purpose of such discussions (Bryce and Gray, 2004). This discomfort was in part due to the nature of the issues being discussed i.e. teachers' knowledge of the facts pertinent to the issues concerned and in the main due to a lack of evident purpose for such discussion as directed by current syllabus documentation.

2.8: Discussion of Socio-scientific Issues in the Science Classroom.

2.8.1 Introduction.

Over the last twenty years, the general public has been confronted by a steady stream of socio-scientific controversies particularly in relation to medical science and environmental issues. There has been a steady increase in media interest in such issues as embryonic stem cell research, the genetic modification of crops, climate change and global warming, and nuclear energy, to name but a few.

The ability of individual members of the public to critically examine and make thoughtful decisions regarding socio-scientific issues is recognised as a major goal for science education (OECD, 2001; Rutherford et al., 1990). Science education is in a unique position to help people develop skills which would enable them to respond critically to media reports on issues with a science dimension. Indeed, a number of reform documents see this as a major goal of science education (Millar et al., 1998; National Research Council, 1996; Rutherford et al., 1990; Scottish Executive Education Department, 2006). Socio-scientific issues have come to represent important social issues and problems which are conceptually related to science. While scientific knowledge and inquiry practices can be useful for the negotiation of controversial socio-scientific issues, scientific practices alone cannot provide solutions.

Several science educators have argued for the inclusion of discussion of socio-scientific issues in the school science curriculum (Bryce et al., 2004; Gray & Bryce, 2006; Kolsto, 2001; Levinson & Turner, 2001; Millar et al., 1998; Zeidler et al., 2003). Moreover, their efforts to persuade curriculum planners to include such issues in the curriculum are not new. The science, technology and society (STS) movement had sought to educate students about the interdependence of these three domains (Aikenhead, 2006). However, the STS movement has become diffuse over time and has had virtually no impact at all in Scotland. Furthermore, it is confined to disparate courses focused on particular STS issues, pedagogical approaches which highlight the links between science and society, and ancillary text boxes in various science textbooks (Pedretti & Hodson, 1995)

In this section of the literature review, a working definition of what constitutes a controversial socio-scientific issue based on the research literature is outlined and the case made for using discussion of socio-scientific issues as a central strategy for the development of scientific literacy.

2.8.2 What constitutes a controversial socio-scientific issue?

The Science rationale of *CfE* states that the aim of the new science curriculum is to enable young people to develop as scientifically literate citizens, able to hold and defend informed views on social, moral, ethical, economic and environmental issues related to science. These issues which emanate from contemporary science are collectively called socio-scientific issues, which may or may not be controversial.

A controversial socio-scientific issue can be described as an issue which has a scientific element; an impact on the general public, locally, nationally or globally; is an issue where the information required to formulate a rational judgment on a personal or societal level is complex, arising from multiple sources and where the facts are often inconclusive, contentious and at times contradictory. In addition, judgment on these issues requires balancing a number of moral, ethical, social and quality of life concerns about which different people have widely varying values and feelings. They may also require some kind of cost-benefit analysis in which risks interact with values. Furthermore, they might involve an understanding of probability and risk and they tend to persist over time (Fleming, 1986; Kolsto, 2001; Levinson, 2003; Ratcliffe et al., 2003; Sadler & Zeidler, 2004; Sadler & Zeidler, 2005a).

By definition, socio-scientific issues are complex, open-ended and potentially contentious problems which lack a simple or straightforward solution. Such controversies can exist over long periods of time and deeply divide diverse groups of people. Often such issues involve complicated lines of evidence and counter-evidence, of claim and counter-claim. Disagreements over controversial socio-scientific issues are possible as these issues tend to encompass large quantities of information and/or putative facts which may be independently contentious.

The difficulty with socio-scientific issues tends to be how one weighs up inconclusive and ambiguous evidence in the context of a variety of political, economic, social, moral and ethical considerations. It can be argued that portraying such evidence as contestable within a given context goes against societal and educational expectations of science as a source of neutral, objective and universal knowledge. This questions whether it is society's and thus education's expectation and understanding of science which should be challenged. The new knowledge derived from contemporary science drives calls for reform and modernisation of school science curricula within Scotland, the United Kingdom and elsewhere.

Despite the complexity of such issues, the discussion of controversial socio-scientific issues within the science classroom can help to bridge the relevance gap that typically exists between the traditional science curriculum and real life science. Furthermore, it can contribute to producing scientifically literate citizens by explicitly teaching pupils contemporary science content and allowing them to experience and practise the critical thinking skills required.

2.8.3 Discussion of Controversial Socio-scientific issues and the Development of Scientific Literacy.

When one looks at the literature on the use of discussion as a pedagogical approach in other curricular areas, particularly within the Humanities, it is clear that when properly applied, it is capable of developing transferable skills such as interpersonal and social skills which include the ability to listen and take turns talking; communication skills; critical thinking skills; the ability to deal with multiple perspectives as well as teaching students the importance of disagreement and compromise in the resolution of potentially controversial issues (Bridges, 1979; Bridges, 1987; Brookfield et al., 2005; Dillon, 1990; Dillon, 1994; Henning, 2008). Thus, discussion of controversial socio-scientific issues could be used within the science context to contribute to the development of these transferable skills in addition to the delivery of scientific content.

Many science educators (Driver, Newton, & Osborne, 2000; Gray et al., 2006; Hughes, 2000; Levinson, 2003; Levinson, 2006a; Levinson, 2006b; Levinson et al., 2001; Lewis & Leach, 2006; Oulton, Dillon J, & Grace MM, 2004; Ratcliffe, 1997; Ratcliffe et al., 2003; Sadler, 2004a; Sadler, 2004b; Sadler, Barab, & Scott, 2007; Sadler et al., 2004; Sadler et al., 2005a; Sadler & Zeidler, 2005b; Sadler et al., 2005c; Zeidler et al., 2003) advocate the incorporation of discussion of socio-scientific issues into modern science curricula in the belief that their thoughtful negotiation is critical to modern conceptualisations of scientific literacy as well as adding relevance to the teaching of school science. However, what can science teachers expect their pupils to gain from discussion of socio-scientific issues? Troy Sadler, a major contributor to the research literature on socio-scientific issues, suggests that students gain a host of skills when engaging in socio-scientific inquiry.

Firstly, Sadler suggests that when engaged in socio-scientific discussion, students are provided with a 'robust' context for situating important science content in real life. This gives meaning to the science content within a social context, which enables students to see the connection between the science being learnt and their everyday life. In addition to the learning of science content, students will gain an appreciation of the nature of science as a process for the production of knowledge and, probably more importantly, the limitations of science (Sadler, 2004b; Sadler et al., 2007; Sadler et al., 2005c).

Secondly, Sadler sees discussion of socio-scientific issues as a potential way to foster citizenship education since socio-scientific curricula promote democratic values (such as the ability to discuss controversial issues in a fair and open manner without prejudice) and promote decision-making based on the balance of evidence. Furthermore, Sadler views the student as part of, and contributing towards, the decision making process. For Sadler and other educators, the fact that contemporary science permeates most areas of modern life leads them to believe that formal education, and science education in particular, should help students prepare for active participation in a modern democracy. This view echoes the views of the educational philosopher John Dewey and those of James Dillon and David Bridges, both of whom have written extensively on the use of discussion in the classroom. However, Sadler goes further to suggest that science education can no longer exclude practice for civic issues, relegating their handling to the humanities classroom. This view is in contrast to the views of Levinson (2001) who questions whether controversial socio-scientific issues should be taught by science teachers. He has suggested that humanities teacher might be better skilled to deal with such issues.

Sadler does concede that "while the notion of promoting citizenship in science learning is theoretically appealing, it remains somewhat nebulous from a pragmatic perspective" (Sadler, 2004b). However, the fact remains that if students become practised in dealing with complex controversial socio-scientific issues in an educational context, this should help them to deal with similar kinds of issues which may arise in their future everyday life.

Finally, Sadler suggests some aspects of student reasoning are improved, in the context of decision-making on a socio-scientific issue, which he sees as important developmental practice for students; these aspects being the ability to recognise the inherent *complexity* of socio-scientific issues, the ability to examine an issue from *multiple perspectives*, being able to appreciate that issues are subject to on-going *inquiry*, and the ability to exhibit *scepticism* when presented with potentially biased information (Kolsto, 2001; Sadler, 2004b).

Part of the contentious nature of socio-scientific issues is down to the fact that well reasoned but differing opinions on an issue may be taken up by interested groups. It is not uncommon for well-meaning and thoughtful people to adopt opposing but equally plausible solutions to a controversial socio-scientific issue. The differing views are usually based on differences in personal priorities, principles and biases (Sadler et al., 2005b).

It is clear when one looks at curricular reform documents such as *CfE* that politicians, broadly speaking, recognise the importance of conceptualising scientific literacy to include informed decision making, the ability to analyse, synthesise and evaluate information, dealing sensibly with moral reasoning and ethical issues, and understanding the connections inherent in socio-scientific issues.

To achieve a practical degree of scientific literacy, it is therefore necessary to practise and experience discussion of socio-scientific issues through which the development of habits of the mind such as acquiring scepticism, maintaining open-mindedness, critical thinking, recognition of multiple forms of inquiry, accepting ambiguity, searching for data-driven evidence can emerge. Dana Zeidler has proposed a framework which addresses scientific discourse in terms of the psychological, social, and emotive growth of the child, derived from a moral reasoning perspective (Zeidler et al., 2003). He suggests that this framework should be viewed as a tentative model that envelopes four broad issues of pedagogical importance central to the teaching of socio-scientific issues and is derived from contemporary visions of scientific literacy, these being: nature of science issues; classroom discourse issues; cultural issues; and case-based & STSE issues (see Figure 2.1). Each of these can be thought of as entry points in the science curriculum through which broader educational themes might be filtered, thus allowing for collaboration with colleagues from other subject areas such as Religious and Moral Education, Modern Studies as well as English. In addition, the discussion of socio-scientific issues can provide a conduit through which cross-cutting themes can be explored between the Science, RME and Humanities departments allowing for mutual departmental input into the progression of the four main capacities of *CfE* (successful learners, effective contributors, confident individuals and responsible citizens).

Figure 2.1: *Socio-scientific Elements of Functional Scientific Literacy.*

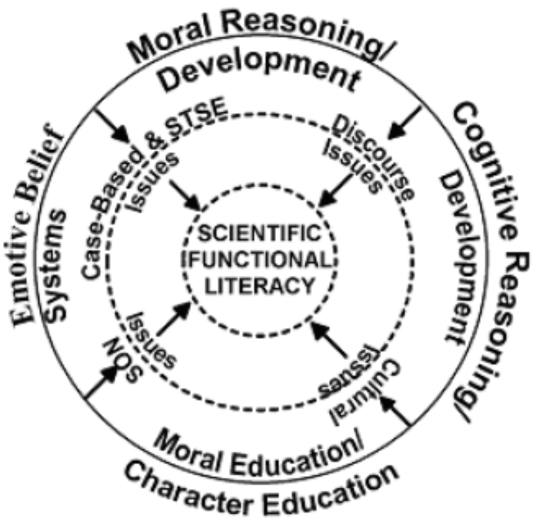


Figure 2.1 taken from Zeidler and Keefer (2003, p.12) shows how functional scientific literacy provides a focal point for a number of developmental themes.

According to Zeidler and Keefer (2003) the broad educational themes which lie on the outer-ring of Figure 2.1 are derived from a neo-Kohlbergian perspective and as such invite the use of post-modern perspectives of moral reasoning, growth and development. The inner-ring of Figure 2.1 contains issues related specifically to scientific literacy and identified due to their central role in moving between the broader educational themes and science educational practices. Science issues become important to scientific literacy because they can reveal how varied epistemological views influence the manner in which evidence is selected, interpreted and evaluated, and is considered to have a significant bearing on students' pre-instructional view of socio-scientific issues.

In the same way, discourse issues hold the key as to how students frame their positions, build a case for argumentation, become aware of fallacious reasoning, and consider how belief convictions influence their emotions and moral commitments to moral issues (Zeidler and Keefer, 2003, p.13). Cultural issues place discourse in context in that, without mutual respect and tolerance of dissenting opinions, discourse is futile. They also help to emphasise the fact that the decisions that are made by students in relation to the issue being discussed are the result of a realisation that as moral agents, we are impacted by normative values as well as cultural beliefs about nature. Taken together, this means that discussion of socio-scientific issues can be both a process for the development of attitudes and the dispositions required by scientifically literate citizens and a product through social interactions and classroom discourse since the discussions require, at times, the use of inquiry skills such as interpretation and analysis of evidence, argumentation and decision-making and may involve resolution of moral dilemmas.

Zeidler and Keefer (2003) suggest that teachers need not be expert at assessing moral development to effectively engage their students in interesting discourse. Furthermore, real-life controversies provide authentic contexts for students to practise and gain experience in the use of hypothetical dilemmas which serve to activate moral schemas, tap into prior knowledge and facilitate moral reasoning. Thus discussion of socio-scientific issues within the science classroom provides an ideal vehicle for the development of scientific literacy.

It is important to note, that although the teaching of socio-scientific issues should be done within the context of science education, other school subjects can help promote such discussions since there are considerable areas of overlap. The prominent British science educator Ralph Levinson has suggested that Humanities teachers may be better pedagogically equipped to deal with such issues (Levinson, 2001). Furthermore, certain socio-scientific issues can intuitively be described as controversial such as: embryonic stem cell therapy, cloning, conservation of energy, waste disposal, gene therapy. What links all of these issues are their contentious nature and the fact that many groups of people see such issues to be of primary importance. In addition, the mass media always seem to carry stories which comment on such issues.

As a science teacher working with the current (pre-*CfE*) science curriculum, this researcher has often encountered a lack of pupil interest; pupil apathy; a lack of understanding of why a controversial issue is important; as well as a lack of relevant science content knowledge, all of which, impede enthusiasm to teach such issues. However, Levinson argues that the lack of clarity about the epistemological and ethical structure of controversy shrouds the place of such discussion with uncertainty (Levinson, 2006b). The teaching of controversial issues, particularly those of a socio-scientific nature, has never been easy or particularly successful. In most cases students contribute little to the discussion (Dillon, 1994; Osborne et al., 2002).

Levinson proposes a framework which takes into account three epistemologically interconnecting strands through which he characterises controversy, based on a liberal perspective of pluralist democracy. These strands are: categories of reasonable disagreement; the communicative virtues or dispositions necessary to engage in reasonable disagreement; and the modes of thought and experience which can best illuminate those disagreements (Levinson, 2006b). In this framework, he suggests that "reasonable disagreements" might be a more helpful term than controversial issues. It has been suggested that controversial issues are those reasonable disagreements that incorporate moral and social values that could be problematic when trying to decide to what extent there is a value-laden element in any disagreement (Bridges, 1986). Issues surrounding the teaching of science are not new, as school science has been portrayed as authoritative, generalised, and academic (Fensham, 1997; Yager, 1992). Indeed this perspective reflects science teachers' own epistemic views of the subject, together with the difficulties that science teaching has had in dealing with ideas where there is no clear resolution (Donnelly, 1999). Socio-scientific issues, as described earlier, rest on facts which are either contentious or tentative and are by their nature full of uncertainty. In addition, they combine political, ethical, social, and personal conflicts that are not commonly found within a science lesson (Layton, 1986).

Levinson, drawing on McLaughlan's nine categories of reasonable disagreement, presents a broad gradation in level of disagreement (McLaughlin, 2003); where category 1 lends itself to the process of verification or falsification of hypotheses through the use of evidence, whereas in category 9 the premises for contending beliefs or arguments are incommensurate and where evidence is linked to incompatible theoretical frameworks or distinct paradigms (Kuhn, 1962). These categories reflect whether people are attached to the same or different values; differences in priorities about the same values and different interpretations about an issue (Bridges, 1986). The nine categories of reasonable disagreement are as follows;

1. Where insufficient evidence is as yet available to settle a matter, but where such evidence could in principle be forthcoming at some point.
2. Where evidence relevant to settling a matter is conflicting, complex and difficult to assess.
3. Where the range of criteria relevant for judging a matter are agreed, but the relevant weight to be given to different criteria in a given decision is disputed.
4. Where a range of cherished goods cannot simultaneously be realised, and where there is a lack of a clear answer about the grounds on which priorities can be set and adjustments made.
5. Where the range of criteria relevant for judging a matter are broadly agreed, but there is dispute about the proper interpretation of a criterion or criteria, given the indeterminacy of many concepts.

6. Where there are different kinds of normative consideration of different force on both sides of an issue, and it is hard to make an overall judgement.
7. Where there is disagreement about the criteria relevant for judgement.
8. Where the differing 'total experiences' of people in the course of their lives shapes their judgements in divergent ways.
9. Where there is no agreement about whole frameworks of understanding relevant for judgement.

However, Levinson suggests that reasonable disagreements presuppose dispositions; for example, being amenable to reason and respect for the point of view of others (Bridges, 1979; Bridges, 1987; Brookfield et al., 2005; Dillon, 1990; Dillon, 1994). Where groups understand each other as having rational and justifiable points of view or as having competing modes of inquiry this may be indicative, that at some level, the contending groups agree on more than they disagree (Billig, 1991; MacIntyre, 1988); that they are willing to engage in discussion and recognise the proprieties of reasonable engagement. Therefore, Levinson suggests that discussion is the best approach to help reach a consensus on the content of the disagreement and the nature of the differences.

The interpersonal skills required to support the kinds of discussions which address reasonable disagreements have been termed "communicative virtues" (Burbules & Rice, 1991) and are those skills required to attempt "dialogue across differences". These can be seen as "a cluster of intellectual and affective dispositions that together promote open, inclusive and undistorted communication" (Rice & Burbules, 1992).

David Bridges has described the necessary dispositions to communicate across differences as follows:

- *Procedural actions*: there is agreement about rules of conduct (e.g., allowing people to speak in turn).
- *Moral obligations*: there are expectations that people will speak the truth reflecting what they mean and that discussants are held to an obligation to speak the truth.

- *Freedom*: participants are not subject to any constraint that may prevent them from stating their opinions.
- *Equality*: people believe they have something to learn from everybody.
- *Respect*: there is respect for persons where any discussion is underpinned by certain moral values so that participants will be engaged in the protection of those values. Such a discussion, for example, will not involve respect for persons if a participant is abused because of ethnic origin, physical appearance, and so forth.
- *Openness*: participants are open in that they are prepared to be swayed by the other's point of view if it is sufficiently persuasive (Bridges 1979).

Bridges sees open discussion as an essential pre-requisite for engagement in the democratic process (Bridges, 1979). However, in schools where discussion does take place, it tends to express 'the authoritative social role of the teacher' (Edwards & Mercer, 1987), and often takes the form of teacher initiation of a question, pupil response followed by teacher feedback or evaluation, (as described earlier) and is the most common type of classroom discourse, known as recitation (Larson, 2000). As the teacher tends to have epistemic control of the content (Lemke, 1989), there is relatively little argumentation (Newton, Driver, & Osborne, 1999; Osborne, Erduran, & Simon, 2004).

The communicative virtues underpin open discussion. However, they can only work when the students understand that their voice is heard, that no one view has a greater weight because of their position of authority in the school or social status in the classroom, and where patient attention to others' words are encouraged. This does have implications for the role of the teacher within class discussion. Questions as to whether the teacher should take a procedurally neutral, devil's advocate, or balanced role has been debated (Bridges, 1986; Crick, 1998; Oulton et al., 2004) but any consideration of this role must occur within the political and cultural context of the school.

In terms of classroom control, an authoritative approach by the teacher may ensure that views and opinions of students, who are not normally heard, get aired within the discussion. Under certain circumstances this ensures greater openness in the classroom. Any move towards more open and dialogic discourse in the classroom suggests that a major change in the culture of science teaching is required. However, there are examples which suggest that with appropriate support it is possible to help science teachers move towards a more open form of discussion (Mortimer & Scott, 2003; Solomon, 1992). For openness to be encouraged in these discussions, it is necessary to anchor the experience and knowledge claims of the participants. Thus, participants coming from a tradition such as a religion or an established secular philosophy are likely to employ the dominant arguments of that tradition. However, it is possible that most individuals do not see themselves as part of one tradition, faith or belief system.

Levinson suggests that in reasonable disagreement, participants are encouraged to position themselves within the tradition that they see as most closely aligned to their own views. In addition, participants are encouraged to reflect on their relationship to the tradition through engagement with the ongoing arguments within that tradition and the conflicts it has with other thought systems. For example, someone from the Jehovah Witness tradition might refuse a blood transfusion on religious grounds as they can find no rational justification within their tradition for using the procedure even although refusal could lead to death. Thus by arguing respectfully from within a tradition, Levinson suggests that participants have the capacity to illuminate the arguments in the inquiry with the possibility that, having exhausted the argumentative resources from within a particular tradition, the participant may find that he/she does not have the necessary concepts to uphold their particular point of view.

However, religious belief is a matter of faith which cannot be rationally reduced through argumentation and that is why discussion of issues which have a moral or ethical basis with religious connection can often become bogged down with dogma as reaching consensus is next to impossible. An example would be the argument between evolution and creationism.

Of the nine categories of reasonable disagreement, only one lends itself to incontrovertible resolution through evidence. When deploying evidence within argumentation models to make a claim (Kuhn, 1991; Toulmin, 1958), there has to be agreement between contending parties that the theoretical meaning of the evidence is consistent and contiguous with the data and the claims that are being made from the evidence. Different parties in a controversy will therefore have to negotiate a point or points on which they can agree. When it comes to modes of thought required for negotiating such issues two modes of thought are helpful. The logico-scientific mode deals in general with the establishment of causes and tests for empirical truth. The narrative mode, constructing stories, are interwoven in seeking to convince, where the term "convince" is used in the context of seeking to give validity to a point of view, not necessarily as a means of changing minds, which is more psychologically complex (Billig, 1991).

Bruner suggests that these two modes of thought can be used in different ways to convince, where the logico-scientific mode seeks to appeal to procedures for establishing proof as a means of seeking to *explain*, and the narrative mode, through verisimilitude, providing narrative stories of lifelikeness as a means of seeking to provide an *interpretation* (Bruner, 1986). Thus the role of evidence is used through logico-scientific thinking and how we know, comes through narrative thinking since this mode of thought allows participants to tell the story of their experiences which may illuminate those participants' reasoning.

The narrative mode infuses a story or a series or a flow of events with meanings, as well as devising beginnings and ends, and is thus "the outcome of a mental process which enables us to excise from our experience a meaningful sequence, to place it within boundaries, to set around it the frontiers of the story, to make it resonate in the contrived silence with which we may precede and end it" (Rosen, 1987). As a meaning-making device for the narrator it has an evaluative framework where he/she, in selecting and organizing experiences, prioritises actions and events that make the story intelligible as a moral account (MacIntyre, 1981). In terms of citizens coping with problems of a scientific nature, the narrative mode of thought is often more relevant for illustrating a point or finding a resolution than the logico-scientific mode. Personal narratives of people encountering science related issues clearly show up the gap between their needs and personal contexts and the information that can be gleaned from scientific knowledge. A study by Aikenhead on the knowledge used by nurses shows that they mainly draw on their professional everyday knowledge, but that they use knowledge which has at some point been deconstructed and reconstructed from canonical knowledge (i.e., the logico-scientific mode) (Aikenhead, 2004). When aspects of science are seen and acknowledged as uncertain by experts, and where experts work alongside lay people, the relevant science involved is often perceived as peripheral to people's concerns (Layton, Jenkins, Macgill, & Davey, 1993). What the expert brings to such discussions must be knowledge of the facts, procedures, evidence and its limitations as well as the dispositions required to arrive at decision or solution to the issue.

When you compare the Zeidler and Levinson models, both are linked by the needs of the student to be able to engage critically with controversial socio-scientific issues utilising a host of interpersonal and communicative skills in order to interpret, evaluate and weigh up lines of evidence from multiple perspectives. The theoretical directions from which these models view such discussions may be different but, it could be argued that they are complementary since they aim to develop the same dispositions within students, that of openness, scepticism, critical evaluative skills, interpersonal and communicative skills, mutual respect and fairness, all of which are democratic virtues required by future, scientifically literate citizens.

The one issue which neither of these models deals with is the question of which pedagogical approaches can be used, particularly by science teachers, effectively to teach and practise such disposition within the context of school science. There are a number of pedagogical approaches which could be used effectively to develop these dispositions. Cooperative learning is an approach which is well researched and provides a model approach which can serve a number of simultaneous purposes in that it helps students to learn and practise the communicative virtues, dispositions of openness, scepticism, respect, interpretation and evaluation of contradictory lines of evidence, as well providing a management tool for use of discussion within the class for the teacher.

2.9 Summary.

Modern society encounters issues which relate to contemporary science more frequently than it has in the past. These issues have been termed controversial socio-scientific issues since they have significant science content, they ignite fierce debate and passionate discussion both nationally and locally between different groups. Many of them require an element of moral, ethical, social, economic and political reason. They often require an understanding of probability and risk as well as relying on knowledge which is often tentative and contested by experts as well as interested parties. These issues can also be seen from multiple perspectives which make decision-making difficult.

Teaching using discussion of controversial socio-scientific issues, it is suggested, helps with the development of scientific literacy on a number of levels. For example, such discussions allow students to practise oral communication skills, critical thinking, argumentation and how to cope with disagreement in a fair and free manner. This could be construed as the practice of democratic citizenship. In addition, discussion of controversial socio-scientific issues allows students to form their own opinions and test their ideas through dialogue with their peers and the teacher in order to re-construct their knowledge in a meaningful context. Furthermore, this learning provides relevance to the science being acquired which can in turn further stimulate students' motivation to learn.

However, the frequency of such discussions within science classrooms is extremely low due to a lack of confidence in their management by the teacher and a lack of clarity as to what such discussions are expected to achieve. Some research also suggests that science teachers lack confidence in their subject knowledge when dealing with socio-scientific issues since the contentious ideas invariably deal with science that is beyond their current syllabus and also may be beyond teachers' undergraduate (science) training.

In order to encourage science teachers to engage in more discussion-based teaching, using controversial socio-scientific issues, model pedagogies need to be shown to work in terms of overcoming the technicalities of managing discussion *per se* and in terms of measurable gains in course content delivery and student attainment.

Cooperative learning is a pedagogical approach to discussion, which one could argue might have utility since it has be shown to work both in terms of managing the process of discussion in the classroom and the delivery of course content (and raise student achievement). In the next section of this review the cooperative learning process and its theoretical underpinning will be described.

2.10: Cooperative learning as an approach to the promotion of scientific literacy.

2.10.1 Introduction.

Cooperative learning is widely recognised as a pedagogical approach which promotes both socialisation and learning among students, through working together in small groups to achieve shared goals, across different subjects (Cohen, 1994b). In addition, its use has been shown to promote better understanding in high school science (Foley & O'Donnell, 2002; Hanze & Berger, 2007; Shachar & Fischer, 2004), problem-solving skills in mathematics (Nichols, 1996; Sahlberg & Berry, 2002) and better reading and writing in secondary school English (Stevens, 2003). Other major benefits attributed to the use of cooperative learning are the promotion of self-esteem and confidence building; the development of a safe learning environment; and better classroom success rates (Jenkins, Antil, Wayne, & Vadasy, 2003). It has been claimed that when students work cooperatively, they learn to share ideas and perspectives, listen to each other with particular emphasis on how things are said, give and receive help, seek ways to resolve difficulties and actively work to construct new understandings and learning (Johnson & Johnston, 2003).

In this section of the literature review the development of cooperative learning from a philosophical and theoretical perspective will be described. Cooperative learning will be defined in terms of its principal elements and how cooperative learning activities are structured in order to promote both social and academic outcomes. How its use can contribute the development of scientific literacy will be outlined.

2.10.2 Theoretical and philosophical background leading to cooperative learning.

The educational philosopher John Dewey believed that education was a process of living. He believed that schools were responsible for capturing children's interests, expanding and developing their horizons, and assisting them to respond to new ideas and influences in an appropriate manner. Dewey argued that learning should be an actively dynamic process which is student-centred and responsive to the students' own developing social interests and activities. As he saw it, school was responsible for building on the students' natural interest in their social environment by developing skills including interpersonal/communication skills and group interaction. Dewey's idea was that through interaction with others, students receive feedback on their activities, through which they learn socially appropriate behaviours, and gain an understanding of what is involved in cooperating and working together. (Dewey, 1940a; Dewey, 1966; Dewey, 1940b)

Educational research on cooperative learning as a pedagogical tool grew from the early twentieth century research field of group dynamics which had gained ground between the 1920s and early 1950s, as interest in how people behaved when exposed to the influence of others within different types of group setting. For example, research studies indicated that when an individual is able to see and hear others working there is a distinct increase in the quality and quantity of that individuals work (Allport, 1924) and that groups think more efficiently than the best member of the group working alone (Watson, 1928). Furthermore, other studies showed that individuals begin to work cooperatively when they are tasked to achieve a shared outcome (Mead, 1937) and that individuals cooperate when they are in close contact and are expected to work together to achieve a shared goal (May & Doob, 1937). In contrast, people compete when they are in a situation where they are not in close proximity and are not expected to complete a shared goal. It has been argued that this focus on group dynamics was born of the need to understand how individuals act within groups, since the answers to such questions were important in terms of the socioeconomic and political imperatives of the day, since this was a period of great social upheaval in the aftermath of World War I, closely followed by the Great Depression and the rise of Fascism in the lead up towards World War II.

How group interactions influence group members' behaviour is determined by the style of leadership within the group (Lewin, Lippitt, & White, 1939). In two experimental conditions, Lewin *et al* (1939) first took two groups of ten-year old boys and exposed them to either a democratic leadership style or an autocratic leadership style as they participated in boys' club activities. What they noted was that the boys exposed to the more authoritarian style became more aggressive and domineering towards each other with successive meetings while the attitude towards the group leader became either submissive or persistently attention-seeking. By contrast, the boys in the group exposed to a more democratic leadership style were more open and friendly towards each other, while their relationship with their group leader was more free and egalitarian. In the second experimental condition, Lewis *et al* exposed four groups of ten-year old boys through successive experiences of autocratic, democratic and *laissez-faire* leadership styles while participating in similar club activities. This research showed that only one of the four autocratic groups showed a similar level of aggression as observed in the first experiment and the authors postulated that the aggression was suppressed since the behaviour reappeared as soon as the autocratic leader left the room. In effect what these studies shows is that leadership style can have a significant effect on group behaviours and that social and psychological phenomena can be observed and measured.

Although many researchers have investigated the interaction between individuals in groups and have observed either cooperative or competitive behaviour in the way that they interact with each other to obtain their goals, it was Morton Deutsch who initiated the investigation of interactions between individuals and group processes that emerged as a consequence of the cooperative or competitive social situation (Deutsch, 1949a). Deutsch set out to determine how individuals perceive they are cooperative or competitively linked, postulating that if students worked cooperatively together to achieve a group goal then they would perceive themselves to be more psychologically interdependent than those who worked competitively. Using fifty first year university student volunteers allocated to ten groups, and ranking them in paired groups with each other on the basis of the productivity of their discussion, Deutsch showed that students in the cooperative groups were rated by the observers as having a stronger sense of group-centeredness or group feeling than their peers in the competitive group. In addition, students in the cooperative groups worked together more, were more highly coordinated and ensured that tasks were divided up so that there was no duplication of labour. They were also more attentive to what others had to say, they communicated more effectively, were more motivated to achieve and were more productive in their achievements than were their peers in the competitive groups (Deutsch, 1949b). This study provided evidence that when groups cooperate, they communicate better, are more motivated, productive, and have better intra-group relations than groups that compete. This challenges the traditional view that students who compete for awards work better than students who cooperate and facilitate each other's efforts. Research into group dynamics carried on at pace (Deutsch, 1960; Deutsch, 1959) until the 1960s where the focus of research dissipated due to a focus of effort on the individual rather than the group (Johnson & Johnston, 2000).

Educational research on cooperative learning picked up in the early 1970s partly due to published research on the efficacy of peer-tutoring on academic and social learning outcomes of children assisting others in their learning (Gillies & Ashman, 2003). These peer tutoring studies suggested that peers could be trained to facilitate academic accomplishments, reduce disruptive behaviour, increase work rate and be used to teach social interaction skills. David Johnston, a student of Morton Deutsch, began to look closely at cooperation in terms of social interdependence and how it contributed to the positive affects attributed to cooperative learning. Other researchers such as Robert Slavin concentrated on the use of student teams as a method of evaluating the effect of motivation on achievement. Spencer Kagan formulated a structural approach to cooperative learning which is content free. However, the main body of literature emanating from research into cooperative learning concentrates heavily on cooperative learning's efficacy and utility within different educational settings and with students of low, medium and high ability under experimental conditions or through case study analysis. Relatively few papers discuss the theoretical perspectives which underpin cooperative learning or how it can be effectively integrated into teaching practice. The theoretical perspectives which impinge on cooperative learning can be grouped together roughly under two main headings, with each containing two perspectives: the motivational and social cohesion perspectives; and the cognitive development and cognitive elaboration perspectives.

2.10.2.1: The Motivational and Social Cohesion Perspectives on Cooperative Learning.

Robert Slavin (Slavin, 1996) suggests that the motivational perspective focuses mainly on the reward/goal structures through which students operate within the learning setting. Cooperative incentive structures create a situation whereby the only way a group member can attain their own personal goals is through the group's success. Thus each member of the group has to help and encourage their group mates (peers) to complete their task successfully for the groups to succeed. Rewarding groups based on good performance creates an interpersonal structure through which group members give, receive or withhold social reinforcers in response to their peers' task-related effort.

The motivational perspective suggest that a reward must be group based, or made dependent on average group score or other individual assignments or assessments which exceed a pre-established criterion. So, if the students value the success of the group, they will encourage and help one another to achieve, which is in contrast to the situation found in most traditional competitive classroom settings (Johnson & Johnson, 1994; Johnson et al., 2003; Slavin, 1995; Slavin & Cooper, 1999). Empirical support for the motivational perspective comes from practical applications of cooperative learning in elementary and secondary schools (Ashman & Gillies, 1997; Hanze et al., 2007; Johnson, Johnson, & Stanne, 2000; Shachar et al., 2004; Slavin, 1994; Zhan, Kagan, & Widamin, 1986).

Essentially these studies suggest that group rewards are essential to the effectiveness of cooperative learning, the caveat being that only if group rewards are based on the individual learning of all group members (Slavin, 1995). Average scores are used to base the rewards for the group on individual assessment scores of each member of the group. Slavin (1994) used the Student Team-Achievement Divisions (STAD) method where students work in mixed ability teams (groups) to master material initially presented by the teacher. After this the students take an assessment on the material and the team may earn rewards based on the degree to which the team members have improved over their own past record. The only way the team can succeed is to ensure that all team members have learned so the team members' activities focus on explaining concepts to one another. If group rewards are based on a single group product there is little incentive for group members to explain concepts to each other and one or two group members may end up doing all the work.

A related perspective is that of social cohesion which suggests that the effect of cooperative learning on achievement is strongly mediated by the cohesiveness of the group. In essence, students have to care about one another's learning and want others to succeed if they are to help one another learn. While the motivational perspective suggests that students help their group mates for purely selfish reasons i.e. it's in their own best interest, the social cohesion perspective suggests that students will help their group mates learn since they care about the group. Slavin (1996) argues that social cohesion theorists place a heavy emphasise on teambuilding activities as part of the preparation for cooperative learning and group processing and self-evaluation. However, empirical evidence in support of the social cohesion perspective is limited at best and inconsistent for the proposition that building social cohesion among students through team building alone without group incentives will enhance students' achievement using cooperative learning (Slavin, 1996).

2.10.2.2: The Cognitive development and Cognitive Elaboration Perspectives on Cooperative Learning.

The cognitive development perspective suggests that interactions among students will in themselves increase students' achievement for reasons which have more to do with mental processing of information rather than motivation. The fundamental assumption is that interaction among students around appropriate tasks increases their mastery of critical concepts. This perspective is supported by elements of the constructivist theory of learning in particular social constructivism as described by Vygotsky. The social context of learning is of course a key feature of peer-mediated discussion approaches. According to Vygotsky, children's mental functioning develops first at the interpersonal level where they learn to internalise and transform the content of interpersonal interactions with others, to the intra-personal level where it becomes part of their repertoire of new skills and understanding. Children learn through interaction with adults or more capable (or knowledgeable) others who scaffold or mediate learning so that they are able to complete tasks that they could not do on their own. This suggests that learning is a social phenomenon which takes place when students interact with others (Vygotsky, 1978).

Fundamental to the process of mediation is the more knowledgeable other's sensitivity to the learner's zone of proximal development (See Figure 2.2). Vygotsky (1978) defined the zone of proximal development as:

> …the distance between the actual developmental level determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with a more capable peer (Vygotsky, 1978, p.86)

In Vygotsky's view, collaborative activities among children promote growth as children of similar ages are more likely to be operating within one another's zone of proximal development, modelling in collaborative groups behaviours more advanced than those they could perform individually. According to Slavin (1996), Vygotsky described the influence of collaborative learning in the following terms:

> Functions are formed in the collective in the form of relations among children and then become mental function for individuals… Research shows that reflection is spawned from argument (Vygotsky, 1978)

Figure 2.2 *Vygotsky's "zone of proximal development".*

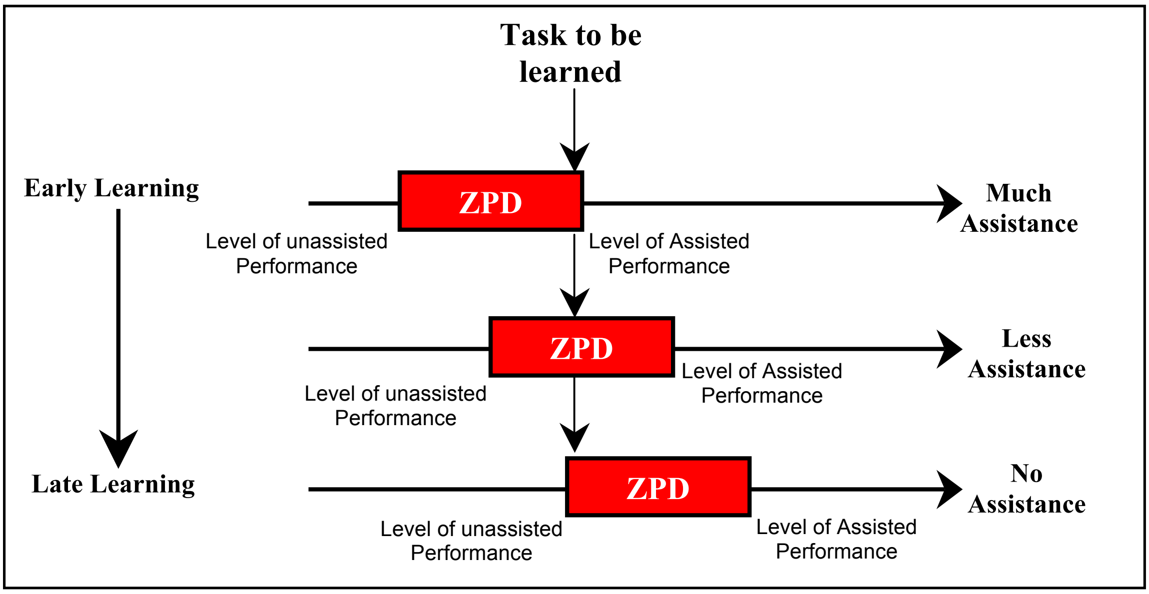


Figure 2.2 taken from (Doolittle, 1995) which shows the dynamic nature of Vygotsky's zone of proximal development since the zone overcomes the task to be learned. Early in the learning process the student needs help to accomplish the learning task since the task is in the upper end of their zone but, with practice, the student's zone moves, as a result of increased cognitive development in the direction of the instruction. Later in the learning process the student is able to perform the tasks on his/her own where before they required help. It must be noted that the degree of difficulty of the task to be learned remains constant as the skill of the learner increases.

For Vygotsky, argument or disagreement is the catalyst for reflection and it is through reflection, internalised thought and deliberation that cognitive development takes place. Vygotsky believed that we should not reduce higher mental functions such as reading, writing, critical thinking or problem-solving to their component parts; but that they need to be studied, taught and learned as a whole within activities. In addition, such activities need to be relevant to the child and embody authentic situations. In other words, there has to be a need for development to occur even if the need is cradled within an overall atmosphere of play. Thus the authentic situation, or whole activity, establishes the correct environment in which the zone of proximal development is embedded. He also believed that children learn through their interactions with others, since children initially experience knowledge and skills through their interactions with them.

As children experience knowledge and skills through interaction with others, they internalise this and eventually use this knowledge and skills to direct their own behaviour. Thus, social interaction between those less experienced and those more experienced is at the heart of the zone of proximal development. The social context of the zone suggests that it must be viewed as not solely relative to the child or the teacher, but of the child immersed in a cooperative activity within a specific social environment. Furthermore, as children learn and develop, the zone of proximal development moves, indicating mastery of the task (at the lower end of the ZPD) and the appearance of other tasks that can now be achieved with significant help (at the upper end of the ZPD). Thus Vygotsky concluded that through collaboration with others, whether they are adults or more knowledgeable peers, the child develops in a culturally appropriate manner. Thus for Vygotsky, formal education is a catalyst for the transmission of cultural ideas, values and behaviour and within the school setting, children are provided with organised structure from which to experience and internalise that culture.

Jean Piaget also believed that social-contextualised knowledge such as language, values, rules, morals and social symbols can only be learned in interactions with others. Peer interaction is also important in logical-mathematical thought in disequilibrating the children's egocentric conceptualisations and in provisioning of feedback to the child about the validity of logical constructions (Piaget, 1926). Many Piagetians argue that the interactions among students on learning tasks will lead to improved student performance in itself. Students learn more from one another since in their discussions of content cognitive conflicts arise, inadequate reasoning is exposed, disequilibration occurs and higher quality understanding will emerge.

From the cognitive development perspective the achievement gains from cooperative learning emanate from the cooperative tasks themselves. The opportunity for students to discuss, argue, to present different views and listen to others views is a critical element of cooperative learning. Damon (1984, p.337) integrates elements of Piagetian and Vygotskian perspectives on peer collaboration to propose a "conceptual foundation for a peer-based plan of education." In this framework, four main points are made:

1. Through mutual feedback and debate, peers motivate one another to abandon misconceptions and search for better solutions.
2. The experience of peer communication can help student master social processes, such as verification and criticism.
3. Collaboration between peers can provide a forum for discovery learning and can encourage creative thinking.
4. Peer interaction can introduce students to the process of generating ideas (Damon, 1984).

The theory underlying the presumed contribution of the group format is that in exploring opposing perceptions and ideas, high order understanding will emerge, also students operating within one another's proximal zone of development will model higher-quality solutions for each another. However, there is little empirical support for pure cooperative learning which depends solely on interaction to produce higher achievement. It is likely that the cognitive processes described by cognitive development theorists are important mediating variables which may explain the effect of group goals and group tasks on student achievements.

A quite different form of cognitive perspective arising from cognitive psychology suggests that if information is to be retained and related to information already held in the memory, the learner must actively engage in cognitive restructuring or elaboration of the material (Wittrock, 1986). An example of such elaboration is explaining the material to someone else. Research on peer tutoring has long shown benefits for the tutor as well as the tutee (Devin-Sheehan, Feldman, & Allen, 1976). This perspective may be illustrated by the following example. Donald Dansereau and colleagues set college students the task of learning through cooperative scripts where students acted as either the listener or recaller. The students read a section of text and the recaller summarised the information while the listener corrected any errors, filled in gaps or omitted materials and helped think of ways both students could remember the main ideas. In the next section of work they switched roles. Dansereau and colleagues found that while both the recaller and the listener learned more than students working alone, the recaller learned more (Dansereau, 1988; Newbern, Dansereau, Patterson, & Wallace, 1994).

How all these theoretical perspective impinge on cooperative learning models is interesting since no individual perspective can be shown to independently explain the positive effects on student achievement reported by the advocates of cooperative learning. It is possible that a synergy between these perspectives may account for the positive achievement effects. However, to date, this researcher has not been able to find reference to any study which explicitly investigates possible synergistic effects of using a theoretical framework which mixes all these perspectives. It is therefore necessary to look at cooperative learning models in detail to determine which model might be most effective.

2.10.3 What is Cooperative Learning and how is it applied?

The expression cooperative learning conjures up ideas based on the definitions of the words cooperative and learning, a potential working definition of cooperation being: *to work together to accomplish a shared goal through which each individual seeks an outcome that is mutually beneficial* and of learning: *to gain an understanding that leads to the modification of attitudes and behaviours through the acquisition of knowledge, skills and values, through study and experience*. One may be forgiven for assuming that cooperative learning is simply the sum of these definitions (Tanner, Chatman, & Allen, 2003). However, a scholarly definition of cooperative learning is much more than the sum of these components. Cooperative learning is the instructional use of small groups in which pupils work together to maximise their own and each other's learning (Johnson et al., 1994; Johnson & Johnson, 1999a; Johnson & Johnson, 1999b). In addition, cooperative learning has also been described as a form of small group instruction where students work in a social setting to solve a problem (Slavin, 1995). Some researchers regard cooperative learning, collaborative learning, peer learning and group learning as distinct and different terms, whereas others use them as synonyms that are interchangeably used to define a process in which students at all levels of ability work together in small groups to achieve an educational task (Boehm & Gallavan, 2000; Boud, Cohen, & Sampson, 1999). Other researchers take a broad view regarding cooperative learning as a form of critical pedagogy that helps move schools and societies closer to the ideal of social justice (Sapon-Shevin & Schniedewand, 1992). Some envisage cooperative learning as a teaching and learning strategy that facilitates students working together cooperatively in small structured groups to accomplish shared learning goals (Hancock, 2004; Johnson, Johnston, & Holubec, 1993; Slavin, 1990; Veenman, Kenter, & Post, 2000; Veenman, van Benthum, Bootsma, van Dieren, & van der Kemp, 2007).

From these definitions one could reason that learning in a cooperative environment is dependent on the socially structured exchange of information between students in groups (Olsen & Kagan, 1992) in which students are held responsible for their team-mates' learning as well as their own (Slavin, 1990), and are motivated to increase the learning of others (Hancock, 2004; Olsen et al., 1992).

However one defines the term "cooperative learning", it is clear that it is a pedagogical approach which has flexibility both in terms of its application to different theories and to various educational contexts. In schools, students do not learn in a compositional vacuum since they are members of a class and a small group. Furthermore, cooperative learning is not a technique for its own sake; it requires content in order to be useful. The specific content is not the result of an arbitrary choice, without any consequences for the design of a curriculum in which it takes place. Content has its own characteristics, which may be used in the design process and in the classroom in order to facilitate the development of thinking as a human activity. Thus the effective use of cooperative learning requires detailed planning and preparation both in terms of its application and in terms of the lesson content. From Table 2.4 five key characteristics emerge as important elements in cooperative learning experience: positive interdependence; face-to-face interactions; individual accountability; social skills; and group processing. However, of the five studies shown, only positive interdependence and individual accountability are common to all.

Table 2.4: *Key elements of cooperative learning according to various theorists.*

Research Studies				
(Johnson, Johnson, & Holubec, 1998)	**(Rottier & Ogan, 2008)**	**(Ormrod, 1995)**	**(Sharan, 1990)**	**(Kagan, 1994)**
Positive Interdependence	Group cohesion	Interdependence of group members	Positive Interdependence	Positive Interdependence
Face-to-face Interaction	Face-to-face Interaction		Face-to-face Interaction	Simultaneous interaction
Individual Accountability	Individual Accountability	Individual Accountability	Individual Accountability	Individual Accountability
Social Skills	Social Skills		Social Skills	
				Equal participation
Group Processing	Teacher monitoring	Teacher monitoring		
	Group self-evaluation	Group self-evaluation	Group self-evaluation	
	Group accountability	Group accountability		

The first element of cooperative learning, positive interdependence, is achieved when each group member understands and see value in the need for the group to cooperate to complete a common task or a shared goal. In order to fulfil personal goals, each group member must cooperate with the group goal as well. Interdependence may take several forms such as goal interdependence, task interdependence, resource interdependence, reward interdependence or role interdependence. As a result of positive interdependence students should be more motivated to work cooperatively since successful completion of the task is dependent on whole group participation.

The second element of cooperative learning is individual accountability which involves the teacher being able to hold each individual member of the group to account for the mastery of the task or relevant material. This involves both the completion of one's own task as well as supporting the work of other group members. In addition, individual accountability prevents situations arising in groups where select members of the group do most of the work and others do nothing or "free-load". This is essential if the teacher is to be able to account for student learning within each task. However, this also helps the students to see that the task distribution is fair and democratic and that account will be taken for the work done so that no one is disadvantaged. In practice, this condition can be achieved by issuing individual students with different coloured pens meaning that at a glance the teacher can identify students who are not contributing. Then when questioning the class the teacher can also call on any member of the group to report on what their group task was and what their group's deliberations and/or conclusions were to the rest of the class.

The third element of cooperative learning is face-to-face interaction. This element works hand in hand with positive interdependence in that face-to-face interaction involves individual members of the group being able to interact with each other on a personal level where each member of the group can encourage and facilitate the group's efforts towards successful completion of the group task. According to Johnston and Johnston (2000) face-to-face interaction is characterised by students

- providing each other with efficient and effective help and assistance;
- exchanging needs and resources such as information and materials and processing information more efficiently and effectively;
- providing each other with feedback in order to improve their subsequent performance on assigned tasks and responsibilities;
- challenging each other's conclusions and reasoning in order to promote higher-quality decision making and greater insight into problems being considered;
- influencing each other's efforts to achieve mutual goals;
- acting in trusting and trustworthy ways;
- being motivated to strive for mutual benefit, and;
- feeling less anxiety and stress.

The fourth element of cooperative learning requires the students to use and develop interpersonal social skills. The social skills necessary for students to perform cooperatively are taught directly during cooperative learning. It is incumbent upon the teacher to do this since one cannot assume that the students already have the required social skills in place to begin with. Social skills such as listening to what others are saying, taking turns to speak, trusting other group members, speaking in a low conversational voice, sharing responsibilities and managing intra-group conflicts usually require specific and often direct teacher intervention.

The fifth element of cooperative learning is group processing or group evaluation, the purpose of which is to clarify and improve the productiveness of all group members in contributing to the achievement of the mutual group goal. In addition, this provides a type of group metacognition which should result in a description of which interactions were beneficial or detrimental for future reference.

In cooperative learning classrooms, the students are expected to help, discuss and argue with each other; assess each other's current knowledge; and fill any gaps in each other's understanding. Cooperative learning often replaces individually set-work, study and individual practice but not direct instruction by the teacher. When properly organised, pupils in cooperative learning groups make sure that everyone in the group has mastered the concepts being taught (Slavin, 1995).

According to Johnson and Johnson (1999b), teachers must understand the nature of cooperation and the key components of a well structured cooperative lesson in order to use it effectively. When students work in small groups, the role of the teacher is to monitor the students' interactions and intervene where necessary to help their students learn and interact more skilfully (Johnson et al., 1994). The teacher's role is to observe the interactions of group members in order to assess their academic progress and their use of appropriate social skills. The teacher, by listening to students' explanations to each other of what they are learning, can determine what students do and do not understand.

2.10.4 Cooperative Learning Models.

Since the resurgence of interest in cooperative learning in the 1970s, several models of cooperative learning have been researched, developed and implemented (Biehler & Snowman, 1997; Kagan, 1992; Karnes & Collins, 1997). Of all the methods researched, the best evaluated are Student Team Learning (Slavin, 1990; Slavin, 1994), Structural Approaches (Kagan, 1992; Kagan, 1994; Kagan, 2007), the Jigsaw

Method (Aronson, Blaney, Sikes, Stephan, & Snapp, 1978), Group Investigation (Sharan, 1990; Sharan & Sharan, 1976), and Learning Together (Johnson & Johnson, 1975; Johnson et al., 1994; Johnson & Johnson, 1989; Johnson et al., 1993).

As previously indicated there are a number of theoretical perspectives which impinge on these cooperative learning models. For instance, Student Team Learning promoted by Slavin is based on the motivational psychology perspective, whereas the Learning Together method of Johnston and Johnston, and the Jigsaw method by Aronson (1978) are all based on the social-cohesion perspective and the theories of Morton Deutsch and Kurt Lewin (Johnson et al., 1994). However, the three most quoted models are Kagan's Structural Approach, the Student Team Learning approach and the Learning Together approach.

2.10.4.1 The Student Team Learning Model

Student Team Learning (STL) is a set of cooperative learning methods developed by Slavin, De Vries & Edwards (Slavin, 1980) that require students to work in four or five-member learning teams that are heterogeneous in terms of academic achievement, gender and race (Brown & Thomson, 2000). These learning teams stay together for five to six weeks or for the duration of a unit of study. During each week the teacher introduces new material in a lecture or by some other method of presentation. The team members then study the presented materials in their teams, making sure all understand the materials for quizzes and other forms of weekly assessments (Swisher, 1990). This method uses the concept of reward, individual accountability, and equal opportunities for success which are thought to be central to all student team learning methods (Slavin, 1994; Slavin, 1996). The team's reward is dependent on the average performance of the team, based on individual team members' scores in class assessments. Individual accountability means that each member of the team is responsible for their own learning as well as the learning of others. This ensures that each team member is capable of performing at the required level without the aid of team mates. Equal opportunities for success allow all ability range students to contribute equally to their team's success by improving on their own past performance (Slavin, 1996). Slavin insists that learning is an individual responsibility where students take quizzes individually to provide evidence of how much they have learned and team scores are determined by the degree of individual improvement over a previous score (Brown et al., 2000; Slavin, 1996). This method is well suited to teaching well-defined objectives with a single answer such as science facts.

2.10.4.2 The Structural Approach.

The Structural Approach to cooperative learning developed by Spencer Kagan is based upon the use of structures that are "content-free" ways of organising the interaction of individuals in a classroom to promote predictable outcomes in the academic, linguistic, cognitive, and social domains (Kagan, 1994). Since the structures are building blocks of a lesson, the Structural Approach recognises the distinction between 'structures' and classroom 'activities'. Structures usually involve a series of prescribed behavioural steps for presenting lesson content where they shape the interaction between students, and between the students and the teacher. Hence, teachers may use structures repeatedly with almost any subject matter and at any age level. In contrast, it is believed that cooperative activities almost always have specific content-bound objectives and thus cannot be used to deliver a range of academic content (Kagan, 1994).

The Structural Approach represents an array of group structures ranging from Think-Pair-Share, Line-ups, Roundtable, Numbered Heads Together, Three-Step Interview, Jigsaw, to Pairs Check (Thousand, Villa, & Nevin, 1994) that describe specific ways of cooperation, and can serve different functions such as subject matter review, concept development, cooperative work on projects, and so on. In addition, the Structural Approach incorporates some procedures from other cooperative learning methods such as Student Team Awards Divisions (STAD), Jigsaw and group investigation. According to Thousand, Villa and Nevin (1994), STAD has been considered as a lesson design for developing mastery. The structures associated with Structural Approach are thought to have positive outcomes on academic achievement, improved ethnic relations, enhanced self-esteem, safe and productive classroom ethos, and social skills development.

2.10.4.3 The Learning Together Model.

The learning together model of cooperative learning was developed at the University of Minnesota by David Johnson and Roger Johnson and involves students working together in small heterogeneous groups to produce a group product (Slavin, 1983). Group members help each other in a cordial environment, based on a collaborative relationship amongst the participants (McCulloch, 1985). As students work towards a common group goal, academic learning and achievement become valued by peers (Slavin, 1987). This is due to the fact that the students know that they cannot reach their learning goals if the other students in the learning group do not complete their tasks (Johnson et al., 1989). The ideal size of the group depends on each lesson's objectives, students' age and experience of working in groups, the availability of materials and equipment, and the time limits for the lesson (Johnson et al., 1994). However, a typical group may contain between two and six members with four being ideal. Since the group members produce a single product and receive rewards together, group building activities and regular discussions within groups about how well they are working together is a major focus of this method (Thousand et al., 1994).

The Learning Together model is not a structured process like STAD or Jigsaw (Harris & Hanley, 2004), as it is a conceptual approach which is used for both higher cognitive process as well as mastery of basic facts and skills (Johnson & Johnson, 1989). It is based upon the integration of the five key elements of cooperative learning as described in section 2.6.3. Essentially, assignments are constructed in such a way as to promote positive interdependence and individual accountability (Thousand *et al*., 1994), because simply placing students in groups and expecting them to work together does not of itself produce cooperation (Johnson, 1998; Kagan, 1994; Slavin, 1996). In support of this claim, Robyn Gilles argues that;

> …some children will defer to the more able children in the group who may take over the important roles in ways that benefit them at the expense of other group members. Similarly, other students will be inclined to leave the work to others while they exercise only token commitment to the task (Gillies, 2003).

As a result, the Learning Together model requires the five key elements, *positive interdependence, face-to-face interaction, individual accountability, social skills and group processing* to be included if true cooperative learning is to occur in small group learning (Thousand, Villa & Nevin, 1994). This means that the teacher must guide/facilitate learning in the Learning Together model by making a number of pre-instructional decisions such as group composition, method of assigning students to groups, group sizes, the social-skill and academic aims of the lesson, the role each student in the group will play, materials required for the tasks and how the room will be arranged. In addition, when the lesson begins, the teacher must set the ground rules and specify the expected social skills for this lesson as well as explain to the students what the tasks are; what the success criteria are; and how the concept of positive interdependence works and will be applied. During the lesson, the teacher's role is to monitor students' learning and to intervene to assist with tasks where appropriate, baring in mind the social skill objectives. Furthermore, the teacher would also be systematically observing and collecting information on each group's work and be ready to intervene when required to assist the students in completing the tasks accurately or when the group is not working effectively. From this the teacher can assess and evaluate students' learning and where appropriate, help the students to reflect on how well their group has functioned (Johnson et al., 1999b; Johnson et al., 1998; Johnson et al., 2003; Johnson, 1998).

2.10.5: Critique of Cooperative Learning Research.

The research literature is rich with studies which show the positive effects of cooperative learning but one is left wondering whether there are any negative effects and if so what might they be? Can they be overcome? Are the theoretical perspectives that underpin cooperative learning flawed in any way? In order to answer such questions, we must first look at the implementation of cooperative learning into teaching practice from the teacher's point of view (a cost benefit analysis). When you question the research in this way it is possible to see negative elements or potential barriers to the implementation of cooperative learning. As a practising teacher, chief among the negative elements is that a cooperative learning lesson can take more time to plan, prepare and execute compared to a more traditional teaching approach. It could be argued that with practice and experience this time differential could possibly be reduced. However, time is a precious commodity in education today, particularly in science education.

Most of the negative effects of cooperative learning are centred on the group dynamic. Group members sometimes seek a “free-ride” on the back of other’s work by leaving the completion of a group task to the other group members. In addition, the student who is left to do all the work sometimes decreases his/her effort to avoid being taken advantage of. Furthermore, pressure to conform may also suppress individual effort. Group work can also break down as a result of power struggles and conflicts between group members. All of these potential problems take time and practical experience to solve. In a curriculum which is content heavy, like the science curriculum, time is not on the teacher’s side, therefore the utility of cooperative learning may be compromised; the costs in terms of time may not be outweighed by the potential learning benefits when compared to the more traditional methods employed by the teacher in question.

Cooperative learning can also pose instructional issues when it creates situations where students of low academic ability or poor social integration become excluded from group interactions. Equitable relations between students can be a major stumbling block to the implementation of cooperative learning within mixed ability classes. Also, some students come to a task with a higher status than others. Research suggests that status problems can lead to learning difficulties. For example, as the high status student interacts more within the group they learn more from the task; as low status students interact less they in turn learn less. It has been suggested that these negative effects can be overcome by assigning competence to low status students, by giving students feedback on their cooperative behaviours and asking them to reflect on how the group members worked together; or by structuring positive interdependence and individual accountability into the lesson (Cohen, 1994a; Cohen, 1994b; Cohen & Lotan, 1997; Cohen, Lotan, Scarloss, & Arellano, 1999; Johnson et al., 1994). However, these suggestions will take time and perseverance to implement.

A critique levelled at cooperative learning research centres on the research paradigm under which these studies were carried out i.e. experimental or quasi-experimental quantitative studies. Siegel (2005) argues that such studies are artificial and researcher-controlled since the class teachers have little input or latitude to change the lesson design; in effect they are just implementing the treatment. This does not take into account the dynamic nature of teaching or the complexities of the decision-making processes which teachers go through during the normal course of a lesson.

> Investigators who conducted these studies employed pre-test/post-test research designs for which cooperative learning instruction was considered the treatment. Accordingly, the instructional methods used to foster cooperation, the frequency and duration of activities, the academic tasks, and the composition of student groups were determined by researchers. Teachers who participated in these studies were not involved in such decision making; they merely implemented the treatment as prescribed. While such quantitative studies may offer generalisable support for models of cooperative learning instruction, they provide little information about how teachers make decisions about and apply these models to their classrooms in natural settings (Siegel, 2005).

In addition, Siegel (2005) points out that most of the popular models of cooperative learning outline the key instructional elements but fail to describe how a teacher might determine the relative importance of each element, the degree to which each element should be used in each lesson, and the total amount of instructional time that should be devoted to cooperative learning activities as a proportion of the total instructional time available to each class.

The literature is awash with studies showing the efficacy of cooperative learning as an instructional model but there is a dearth of studies which outline how cooperative learning might be implemented. Of those studies that are based on teacher-initiated cooperative learning lessons, the results are mixed. Increases in student achievement were demonstrated in some (Hertz-Lazaworitz, Ivory, & Calderon, 1993), but not the majority (Sapon-Shevin, 1992) of these investigations. Upon analysing these findings

Stevens *et al* (1995) suggest that teacher departure from research-based models during implementation accounted for limited positive outcomes (Stevens & Slavin, 1995). They suggest that when researchers provided ongoing training and coaching to teachers who implemented cooperative learning as their primary method of language, arts and mathematics instruction, increases in student achievement were documented. However, this degree of researcher support and structured instruction is not typically available to teachers attempting to integrate cooperative learning into their classroom lessons.

This variation in outcome when cooperative learning is implemented can be traced back to a number of factors such as differences in perception, training, curriculum content, administrative requirements and school structure. Proponents of the experimental paradigm may view these influences as threats to internal validity, whereas teachers consider the modifications they make to instructional methods as evidence of their inventiveness, active problem solving, and practical necessity given their situation (Cuban, 1996). Thus, variations in teacher-initiated use of cooperative learning within a natural setting ought to be expected. Teachers don't teach the same lessons content in an identical way with different classes; they take the class context and ability range into account with each lesson.

When one looks at the theoretical underpinning of cooperative learning, namely social constructivism, one must take into account the criticisms of social constructivism when applying the cost benefit analysis to cooperative learning. A major problem in education is the deep rooted nature of misconceptions, and the difficulties associated with combating them. Cooperative learning's Vygotskian underpinning can present problems when it is put into practice, in terms of the more knowledgeable other. If the more knowledgeable other is a student and that student carries a misconception with regard to the subject matter of the lesson, it is possible that the misconception could be passed on to others and possibly amplified through cooperative learning. This means that the teacher must be extremely vigilant in order to be able to intervene if and when this occurs. However, once a misconception is seeded it is difficult for the teacher to remediate, particularly if the students fail to understand why the misconception is wrong. This danger is increased with larger classes since the frequency of teacher moderation inevitably decreases.

Furthermore, many implementation studies on cooperative learning come from Australia, the US and mainland Europe and, as such, one must take into account the student culture into which cooperative learning is being implemented, particularly since the theoretical basis of cooperative learning is socially dependent and thus by extension culturally bound. To date, there have been few, if any studies on cooperative learning with secondary school pupils in Scotland. This gap in our knowledge of how student culture (attitude and motivation to learning) affects the implementation of cooperative learning presents a real opportunity to study the effectiveness and efficiency of cooperative learning within a setting where pupil attitude to learning is poor and motivation to learning is questionable.

In terms of what cooperative learning contributes to the development of scientific literacy, it can be seen that as a method for managing small group discussion, it contributes greatly towards the development of pupils' interpersonal, social and communicative skills. In addition, it can contribute towards the development of the thinking skills required by pupils to negotiate their way through discussions of controversial socio-scientific issues which are commonly regarded as essential for the development of functional scientific literacy.

2.11 Summary.

Cooperative learning is a well researched pedagogical approach which has been advocated for a number of years, as a basis for teaching and as a method for the development of interpersonal and social skills. A large body of research on cooperative learning reveals positive effects on students' achievement, peer relationships and social development. Cognitive theorists for example, particularly Vygotsky (1978), emphasise that students' collaboration promotes growth and understanding, and there is a growing realisation that students must learn to think, solve problems, integrate their knowledge and apply their skills (Slavin, 1995). Cooperative learning is a vehicle for doing this (Veenman et al., 2000). Cooperative learning can positively influence the social relations with students of different ethnic backgrounds and mainstreamed special education pupils and their classmates (Slavin, 1995).

The use of cooperative learning methods like Student Team Learning, Structural Approach, and Learning Together range from the development of higher cognitive process to the mastery of basic concepts and skills. All of these methods require students to work in small groups to accomplish their assigned activities or tasks. Although individuals work toward a group goal, each group member is assigned a variety of responsibilities within the group and the members are held accountable for their own learning and contributing to the group goal. In terms of cooperative learning's contribution towards teaching for scientific literacy, its focus on the development of social and communication skills provides a means for students to experience and practice discussions involving controversial socio-scientific issues.

2.12 Using Cooperative learning to enhance the use of Discussion of Controversial Socio-scientific issues for the Development of Scientific Literacy.

Cooperative learning research indicates that, as a pedagogical tool, it is particularly good for developing pupils' interpersonal and social skills. These skills are required to allow them to function effectively within groups. In addition, the acquisition of these skills allows pupils to develop good behaviours and habits of mind and the communicative virtues which are required for the proper functioning of discussion, since the ground rule of cooperative learning sets clear parameters within which the pupils must operate. Furthermore, it is an effective way to foster positive attitudes, critical thinking and provides a way to expose pupils to multiple perspectives which impinge on any discussion. Thus it could be argued that cooperative learning is a suitable pedagogical approach for the promotion of discussion within school science, which would fulfill a number of purposes simultaneously. For example, the need to train science teachers how to manage discussion effectively could be easily fulfilled by training them in the use of cooperative learning as well as helping develop the interpersonal, social and critical thinking skills of pupils.

The use of cooperative learning by science teachers would allow the development and practice of discussion skills with the purpose of exposing pupils to the multiple perspectives which have a role to play in the differing and ongoing debates which surround contemporary science. It would also provide a platform from which pupils learn the basics of democratic citizenship, in particular how to develop, hold, and defend their opinions, based on evidence, and how to argue the merits of their opinions as well as how to be constructively critical of the arguments of others. As pupils engage with controversial socio-scientific issues, they construct their own knowledge and understanding of the facts pertinent to their discussion, thereby, giving them a sense of ownership since they actively had to discover the knowledge rather than passively absorb it. This should foster within the pupils the motivation to learn more.

When one looks at some of the characteristics of functional scientific literacy it is clear that cooperative learning provides science teachers with an approach which should help them to develop their practice, giving them the management and monitoring skills required to lead group discussion in a school science context. This should be valuable since science teachers have been shown to lack confidence (Bryce and Gray, 2004) and, apparently, the skills required to develop the less concrete and more subtle aspects of discussion (Levinson, 2001; Levinson, 2003).

The American National Research Council's *National Science Education Standards* suggest that a scientifically literacy person should be someone who has the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity. It also includes a range of specific types of abilities stating that

> Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences… entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions… implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the

> quality of scientific information on the basis of its source and the methods used to generate it... also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (National Research Council, 1996).

Cooperative learning provides a suitable vehicle through which these abilities could be taught and practised. Figure 2.3 show how these abilities and dispositions are interconnected.

Figure 2.3: *Schematic Diagram of how Cooperative learning can help develop Scientific Literacy.*

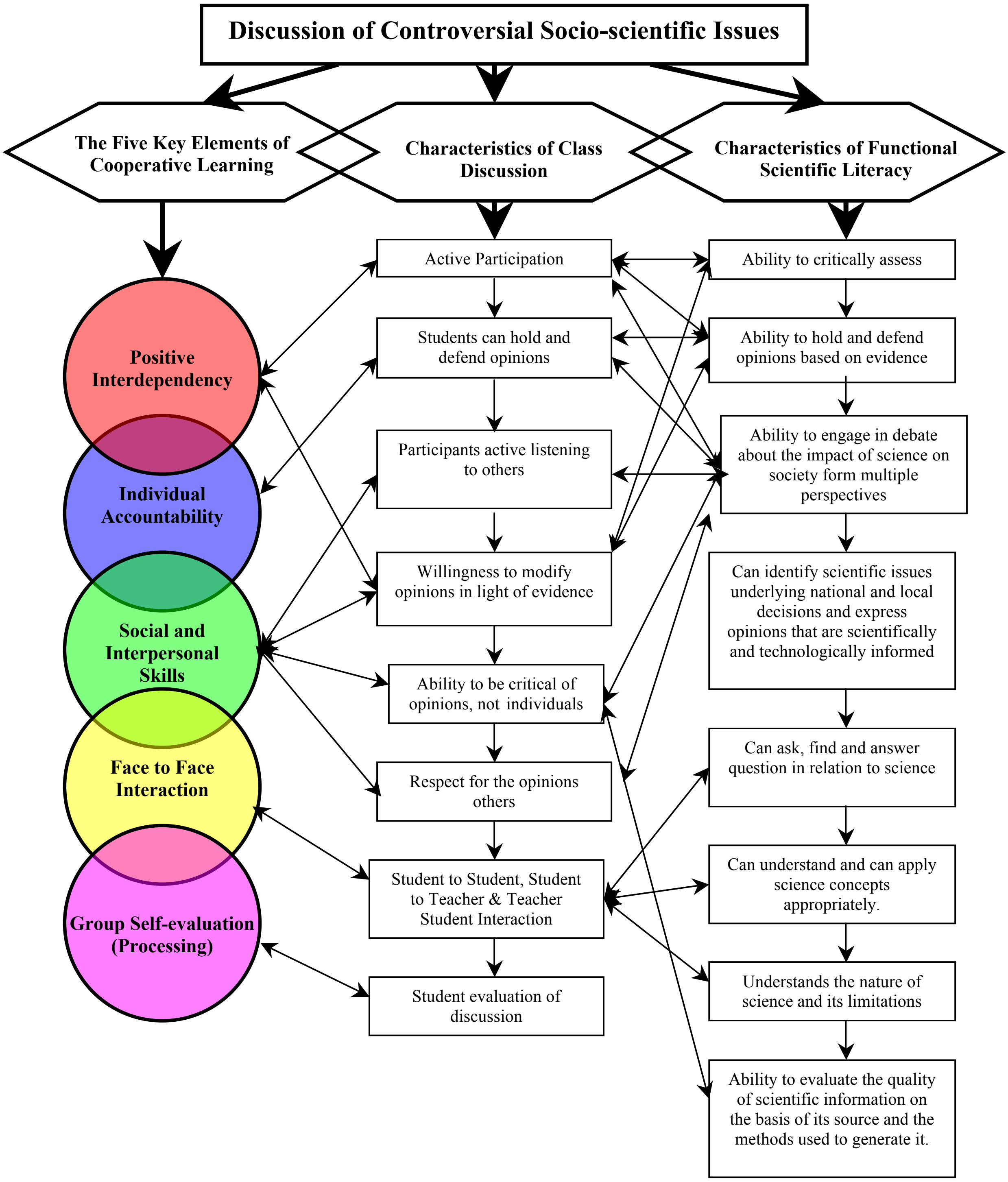


Figure 2.3 shows that the development of social skills through cooperative learning is a key element when one is trying to develop pupils' scientific literacy through the use of discussion of controversial socio-scientific issues. This element is a mirror of

the communicative virtues described in Levinson's framework for the use of discussion of controversial socio-scientific issues (Levinson, 2006b). The ability of the pupil to ask questions about and find information on socio-scientific issues is linked back to the face-to-face interaction within cooperative learning through the student-to-student, student-to-teacher and teacher-to-student interactions in the Dillon model of discussion described in section 2.5 (Dillon, 1994).

The development of functional scientific literacy for all pupils will be challenging for Scottish science education. However, we must also understand that this goal must include interaction with colleagues in the Humanities and Mathematics as the themes of Literacy and Numeracy also a play pivotal role in the development of pupils' scientific literacy. If pupils are to be expected to successfully engage with discussion of controversial socio-scientific issues, the ability to read for understanding, interpret and draw valid conclusions from data (which are key literacy and numeracy skills) is essential. In terms of literacy, students need to be able to communicate their ideas, views and opinions in both oral and written forms concerning controversial socio-scientific issues, since the ability to hold and defend their opinions about such issues is clearly stated in the science rationale of *CfE* (Scottish Executive Education Department, 2006).

The research on how teachers conceptualise and implement discussion as pedagogy suggests that science teachers, in particular, require access to high quality continuing professional development in order to help them deal effectively with discussion of controversial socio-scientific issues (Gray and Bryce, 2006). However, one must also bear in mind that even this may not be enough depending on the assessment system. Also one must not hold our Humanities colleagues up too highly as models of good practice, as research suggests that English and Social Science teachers (who do hold complex conceptual models of discussion) when they reportedly use discussion in their classroom, often fail to enact them when observed teaching (Alvermann et al., 1990; Hess, 2004; Nystrand, Gamoran, & Carbonaro, 1998).

The use of cooperative learning, as a method for managing discussion within science, furthers the development of pupils' scientific literacy by providing pupils with a socially constructed learning environment where they can air their opinions, evaluate the opinions of others, elaborate on the reasoning behind their opinions, and test the merits of differing opinion without fear or prejudice. In addition, it allows the pupils to learn together, how best to evaluate, analyse and interpret evidence from many sources by creating a forum through which they can assess the evidence openly. Cooperative learning activities also allow pupils to take control of the direction of the information retrieval process, the processing of the information found and the synthesis of meaning from that information. However, cooperative learning provides a method whereby pupils can practice the communicative virtues of openness, respect, equality, freedom, procedural action and a moral obligation to participate with the honesty required. These communicative virtues also form an integral component of pupils' scientific literacy.

From the teacher's perspective, cooperative learning allows the teacher to develop lessons that provide a more democratic, student-centred experience which exposes pupils to multiple perspectives and potential conflicting views in a progressive and supportive environment. It could also be argued that cooperative learning gives the science teacher a management tool which allows them to release control of the discussion to pupils without there being an appreciable decrease in class discipline or off-task behaviour. Furthermore, it may also provides science teachers with strategies which develop their ability to monitor and moderate the discussion with minimal intrusion, as well as allowing them to impose a structure to the discussion in terms of time management, pace of the lesson and the extent to which they become involved in that discussion.

Cooperative learning may provide a suitable bridge in terms of experience for the pupil to be able to begin the transition from primary to secondary school, in terms of managing the change in expectation from teachers and in terms of the difficulty level of the work being undertaken by pupils as they progress through the transition from primary to secondary school.

Developmentally, cooperative learning provides a staging post from which other pedagogical approaches may be developed, since it develops the social skills upon which other pedagogical approaches may rely. For example, as pupils move from the lower to middle secondary stage, the teacher may wish to use a more open form of inquiry such as problem-based learning which might involve the pupils having to solve a problem with minimal teacher input. In problem-based learning the pupil is usually expected to find the relevant information to help them solve the problem. This means that they will need to find, evaluate, interpret and synthesise meaning from the information available. These skills must first be developed by the pupil before they can engage effectively in a problem-based learning environment. Ultimately these skills will allow pupils to engage with controversial socio-scientific issues more effectively since they are not restricted to a rigid knowledge base of learned facts, as they will have become more familiar with the tentative nature of the science which underpins many of these issues.

Chapter 3. Methodology.

3.1: Introduction.

This chapter sets out the methodological approach of the research. First, a justification is given as to why action research was chosen as a methodology. Second, a brief résumé of the theoretical literature behind the paradigm is presented. Third, the methodology as applied to the research is set out. Lastly, the methodology is justified in relation to the aims of the research and the research questions set out in Chapter 1.

3.2: Background Context of the Thesis

The research paradigm through which the research was conducted was educational action research. The rationale for the study was the science department's response to the impending implementation of discussion of controversial socio-scientific issues in secondary science education, in the context of curricular changes required by the Topical Science strand of the new science curriculum. The proposed science learning outcomes emanating from *CfE* place the topical science strand and its clear emphasis on the use of discussion of topical issues in science at the centre of the new curriculum (see Figure 1.2). Key issues emanating from contemporary science such as climate change and global warming, sustainable development, embryonic stem cell research and therapeutic cloning are expected to be discussed within the science classroom in some form.

However, what is not clear from the professional perspective is how teachers might plan and deliver such lessons, when the use of discussion within their normal practice is limited at best. It was therefore decided that a useful way to assess the difficulties facing the implementation of this strand of the new science learning outcomes was to design a series of lessons which would test pupil prior knowledge, assess what knowledge needed to be assimilated in order to begin the discussion of a controversial socio-scientific issue, identify which skills the pupils would have to acquire in order to allow them to assess critically the information that would be presented to them during the course of such discussions, and to assess what factors might limit pupils' understanding of the issue being discussed.

In addition to pupil derived factors, it was also decided that it would be helpful to know what teachers' conceptual understanding of discussion was and what they thought about its educational purposes. As a department, we had lengthy discussions about *CfE* and together had identified the topical science strand as being potentially problematic from a pedagogical point of view.

The science department agreed that the approach to be used as the means of delivering discussion was to be cooperative learning, since the local authority had been encouraging its entire teaching staff to increasingly adopt this pedagogical approach within all curricular areas. In addition, all of the permanent science staff members had been trained to use cooperative learning as part of a rolling programme of teacher CPD (which involved a three day course in cooperative learning delivered by Canadian 'experts'). Furthermore, all the probationary science teachers had been given some CPD in cooperative learning by the local authority prior to the commencement of this research.

3.2.1: Why choose Educational Action research?

As a research paradigm, educational action research fits well with this research in that it aims to introduce, evaluate and improve upon new pedagogical practice within one science department. The strategy also allows the use of a mixed-method model of data collection and analysis since it allows both quantitative and qualitative data collection and analysis. In addition, action research allows a rich picture of the reality of a practical situation to be observed and investigated without forcing a quasi-experimental design on the research. This is particularly important as the study involved the investigation of practice within a non-contrived setting, which is comparable and should be readily recognisable within any Scottish secondary school. Furthermore, the participants and ultimate consumers of the findings of this research are practising teachers and, as such, the research would need to be accessible to them, both in terms of the values of the research to their practice, and in terms of providing evidence to support the comparability (rather than generalisability) of the findings to teachers' own situations.

3.3: Educational Action Research: *a theoretical background*

Action research is known by many names, such as action learning, emancipatory research, participatory research, collaborative inquiry, and contextual action research. However they are all variations on a theme. Locking down a definition of what action research can be is complicated, due in part to the diversity of its application and, mainly, to the theoretical positions on action research which appear within the research literature. "Learning by doing" can provide a somewhat simple description of what action research is, since action research usually consists of a group of people identifying a problem, who then go on to do something to resolve that problem then, through observation of their intervention, evaluate their efforts, and, if not satisfied, try again until they are satisfied. While this description captures the essence of the action research approach, there are other key elements to it which differentiate it from common problem-solving activities that we all engage in every day.

Kemmis and McTaggart (1988) in their 2nd Edition of *The Action Research Planner* draw together a number of different strands of action research offering a definition by describing it as;

> … a form of collective self-reflective inquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social and educational practices, as well as their understanding of these practices and the situations in which these practices are carried out…The approach is only action research when it is collaborative, though it is important to realize that the action research of the group is achieved through the critically examined actions of individual group members (Kemmis & McTaggart, 1988).

Four years later in the 3rd Edition of *The Action Research Planner* they make the distinction between action research and the everyday actions of teachers by concluding that action research is not the same as the usual thinking that teachers do when they reflect on their teaching. Action research is more systematic and collaborative in the collecting of evidence on which to base rigorous group reflection. They go on to suggest that action research involves both problem-posing as well as problem-solving and, as such, is not research done on people but is research done by particular people on their own work, to help improve what they do, including how they work with others. They suggest that action research is not ‘the scientific method’ applied to teaching, since there is not one view of ‘the scientific method’ but there are many views (Kemmis & McTaggart, 1992).

However as alluded to previously, a number of researchers have chosen to characterise action research in many ways. For example, Noffke and Zeichner make a number of claims for it with teachers, particularly that it brings about changes in their definitions of their own professional skills and roles and that it increases their feelings of self-worth and confidence. As a consequence, this increases their awareness of classroom issues and improves their disposition towards reflection, which can lead to them changing their values and beliefs. Furthermore, they claim that action research improves the congruence between practical theories and practice and can broaden teachers’ views on teaching, schooling and society (Noffke & Zeichner, 1987) .

Action research, the combination of action (*praxis*) and research (*theoria*), suggests that action is a form of disciplined inquiry, in which a personal attempt is made to understand, improve and reform practice (Ebbutt, 1985; Hospkin, 1985). Other researchers define action research as small scale intervention in the functioning of the real world and a close examination of the effects of such interventions (Cohen & Manion, 1994). Kemmis and co-workers argue that to do action research is to plan, act, observe and reflect more carefully, more systematically, and more rigorously than one usually does in everyday life (Kemmis et al., 1992). The significant feature arising from Noffke & Zeichner (1987) is the claim that action research is a means of continuing professional development for teachers. Others have supported this claim since action research is situated learning; setting professional learning in the workplace, about the work place (Collins & Duguid, 1989). Educational action research acts as a bridge between research and practice (Somekh, 1995) which strives to overcome the persistent failure of traditional educational research to impact on or improve practice (McCormick & James, 1988; Rapoport, 1970). It has been suggested (Stenhouse, 1979) that action research should contribute not only to practice but also to a theory of education and teaching which is accessible to other teachers, making educational practice more reflective (Elliot, 1991).

John Elliot, a leading British proponent of educational action research, presents the ‘traditional’ view of educational research by proposing that there is a whole field of research which claims to focus on teachers’ practical knowledge, thinking, beliefs and the assumptions which underpin their practices and how they are constructed in the workplace. Yet traditional researchers do not passively mirror the teachers’ views but represent them as stories. He goes on to suggest that very few researchers report whether the teachers that they have researched have ever challenged their construction of their own knowledge, citing that textual meaning is a personal construct which can be read in an infinite number of ways and thus teachers’ experiences of schooling can also be interpreted in several ways. Different teachers, like eyewitnesses, tell different often conflicting stories about similar situations and events (Elliot, 1994).

He goes on to suggest that what validates a story is that it constructs meaning for the person telling the story, and goes on to argue that the point of telling the story is to share the experience with others, not to debate its credibility or validity but to have the view of the self-constructed in the story affirmed by others. He also points out that researchers tend to have easy access to teachers for research through the delivery of teacher education. Thus the subjects may already be known to them from initial teacher education. Yet the literature rarely examines this role and context and the way in which factors operating in it influence the way teachers’ knowledge is represented by the researcher. Further, Elliot suggests that teachers hold commonsense, intuitive theories which are embedded within teachers’ culture and that it is these commonsense theories which create the conflict between research and practice and that researchers need to explicate what these teacher-held, commonsense theories are and explain why they are adhered to so persistently in spite of the evidence. Elliot goes on to suggest that valid and reliable knowledge can only be acquired by replacing the vernacular culture which shapes these commonsense understandings of experience with contemplative academic cultures whereby the research into teachers' knowledge is simply a technical means of subordinating the vernacular culture with the neo-platonic forms of objective knowledge which have evolved in academia.

By way of contrast, Elliot also presents his view of educational action research by arguing that its main features are quite different from 'traditional' educational research in that:

- It has a pedagogical aim which embodies an educational ideal through which all those involved in the research are committed to realising.
- It focuses on changing practice to make it more consistent with the pedagogical aim through the gathering of evidence about the extent to which practice is consistent or inconsistent with the aim.
- Through identifying inconsistencies between aspiration and practice, it problematises the assumptions and beliefs (theories) tacitly embodied in the latter.
- It involves teachers in the process of generating and testing new forms of action for realising their aspirations and thereby reconstructing their practical pedagogical theories.
- It is a pedagogical process characterised by teacher reflexivity. From an action research perspective, teaching is a form of research and vice versa.

Thus Elliot sees action research as different to 'traditional' educational research as the former embeds teacher knowledge in concrete practices. Understanding comes from the analysis of evidence about practice and the generation of new knowledge comes via the formulation and testing of action hypotheses in the light of such analysis, thus integrating the process of pedagogical change and theory generation. Educational action research assumes that such knowledge can be questioned and challenged by outsiders and theorists alike. In addition, educational action research is not threatened by new theories if they are translated into concrete curriculum proposals which can be reflectively explored through teachers' action research. Furthermore, such theories do not simply replace teachers' theories since it is the teachers who decide what theories to adopt as a basis for practice. Thus the gap between educational research and educational practice might be bridged since the teacher becomes the researcher.

3.4: Application of the methodology to the research

3.4.1 Ethical considerations related to the research.

This research employed a mixed-method (qualitative and quantitative) model where data was gathered using semi-structured interviews, classroom observation and questionnaires from teachers and pupils.

The research was conducted within a typical West of Scotland non-denominational comprehensive secondary school which throughout this thesis will be referred to as XHS. Written permission to carry out this project within XHS was granted by the local Education Authority (see Appendix A) and then by the head teacher of the school. All of the teachers who were identified as being suitable for inclusion in the study were issued with an information pack explaining the project and its aims, as well as with a consent form should they wish to take part in the research. In addition, all S2 pupils (age 13-14) were issued with project information packs, which outlined the proposed aims of the research as well as a written description of how it would be applied over the course of the project. This pack also contained a parental letter seeking consent for their children to take part in the pupil group discussion in accordance with local policy. The authority insisted that their parental consent form was used as the basis for consent as they preferred that parents opt out of the research, should they choose, rather than opting in.

Privacy, confidentiality and anonymity were assured as the teachers involved in the semi-structured interview part of the study did not know who else was participating. The teachers were interviewed at random over a three year period and, with the exception of the science teachers, were only interviewed once. All teachers were assigned a code that identified which group they belonged to and their position within that group, for example experienced science teachers were given the prefix ExST; a number of probationary science teachers were given the prefix NQST; and a number of experienced humanities teachers were given the prefix ExHT. All interviews were audio-taped within the school and transcribed by the author at home.

The interviewees were given a copy of their interview transcript to read and if they so wished could modify it if they felt that the transcript was in any way inaccurate. Each teacher was then asked to sign that they had read and agreed that the transcript was accurate.

For the pupil group interviews, all pupils who participated were reminded at the start of the interview of their right to confidentiality and anonymity and it was explained to them that anything that was said during the group discussion was private and confidential and that no teacher would know who said what. In addition, an explanation as to why the research was being done was given and it was stated that if they so chose, they could terminate the interview at any time. Each of the group interviews was treated in the same manner as the semi-structured teacher interviews in that they were audio-taped in the school but were transcribed by the author at home. However, owing to the time taken to transcribe, transcripts were not checked by the pupils for accuracy. At no point in this research would the personal details of the participants be divulged to a third party and so the only personal details noted were names, age, gender and, in the case of the teachers, their number of years of experience in teaching.

It was agreed with the local authority and the head teacher that feedback on the research would take the form of a written report and presentation of findings to the authority and as a presentation to the whole school staff at a future staff development event in 2010.

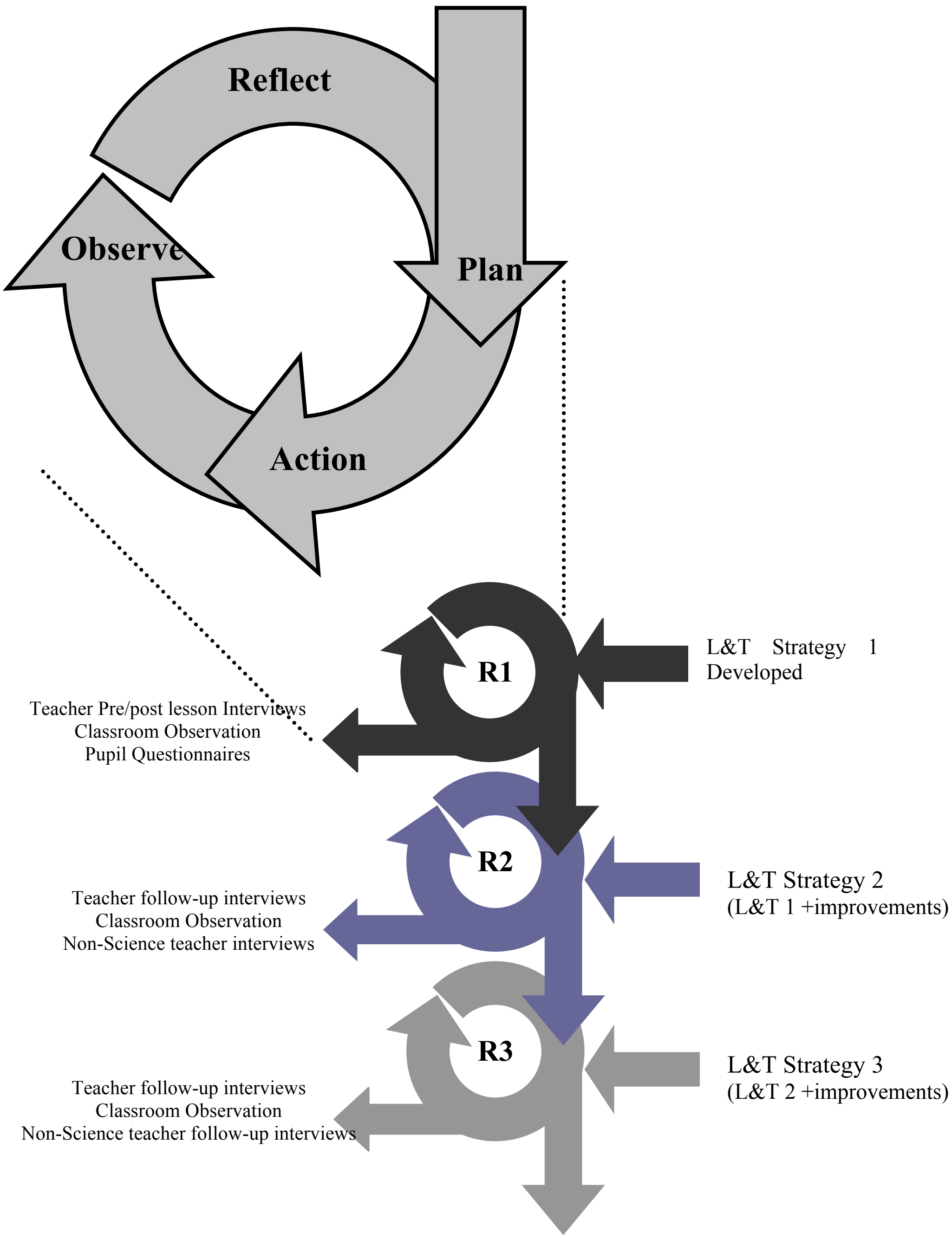
3.4.2 School context of the research

The research was in three parts. Part one was based around semi-structured interviews with teachers in order to determine their conceptual understanding of discussion. For this part of the study the teachers were split into three groups: experienced science teachers; newly qualified science teachers in their probationary year; and experienced humanities teachers.

Part two was based around the action research study itself which included the planning of the learning and teaching strategies that would be employed through discussion of the controversial socio-scientific issues. Lessons were observed as they were taught by the teachers *in situ*, and the evaluation of the learning and teaching strategies carried out afterwards in order to further develop the strategies prior to the next round of action research.

Part three was based around the analysis and reporting of the evidence derived from the pupil questionnaires, teacher interview transcripts, pupil group interview transcripts and lesson observation field notes. The data from this study would be used to provide a better understanding of how successful the process was and to enable the department to evaluate the management of curricular change through the development of evidence-based practice. In addition, the results of this study would be used as quality and standards evidence, hopefully to show that the incorporation of discussion of controversial socio-scientific issues into secondary school science was implemented in a thoughtful and effective manner based on the evaluation of evidence. Figure 3.1 shows a diagram of how the action research project proceeded over a three year period from August 2006 to June 2009.

Figure 3.1: *Schematic Diagram of the action research process*



3.5: The Action Research Project.

The action research project was set up to run for three cycles between April 2007 and June 2009, in order to develop and evaluate a series of lessons which incorporated the discussion of climate change and global warming into the teaching of the S2 Science course.

As depicted in Figure 3.1 each lesson in the first round of action research was designed to meet the needs of different learning outcomes. For example, lesson one in the series of three was designed to build on the pupils' prior knowledge, to extend their knowledge and to set questions that they would use to research areas of the topic. Lesson two was designed to cover numeracy outcomes which included drawing graphs, interpreting the data and drawing conclusions from that data. This lesson was designed to show that the data presented *contradicted* the hypothesis that increasing CO_2 concentration in the atmosphere was causing increased global warming. Lesson three was designed as a decision-making exercise built around a political debate in the House of Commons where pupils were asked to choose which option they would choose from three and why. During the teaching of the lesson series, the researcher (author) observed a cross-section of the lessons given by teachers. At the end of this round of research the pupils were asked to complete a questionnaire which probed their views on science and technology, school science and the series of lessons on climate change and global warming. The teachers were interviewed pre- and post- lesson series to gather their views on the teaching of discussion and to clarify their thoughts on the use of cooperative learning and how the lesson series went for evaluation purposes.

The second round of action research incorporated changes suggested by the teachers and involved modifications to the learning and teaching materials, observation of a cross-section of the lessons *in situ,* and teacher evaluation of the lessons afterwards. This round saw the creation of a review committee to oversee the evaluation and changes to the learning and teaching strategies prior to the third round of action research. The general theme of each lesson was consistent. However, modifications to the materials varied depending on feedback from the teachers. At the end of each round of teaching, the S2 cohort was given an assessment to see how well they understood what they had been taught. The assessment at the end of each round of research varied since as a department we were trying to develop an assessment tool that would account for different aspects of the lesson, i.e. knowledge and understanding as well as literacy.

The third round of the action research cycle incorporated changes to the learning and teaching strategies employed in round 2 and was seen by the teachers as a refinement of the lessons presented in the previous rounds. The content of each lesson was the same but the cooperative learning approach was more the focus since the majority of the teachers were now more comfortable with cooperative learning and felt more confident trying to incorporate areas of formative assessment into their lessons. This included peer review through the ladder of feedback where pupils made presentations of their own area of research which impinged on climate change as the topic of discussion.

Throughout each of the rounds of action research, pupils' questionnaires, worksheets, posters, graffiti boards and test papers were retained for analysis to provide a rich picture of the pupils' work in each class as a method of evaluating what they achieved in each lesson.

3.5.1: Round one of the action research

Round one of the action research project began in January 2007 with the development of a series of three lessons on discussion of climate change and global warming. Each lesson was based around a key concept in order to fulfil a number of learning outcomes designed to develop specific components of scientific literacy, these components being scientific knowledge, data analysis and interpretation, discussing multiple perspectives on the topic and democratic decision making.

The lessons were planned to incorporate all the key elements of cooperative learning as the pedagogical approach to teaching each lesson. Figure 3.2 shows the plan of action for the gathering of data which followed on from the teaching of the lesson series.

Figure 3.2 *Action Research Round One Data Gathering Plan.*

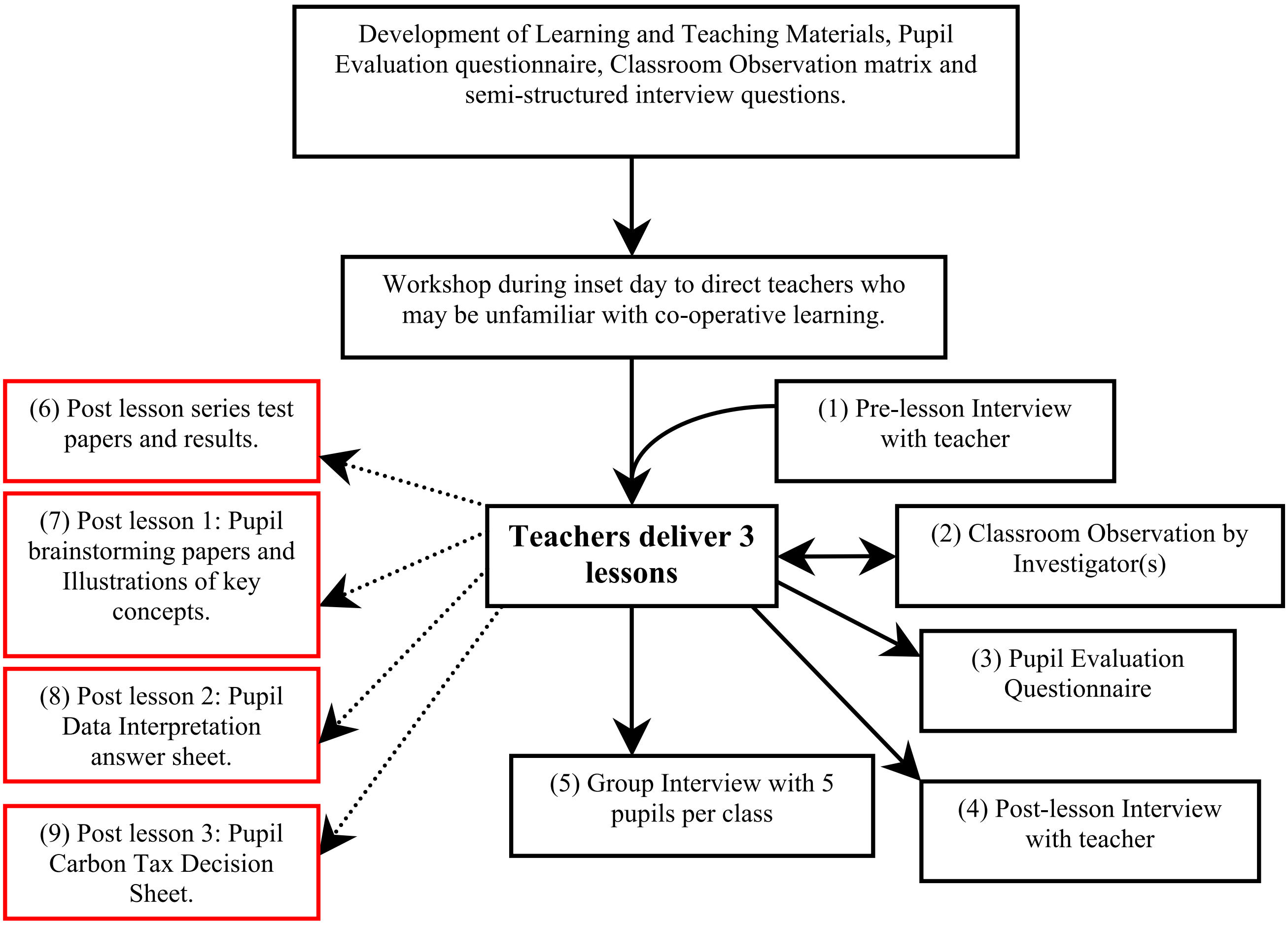


Figure 3.2 shows the action plan for the gathering of data during round one of the action research project. The red boxes show data derived from the pupils' work in each lesson (boxes 6 to 9). Boxes 1 to 5 detail the data gathering procedure used by the investigator in round one.

3.5.2 The lesson series: Round one.

The lesson series was preceded by two periods of cooperative learning training for each class which involved group formation and team building activities to allow the pupils in each class to experience the approach and to allow the teacher to set the ground rules for how they wanted these lessons to work within their classroom. These sessions gave the pupils the opportunity to become familiar with their roles and the approach.

Lesson one in the series was designed to assess pupils' prior knowledge on global warming and climate change by using both brainstorming and a KWL grid to bring to the fore prior knowledge gained by the pupils from both their primary science and secondary science experience as well as possible information from the media. A KWL grid is a grid with three columns which set out what pupils think they **know** about a topic, what they **want** to know about a topic and what they have **learnt** about the topic. In addition, this lesson sought to establish what knowledge needed to be gained to help establish a fuller understanding of the issue of climate change and global warming. The lesson was concluded by the pupils in their groups presenting a poster describing the greenhouse effect.

Lesson two was designed to assess the pupils' ability to construct graphs from data and interpret the underlying meaning of the data. This involved the pupils drawing two graphs and answering questions based on the graphs. This was done using a worksheet called Analysing Greenhouse Gas data worksheet.

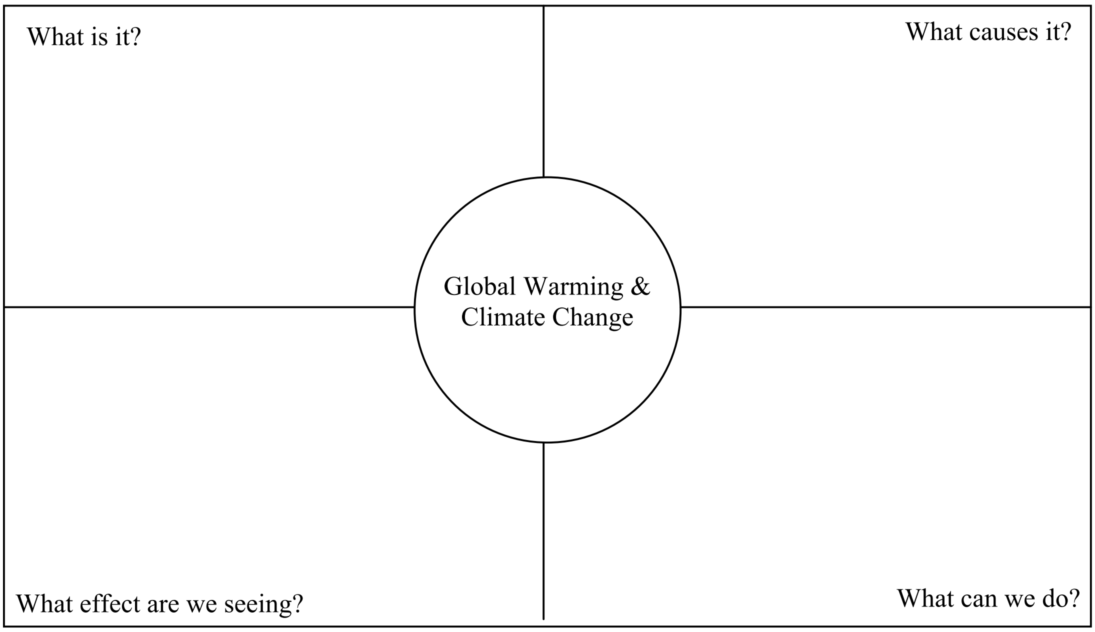
Lesson three was designed as a class debate where they were given three statements from three MPs; one Labour, one Conservative and one Liberal Democrat. Each statement outlined their party's thinking on the issue of climate change and their views on a carbon tax. In this lesson the pupils were to discuss each statement and fill in a decision grid which would help them weigh up the proposals, after which they were to vote on which view they agreed with and why. In each lesson, the teacher used cooperative learning as the main pedagogical approach.

Teachers were interviewed both pre-and post-lesson to establish what their conceptual understanding of discussion was and what their views were on the use of cooperative learning as an approach to delivering such discussion. The pupils were also tested at the end of this round of research to assess their knowledge and their ability to communicate their views in the written form.

3.5.3: Lesson Series: Round Two.

In the second round of the action research project the lesson series was modified from a series of three lessons to a series of seven lessons. Lesson one was changed from a brainstorming session and KWL grid to a graffiti board which served the same purpose of assessing the pupils' prior knowledge and highlighting any pupils' misconceptions. The graffiti board was set up as in Figure 3.3.

Figure 3.3: *Graffiti board configuration.*



During this lesson, the teacher collated all the information gathered from the groups to build a mind map which represented the class's current ideas and where the teacher could challenge any misconceptions.

Lesson two focused on reviewing four documentary programmes on climate change and global warming. Each group would take one documentary and review it for aspects of the issue such as what is global warming, what causes global warming, what are the effects of global warming, what is currently being done by governments and individuals. The four documentaries reviewed were: The great global warming swindle, An inconvenient truth, Global warming: you can make a difference, and The Eye of Nye - Global warming and climate change.

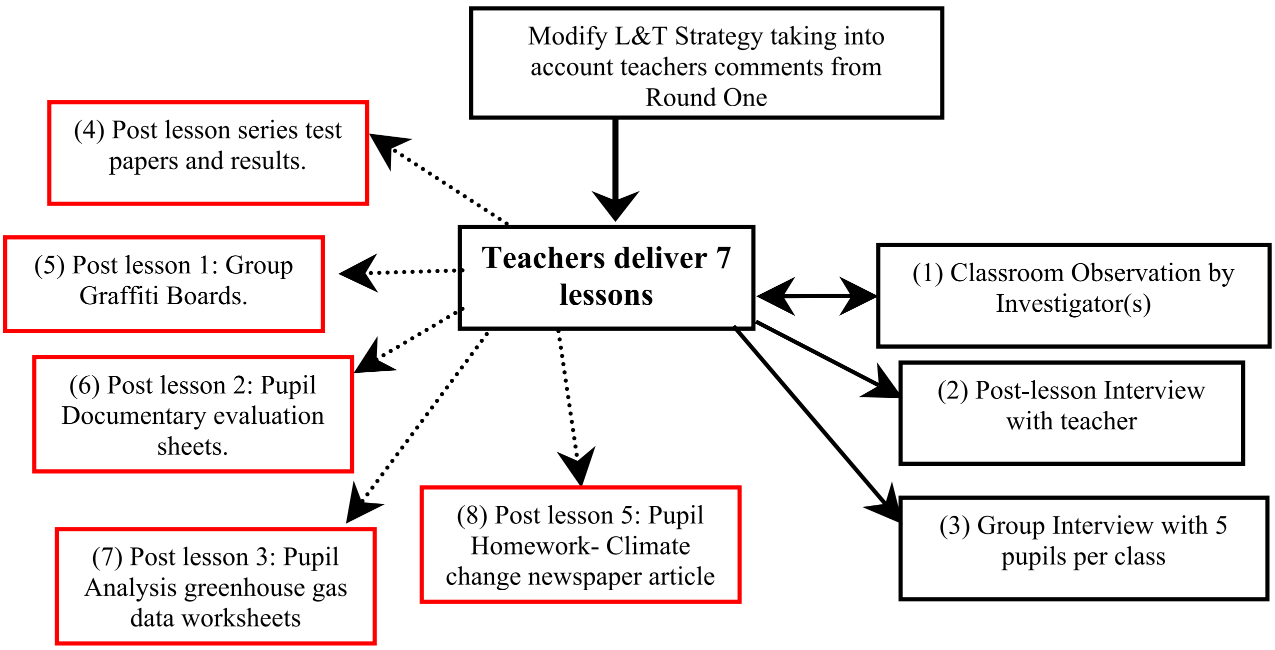
Lesson three involved the evaluation of each documentary programme in order to compare and contrast the views expressed in each programme. This helped the pupils to see that the scientific evidence can be interpreted in very different ways. It also provided the focus for group research topic later in the series of lessons. In the second half of this lesson the 'analysing greenhouse gas data' worksheet from round one was used to assess the pupils ability to draw graphs and conclusions based on greenhouse gas data.

Lesson four involved the pupils researching an aspect of global warming in their groups using the internet. After the pupils had completed their research they had to plan and deliver a mini-lesson to the class the following day using either a poster, a story board or as a PowerPoint presentation.

Lesson five involved the teaching by the pupils of their mini lessons to the whole class during which their lesson was peer assessed using the ladder of feedback technique after the class had negotiated the criteria for success. At the end of this lesson the class was issued with homework which involved each pupil writing a newspaper article on global warming and climate change which drew on what they had learned so far.

Lesson six took the same format as the third lesson in round one where the groups analysed political party positions on climate change and global warming. In this lesson each group had to take part in a mini debate in the 'House of Commons' facilitated by the teacher in order to ensure that all the political parties' views were expressed. At the end of the debate the pupils would take part in a class mock election. Lesson seven involved the class sitting an end of topic written test.

Figure 3.4: *Research Action Plan Round Two*



3.5.4: Lesson Series: Round Three.

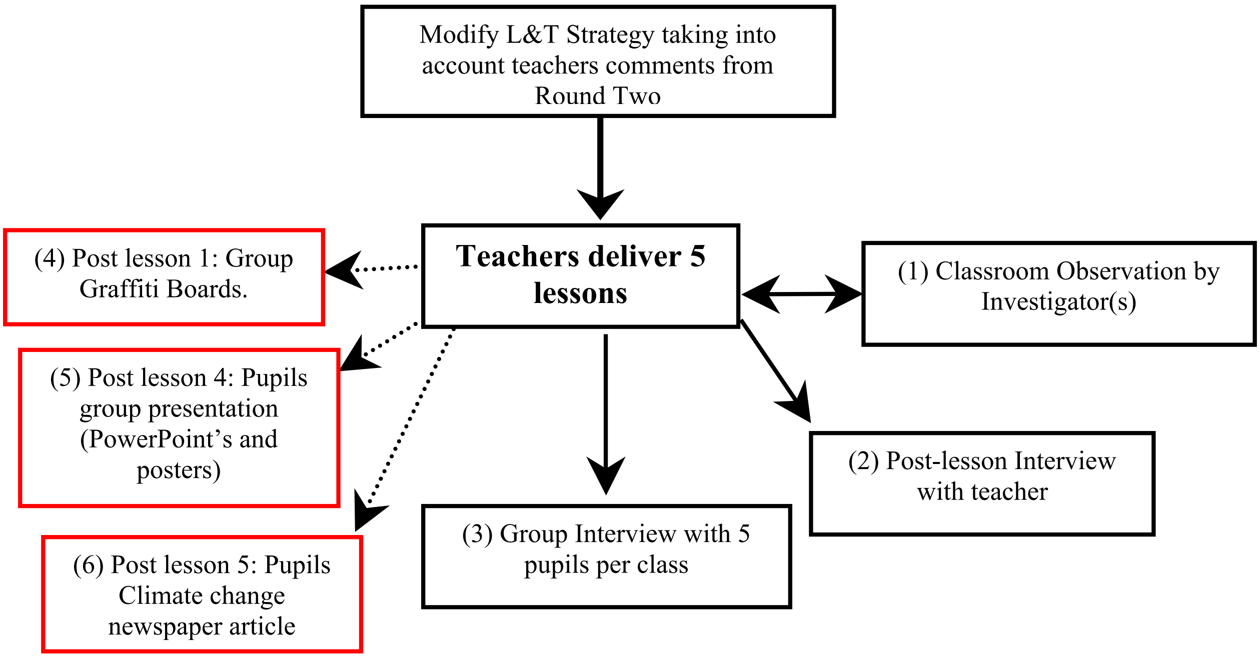
In the third round of the action research project there were a number of minor changes to the structure of two of the lessons from the second round. Lesson one remained unchanged, whereas lesson two changed from using four whole documentaries to using two which had been edited down using key questions to stimulate discussion. The Inconvenient Truth and the Great Global Warming Swindle were the chosen documentaries since they took up diametrically opposing views while using mostly the same scientific evidence. This lesson revolved around a PowerPoint presentation which had video clips embedded into it. Each video clip was set in context by the posing of a question about the theory of climate change due to man-made global warming. The clips were set in order so that the questions and extracts from an Inconvenient Truth came first, then the same question as for the Inconvenient Truth set the video clips for the Great Global Warming Swindle in context. The clips were edited in such a way as to help answer the key questions and in the case of the Great Global Warming Swindle, to tone down the dramatic overtones and obvious editorial bias of the documentary.

Once the PowerPoint of the two documentaries was complete the pupils had to discuss in their groups, using a card sort exercise, what evidence and theory the Inconvenient Truth and the Great Global Warming Swindle has put forward to support their claim that man-made CO_2 was increasing global warming and climate change and that rising CO_2 levels were not causing increased global warming and climate. Then using a second larger card sort the pupils in their cooperative groups had to sort 25 statements under the headings 'Statements for CO_2 causing global warming', 'Statements for solar activity causing global warming', statements which describe the effect of global warming and a number of irrelevant facts.

Lesson four involved research by the pupils in their groups into the effects that global warming and climate change are having on animal habitats, the spread of disease, on the weather and the water cycle, on food availability for humans, and on rising sea levels and the melting of the polar ice caps. This lesson was designed to run over three to four class periods for as long as it took for the groups to be satisfied that they had found enough information to fulfil the task of delivering a presentation to the whole class on their research topic. Assessment of their presentation was through peer assessment using the ladder of feedback. Before the groups began their research the ‘ladder of feedback’ peer assessment process was explained to the whole class, where the teacher explained that the presentations would be assessed for *Clarity*: Is there anything in the presentation that you didn’t understand?; *Value*: What did you think was good about the presentation?; *Concerns*: Are there any aspects of the presentation that you think the group should have thought about or could improve on?; and *Suggestion*: Can you make any suggestions on how they could improve their presentation? This meant that the groups were fully aware of the assessment criteria before they researched and developed their presentations. The class was then asked to discuss in their groups what the success criteria could be for the presentation. This session could be directed by the teacher so that the groups would include success criteria such as: relevant material that is easy to understand, presentation is interesting and eye-catching where you want to find out more and delivery of the presentation; does it keep the audience engaged?

Lesson 5 involved the ‘expert witness’ technique where groups were re-formed with a ‘specialist’ from each of the research area groups. The group task was to produce a special feature newspaper article on climate change and global warming. The pupils could use any medium to produce this. This piece of work would be used as an additional assessment of the research lesson as each article would have input from each pupil individually.

Figure 3.5: *Action Research Plan Round Three.*



3.6 Data Analysis

3.6.1: Pupil Questionnaire, development, administration and analysis.

All pupils were issued with a pupil questionnaire survey which was based, in large part, on the Relevance of Science Education (ROSE) questionnaire with some additional sections added in order to gather some issue-specific information. (See appendix H) The survey used a four point Likert scale to allow for both a simple analysis and for a more in-depth analysis later on. In all, 238 questionnaires were issued. The questionnaire contained 239 item split into thirteen sections.

Sections A, D & I (corresponding to sections A, C & E in the ROSE survey) contained 107 items on "what I want to learn about". Section B (corresponding to section D in the ROSE survey) contained 18 items on "me and the environmental challenges". Section C (corresponding to section G in the ROSE survey) contained 16 items on "my opinions about science and technology". Section E (corresponding to section F in the ROSE survey) contained 16 items "my science classes". Section F was the Statements about Science Instrument (SASI) which contained 13 items. Section G (corresponding to section J in the ROSE survey) asked pupils to estimate "how many books are in your home". Section H asked pupils about their S3 course choice. Section J contained 18 items on the global warming discussion lessons. Section K (corresponding to section B in the ROSE survey) contained 26 items "my future job". Section L (corresponding to section K in the ROSE survey) contained 8 items "how I feel about science in school". Section M (corresponding to section I in the ROSE survey) asked the pupils about "myself as a scientist".

3.6.1.1: Validation and Processing of Survey Returns.

All of the returned questionnaires were first examined to determine the extent of completion and scanned by eye for patterns. If sections G, H, I, J, K and L were not reasonably fully completed the paper was rejected. Questionnaires where the responses appeared to present patterns on the page were also rejected. However, as with the Scottish arm of the ROSE project it should be noted that papers where many of the responses in Sections A, D and I selected the same left-most option, indicating extreme lack of interest in science topics, were not rejected, provided that a wider mix of responses had been selected for items in other sections of the survey. The authors of Scottish ROSE survey felt that such returns might represent a frivolous response, but it was felt that these responses seem to be from pupils who genuinely regard science as a deeply uninteresting subject. This view has also been supported by those analysing the Norwegian survey. This was reinforced when reviewing responses to the section on "myself as a scientist" where the pupil was asked what they would like to research if they were a scientist. Several answered that they did not wish to be a scientist under any circumstances as they found the subject too 'boring'. This extreme negative response to sections A, D and I were provided in 4% of the returns.

The data was then inserted into an excel spreadsheet manually by the researcher in class batches. Each class group started the series of lessons at different times so questionnaires were returned in batches with the time between the first and last batch being three weeks.

The coding of the responses to the questionnaire was designed by the ROSE group to be as straightforward as possible. As a general rule, the actual position of a pupil's response to an item in the questionnaire was the value to be entered. Thus, a tick in the first box opposite each item was entered as '1', in the second box as '2' and so on. The following examples illustrate what this meant in practice.

Questions A01 to A48: stem question: 'What I want to learn about'
Measurement variable: ordinal
Value labels: 1 not interested, 2 low not interested, 3 low very interested, 4 very interested
Missing value: 0

Questions C01 to C16: heading: 'My opinions about science and technology'
Measurement variable: ordinal
Value labels: 1 disagree, 2 low disagree, 3 low agree, 4 high agree
Missing value: 0

3.6.1.2: Interpreting the Likert Scoring System.

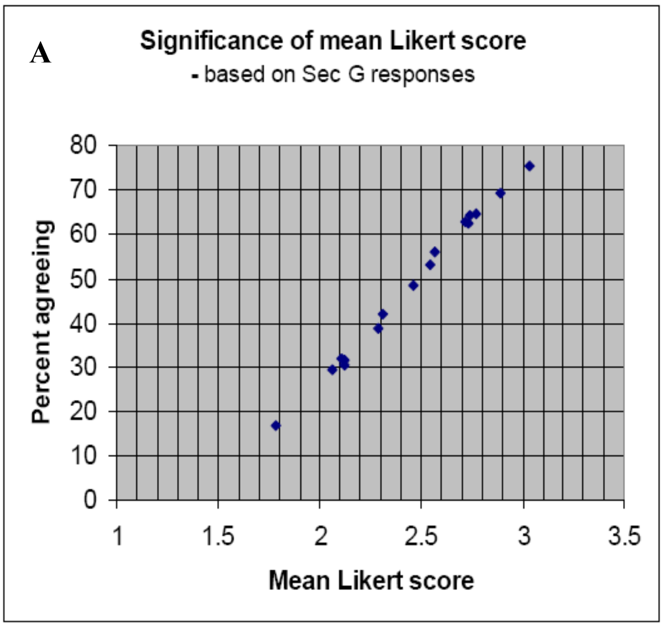
In terms of preliminary analysis it was convenient to review the 'mean Likert score' for an item or a group as a single measure of responses. The four point scale gives information on both the direction and the intensity of each pupil's view. If one is looking for policy responses that might better engage pupils' interest, or seek to challenge their opinions, it is helpful to know not only the 'average response', but also how strongly views are held, and whether opinion is polarised.

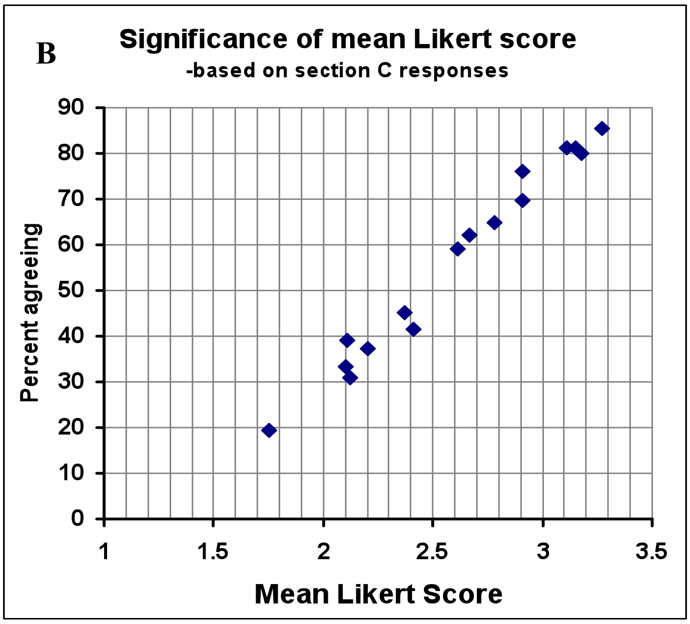
However, at this point it should be noted that the international ROSE data can be criticised from a statistical standpoint since the data derived from the ROSE questionnaire is of an ordinal nature. As such the use of a mean Likert scores is mathematically incorrect since an ordinal scale is strictly speaking not continuous and as such a value of 2.5 is not valid as a data point falling half-way between the categories of 2 and 3, since the respondents could only chose either 2 or 3 with no choice between the two points (Reid, 2006).

This point notwithstanding, the 'mean Likert score' is the evidence most heavily referred to within the context of this study since the data from the Scottish arm of the ROSE study is reported using mean Likert scores, thus allowing comparisons to be made. In addition, international research published from the ROSE group also refer mainly to these values. It is therefore important to appreciate the significance of the range of values that this quantity might take. On the 4-point scale the lowest two values (1 and 2) represent negative responses, whilst the highest two values (3 and 4) are weak and strong positive responses. If opinion on an item is evenly divided, and if negative views are held as strongly or weakly as are positive views, then the mean Likert score will be 2.5. So values above 2.5 can be interpreted as 'net positive' and values below 2.5 as 'net negative.' In a survey such as this it is common for most mean Likert scores to lie quite close to the central value of 2.5, and values above 3 or below 2 tend to occur relatively rarely. In most other surveys familiar to non specialists, questions of opinion tend to be asked on a 2-point scale: the respondent is asked whether they agree or disagree with a given view, or whether they support or oppose a particular policy direction. In these 'opinion poll' terms, the balance of opinion is judged on the relative scale of the majority attributed to the prevailing view.

The ROSE Scotland survey chose to analyse section G in this manner. Figures 3.6A shows the analyses of the ROSE Scotland survey group section G and Figure 3.6B shows similar analysis of the S2 cohort response to the corresponding section in S2 Science XHS survey.

Figure 3.6: A *mean Likert score versus percent agreeing from Section G ROSE Report Scotland and* **B**: *mean Likert score versus percent agreeing from Section C S2 Science XHS Survey.*





The significance of the mean Likert score lies in the fact that a difference of 0.10 in the mean Likert score for an item corresponds approximately to a 10% change in the margin of the 'majority vote', for or against the proposition concerned.

3.6.2: Teacher Semi-structured Interviews

All the semi-structured interviews were audio-taped and transcribed for subsequent qualitative analysis. The total number of teachers interviewed was eighteen. Each teacher was one of a group of 6 experienced science teachers, newly qualified probationary science teachers and experienced humanities teachers. All the participants were teachers within the same high school (the researcher's school). The sample is not random since all of the participants worked either within the science department of the school or in the case of the humanities teacher group worked within the Religious and Moral Education, Geography/History or English departments of the school.

All participants freely volunteered to take part in the study. The experienced science (and experienced humanities) teachers had at least five years teaching experience and had taught all year groups at all levels from S1 Science up to at S5/6 Higher and S6 Advanced Higher in their respective subject discipline. The newly qualified probationary science teachers were in their first teaching post within the school and had teaching responsibilities for the teaching of science for S1 and S2 science as well as either Intermediate level one and/or Standard Grade classes in S3 and S4.

All participants were asked a series of common questions to elucidate the conceptual models of discussion held by each group of teachers. These common questions were as follows:

- *What is your understanding of what class discussion is?* Prompt: Give specific illustrations or images of discussion, either experienced or observed, which exemplified characteristics important to discussion.
- *Can you describe an ideal discussion?* Prompt: Focus on specific events within an ideal discussion.
- *Can you give a description of a failed discussion?*

- *Can you list classroom activities which you use or could be used which incorporate discussion?*
- *What do you think the educational purpose of discussion is?*

In addition to these core questions, science teachers were asked questions relating to their comfort levels when discussing controversial socio-scientific issues as well as questions relating to their views on factors which, at present, hinder such discussions. These questions were designed to gain an insight into practising science teachers' views on the discussion of socio-scientific issues in *CfE* (these questions help answer research question 5). Furthermore, all teachers were asked questions relating to their views on cooperative learning. These questions were designed to help answer research question 3.

Teacher post-lesson series interviews were carried out in the same manner as the teacher semi-structured interviews in that they were audio-taped and transcribed for subsequent analysis. However, the science teachers were asked a series of questions relating to the lessons taught. Incidents that were observed in them by the researcher served as discussion points. As each observation was different, the nature of some of the interviews was less structured than others depending on how the teachers responded to the questions posed.

3.6.2.1: Analysis of teachers' semi-structured interviews using Grounded Theory.

Grounded theory is a qualitative research methodology that aims to develop theory which is grounded in empirical data, where data analysis is linked with data collection using a systematically applied set of methods to generate an inductive theory about a substantive area (Glaser & Strauss, 1967). The method of analysis of the interview data utilised grounded theory where the analysis of the data consisted of four stages. In the first stage, 36 categories were generated by reading the interview transcripts while listening back to the taped interviews in an attempt to identify common themes in the data. This stage was the constructive phase of data analysis where the categories designated the grouping together of instances that shared common features or characteristics with one. Identification of categories occurred through the constant comparison of interview or observation transcripts with one another and developing theory to identify underlying themes. This constant comparison highlights similarities and differences that lead to the derivation of theoretical categories which help explain the phenomena under investigation. The coding process at this stage was open and involved breaking down the transcripts into distinct units of meaning i.e. looking for key words or phrases that grouped together to form categories and properties that become the building blocks in grounded theory construction (Glaser et al., 1967).

The second stage involved the integration of the categories and their properties by comparing similarities and differences among the categories created in stage one. This is termed axial coding as this is the process whereby core categories and their sub-categories are identified by a combination of inductive and deductive reasoning. The third stage involved integrating the data around fewer more encompassing categories which meant that new categories had to be created; the categories were refined and sharpened and existing categories were further elaborated. However, this process was not linear; rather they formed an iterative process of coding, comparing and refining (Glaser & Strauss, 1967). This constant comparison of data allowed for themes to develop from the data which could then form a rich description of what this group of teachers' (science and humanities teachers') conceptions of what discussion is to them. This fourth stage was the theory in process stage.

3.6.2.2: Teachers Background.

For the sake of brevity the academic and teaching backgrounds of the teacher involved in this research are outlined in Appendix C. While it is proper to scrutinise the backgrounds of the teachers to assess their level of experience, this information does not add substantively to the arguments being forwarded in the thesis and thus it was felt only required to be posted in an Appendix. However, all of the teachers involved in this research were randomly assigned with a code identifying the teacher with the group as follows: experienced science teacher 1 was coded as ExST1, newly qualified science teacher 1 was coded NQST1 and experience humanities teacher 1 was coded ExHT1.

3.6.3: Pupil Group Interviews.

From each round of the action research a cross section of pupils were interviewed in an effort to triangulate with the teacher interviews, pupil questionnaire results and with the classroom observations. The pupil interviews were conducted using a semi-structured format: a series of common questions were asked and thereafter the interviewer would explore the pupils' views on both class-specific events seen during observation of that group of lessons and on issues arising from the pupil questionnaire. All interviews were audio-taped and transcribed for subsequent analysis. The analysis for the pupil group interviews involved comparing each group of pupils' experience of the lessons with each other to check for differences between groups. Then they were checked against the observational field notes and the teacher post-lesson interview transcripts for the purpose of triangulation of references within the lesson. This allowed the researcher to corroborate views expressed by the teachers with pupils and his observational field notes.

3.6.4: Classroom Observation

From each round of the action research project, a cross-section of lessons were observed for each participating teacher and class groups in order to evaluate whether discussion was taking place using criteria described by Dillon (1994) as set out in Chapter 2 and to establish if the model of cooperative learning was been applied accordingly by each teacher. These observations helped to establish follow-up questions which would be used in the pupil group interviews. Furthermore, they also helped to triangulate findings between the teacher interviews, pupil questionnaire items and the pupil group interviews.

During the observations, a tally system was used to calculate the frequency of teacher-to-pupil, pupil-to-pupil and pupil-to-teacher interactions as well as an open note board under the headings for the five key elements of the learning together model of cooperative learning to check whether it had been applied accordingly. In this section of the observation schedule, memo notes were made to aid with the writing up process. Field notes were written up after each observation of each teacher with each class. Issues arising from each observation were used as discussion points in the post-lesson interviews with the science teacher.

3.7: Issues Relating To Validity and Reliability.

Validity and reliability are key elements of effective research. However what constitutes validity and reliability in qualitative research is more difficult to describe. For example, reliability in qualitative research can be elusive if similar criteria for the measurement of reliability are applied as for quantitative research. Validity, in qualitative research needs to be described in terms of ecological, internal, external and concurrent validity. Thus, when conducting research with a qualitative component, as in this study, one must bare in mind the type of research being performed and the methodology being applied, in order to assess issues of validity and reliability.

3.7.1: Defining Validity.

Validity can be viewed as a demonstration that a particular instrument measures what it purports to measure. However, validity can also be defined in broader terms, for example, through the honesty, depth, richness and scope of the data, the participants taking part and the extent of triangulation and objectivity of the researcher.

In addition, validity in qualitative research can be improved through careful sampling, use of appropriate instrumentation and an appropriate use of statistical analysis. Validity has to be seen as a matter of degree rather than an absolute state.

In educational research, validity should be faithful to the particular tradition of that research.

The research conducted here was highly qualitative in nature in terms of;

1. A rich picture of the reality of the setting sought (a ‘thick’ description of the teaching and learning situation being investigated).
2. The researcher was fully integrated into the establishment being studied.
3. The data derived was descriptive.
4. Data analysis was inductive rather than using *a priori* criteria

5. The data presented was in the terms of respondents' views rather than those of the researcher.
6. The data was socially situated and therefore socially and culturally saturated.
7. The intention of the research was to look at multiple perspectives.
8. The complexity of the issues was maintained during the analysis.

When conducting qualitative research one needs to be cautious not to work to a positivist agenda (Maxwell, 1992). Also in terms of validity, there is a need for qualitative research to replace the positivist notion of validity with the notion of authenticity (Guba & Lincoln, 1989). Maxwell suggests that 'understanding' is a more suitable term than 'validity' in qualitative research.

> We, as researchers, are part of the world that we are researching, and we cannot be completely objective about that, hence other people's perspectives are equally as valid as our own, and the task of research is to uncover these. Validity, then, attaches to accounts, not to data or methods (Hammersley & Atkinson, 1983).

It is the meaning that subjects give to data and inferences drawn from the data that are important. Fidelity requires the researcher to be honest regarding to the self-reporting of the participants (Blumenfeld-Jones, 1995). Qualitative data collection, the intensive personal involvement, and in-depth responses of individuals secure a sufficient level of validity and reliability (Agar, 1986). However, whilst immediacy and authenticity make for interesting journalism, qualitative research must have more rigorous notions of validity and reliability (Silverman, 2001). Validity in qualitative research replaces certainty with confidence in results and as reality is independent of the claims made for it by researchers, our accounts will only be representations of that reality rather than reproductions of it (Hammersley, 1992).

3.7.1.1: Internal Validity

Internal validity 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. This to some degree is concerned with accuracy. In other words the findings must actually describe the phenomena being researched. In this respect, the researcher carefully endeavoured to make sure that the accuracy of the teachers' responses was high.

3.7.1.2: External Validity

External validity refers to the degree to which the results can be generalised to the wider population, cases or situations. The issue of generalisation is problematic. From one perspective generalisability through stripping out contextual variables is fundamental whilst, for the other, generalisations that say little about the context have little that is useful to say about human behaviour (Schofield, 1993). Generalisability in qualitative research ought to be interpreted as comparability and transferability (Eisenhart & Howe, 1992; Lincoln & Guba, 1985). These writers suggest that it is possible to assess the typicality of a situation, the participants and setting, to identify possible comparison groups, and to indicate how data might translate into different settings and cultures.

Positivist researchers are more concerned to derive universal statements of general social processes rather than to provide accounts of degrees of commonality between various social settings (Bogdan & Biklen, 1992). Thus qualitative research may not be generalisable in the widest sense but what is described may be transferable in terms of setting, people and situations.

The external validity of a qualitative study may be undermined if a selected construct is only relevant to a select group, or where the results are largely a function of context. In addition, the external validity could be further diminished when the situation has been arrived at by unique circumstances and are therefore not comparable or where the constructs being used are peculiar to a certain group. The present study has a high degree of external validity as teaching through discussion of controversial socio-scientific issues is prescribed as part of the new science curriculum emanating from *CfE.* Therefore, most schools in Scotland will be undertaking a similar developmental process in the near future.

3.7.1.3: Ecological Validity.

In quantitative, positivist research the variables are frequently isolated, controlled and manipulated in contrived settings. However, in qualitative research the fundamental premise is that the researcher deliberately does not try to control or manipulate variables or conditions. This means that the situation under research occurs as naturally as possible, the intention being that this gives an accurate portrayal of the reality of the situation in its own terms, in the natural conventional setting. In educational research, ecological validity is particularly important. For it to be demonstrated, it is important to include and address in the research as many characteristics in, and factors of, a given situation as possible. Again this researcher would argue that this research has a high degree of ecological validity as an endeavour has been made to faithfully describe the introduction of discussion into science teachers' pedagogical armoury, from both the teachers' and the pupils' perspective.

3.7.2: Defining Reliability.

Reliability is seen in terms of consistency and replicability over time, over instruments and over groups of respondents. For research to be reliable it must demonstrate that if it were to be carried out on a similar group of respondents in a similar context, then similar results would be found. There are three principal types of reliability: stability, equivalence and internal consistency.

3.7.2.1: Reliability in Qualitative Research.

The canons of reliability for quantitative research may simply be unworkable for qualitative research (LeCompte & Preissle, 1993). Typically, quantitative methods require a degree of control and manipulation of phenomena. Indeed the premise of qualitative research includes the uniqueness and idiosyncrasy of situations, in that the study in some respects may not be replicated. This could be seen as both a strength and a weakness. Reliability as replicability in qualitative research can be addressed in a number of ways (Denzin & Lincoln, 1994). For example, *stability of observations*, where the researcher would have made the same observations and interpretation of events, even if they had been observed at a different time or in a different place. *Parallel forms,* where the researcher would have made the same observations and interpretation of what had been seen if they had paid attention to other phenomena during the observation and *inter-rater reliability,* where another observer with the same theoretical framework and observing the same phenomena would have interpreted them in the same way.

This is clearly a contentious issue for it is seeking to apply to qualitative research the canons of reliability of quantitative research. In qualitative research, reliability can be regarded as a fit between what researchers' record as data and what actually occurs in the natural setting that is being researched (Bogdan and Biklen, 1992). However, this does not suggest that one must strive for uniformity as two researchers who are studying a single setting may come up with very different findings, but both set of findings might be reliable. In interviewing, there might be as many different interpretations of the qualitative data as there are researchers (Kvale, 1996).

Qualitative research, being holistic, strives to record the multiple interpretations of, intentions in, and meanings given to situations and events. Thus the notion of reliability is constructed as dependability (Brock-Utne, 1996). Dependability involves member checks, debriefing, triangulation, prolonged engagement in the field, persistent observations in the field and audit.

This discussion on validity and reliability in qualitative research rehearses the arguments set forth in the paradigm wars: Quantitative measures are criticised for combining sophistication and refinement of process with crudity of concept and for failing to distinguish between the concept of educational and statistical significance. Qualitative methodologies, whilst possessing immediacy, flexibility, authenticity, richness and candour, are criticised for being impressionistic, biased, commonplace, insignificant, ungeneralisable, idiosyncratic, subjective, and short-sighted (Ruddock, 1981).

While such intellectual discussion is interesting, the main issue is the fitness for purpose of the research methods in relation to the central research questions being investigated. The model of action research applied in this research is fit for purpose in that it is ecologically valid since it seeks to find a solution to an area of teaching that science teachers find difficult and are presently uncomfortable in handling. In addition, it is internally valid in that the data analysis process utilises a grounded theory approach that assumes nothing theoretically from the beginning of the research and only develops theory from the data gathered during the research. Thus new knowledge developed from the research is grounded in the data and is emergent from that data. Furthermore, in terms of reliability the research detailed here has been triangulated at each stage and shows stability of observations since the same issues arose in each class over the three years of the action research and was commented on by the teachers involved in post-lesson interviews.

It is important to note however, that the researcher was not involved in the direct teaching of the second year pupils during the action research cycles over the three years. His only involvement with these year groups over the three years of the action research was in the development of the learning and teaching materials involved in the teaching of the climate change and global warming lesson series. He had not taught any of the pupils involved so could act as an impartial observer of the S2 classes.

3.8 How the research methodology was deployed to answer the research questions.

The research questions stated in chapter 1, section 1.4 were addressed by the methodology as follows;

Research question 1 *(What is 'scientific literacy' and what are the characteristic elements which define it as a concept which can be developed with secondary school science education?)* was answered through critical examination of the research literature.

Research question 2 *(What conceptual models of discussion do science teachers hold and do they differ from those held by humanities teachers?)* was answered by using semi-structured interviews and qualitative analyses of those interviews.

Research question 3 *(How useful is cooperative learning as a pedagogical approach for the teaching of discussion within the science classroom setting?)* was answered by observation of the teaching of a series of lessons using discussion of the controversial socio-scientific issue of climate change and global warming. In addition, the post-lesson teacher interviews and pupil-group interviews helped to answer this question

Research question 4 *(What are the pupils' attitudes towards Science & Technology and School Science and how does pupil attitude to science impacts on their engagement with socio-scientific issue?)* was answered by analysis of returned pupil questionnaires based on the Scottish ROSE survey materials.

Research question 5 (*What issues arise from teaching the new topical science strand of the new science curriculum in terms development of teaching materials, time to deliver, teacher CPD and management of recourses?)* was answered through teacher semi-structured interviews and questionnaires and through observation of the lesson series throughout the project.

Chapter 4: Scottish teachers' conceptual models of discussion, comfort levels using discussion and views on cooperative learning.

4.1 Introduction.

This chapter details the findings of the semi-structured teacher interviews which were designed to answer research question 2 as stated in Chapter 1. In addition, supplementary questions were asked in order to gain an insight into teachers' views on cooperative learning and their comfort levels when discussing controversial socio-scientific issues. These supplementary questions were designed to help answer research questions 3 and 5 respectively. However, before a detailed description of what was found during these interviews is outlined, the educational context of this part of the research must be set out in order to justify why it is important to understand science teachers' conceptual models of discussion in particular compared to those of Humanities teachers.

4.2 The educational context of teaching using discussion.

As stated in Chapter 2, teachers commandeer the term discussion to describe a multitude of different types of classroom discourse, for example, conversation, debate, dialogue, argument, etc… However, an understanding of teachers' conceptual models of discussion could offer an insight as to why some teachers fail to enact discussion effectively within their teaching. It must be noted that the use of discussion by Scottish Science teachers at present is limited. Indeed a number of recent studies have shown that, while science teachers understand that discussion within the context of science is useful, they fail to see the purpose of such discussions and report that they are generally uncomfortable leading them (Bryce et al., 2004; Levinson et al., 2001; Millar et al., 1998).

In England and Wales, under the sponsorship of The Nuffield Foundation, an AS level course called Science for Public Understanding (SPU) was designed in partnership with The University of York in 1999. This course, implemented in 2000 and evaluated by Kings College London between September 2001 and April 2002 (Osborne et al., 2002), represented a step forward in curriculum design for the promotion of scientific literacy as, from the outset, this course targeted students who wished to continue to study science but did not wish to specialise in a discrete Science at A-level. It deliberately contained scope for discussion of socio-scientific issues arising from contemporary science. This course has now been updated and renamed A-level Science in Society with the first diet of the new AS level exam being sat in 2009 and the A-level exam to be sat in 2010.

In the report *Breaking the Mould? Teaching Science for Public Understanding* Osborne *et al* (2002) suggested that many of the lessons which involved discussion were of poor quality as evidenced from their observation of the teaching of discussion of socio-scientific issues contained within this AS level course, a sentiment exemplified by the following statement:

> The first and most noticeable feature of these lessons was the dominance of classroom discourse by the teachers. Time and time again, it was the teachers who were observed to initiate the discourse in the classroom, controlling its form, and possibly its function, by using predominantly discourse strategies in which the teacher initiated discussion by asking a question (often closed), seeking a response and then providing an evaluative response that indicates to the student and the class whether their answer is correct or not (Osborne et al., 2002).

Osborne goes on to comment that this observation is unexceptional, when placed in context, since it is the teacher's responsibility to initiate and control the learning activities in the classroom but that it was surprising that so much of the dialogue took this form. In addition, Osborne justifies this comment by indicating that analysis of the case study data provided in the report showed 76 instances where such types of discourse were noted and goes on to state:

> It is surprising because one of the primary aims of the SPU course is for students to 'develop, and be able to express, an informed personal point of view on issues concerning science and technology'. It is hard to see, therefore, how this aim can be achieved when insufficient space is provided for students to develop such capabilities by opening up the

> nature of the discourse in the classroom to make it more of a genuine dialogue. (p27)

The tone of this quote suggests that the teachers who took part in this research and who taught this course required help to develop pedagogical skills which would improve the quality of discussion as a teaching and learning strategy within their practice. This comment has been echoed in a number of studies which deal with such discussion (Bryce et al., 2004; Hodson, 1999; Hodson, 2003; Levinson, 2001; Levinson, 2003; Levinson et al., 2001; Millar et al., 1998; Oulton C, Dillon J, & Grace MM, 2004; Reiss M, 1999; Sadler, 2004a; Sadler, 2004c).

Although in this report Osborne *et al* did not probe the teachers' understanding of what discussion was in their evaluation of the SPU course, their conclusion that the quality of discussion within the lessons that they observed was poor begs some deeper questions. *Do science teachers hold a poor conceptual understanding of what discussion is? Do they know what the purpose of discussion is? And is science teachers' prior experience a hindrance to their development of discussion within their own classrooms?* Osborne defends the teachers by suggesting that;

> The best explanation for these findings is that science teachers and their actions are structured by the nature of the agency they serve; science education, a practice which has been characterised as the last authoritarian socio-intellectual discipline (Ravetz, 2002). …much of the teaching of science requires the teaching of consensually, well-established knowledge which is uncontroversial and not open to challenge or questioning. Consequently, science teachers tend to adopt a style which attempts to persuade their students of the validity of the scientific world-view and construct for themselves the entities that populate the scientific universe. The result is a dialogue which tends to be closed and authoritative. The normal daily practice of the science teacher does not provide many opportunities for the kind of interpretive and open discussion that the English teacher or History teacher might encourage (p.29).

The suggestion that Humanities teachers are better equipped to deal with open discussion is a view shared by Levinson (Levinson, 2001; Levinson, 2003; Levinson et al., 2001). Research suggests that Humanities teachers hold multiple conceptual models of discussion (Larson, 2000; Parker et al., 2001). However, Alvermann *et al* (1990) showed that, although Humanities teachers could articulate abstract definitions of a good discussion, their enacted discussions seldom resembled these definitions. The teachers, due to perceived pressure from outside forces, were more concerned with maintaining control and about covering content than with encouraging active participation from students in constructing meaning (Alvermann et al., 1990).

On the face of it, the suggestion that Science teachers need more opportunities to observe experienced Humanities teachers to see the models, strategies and approaches they employ to foster and stimulate discussion, seems to be a good idea. However, this could potentially lead to problems since Alvermann *et al* (1990) suggest that teachers' conceptual understanding of discussion does not necessarily lead to better planning and execution in the classroom. Furthermore, other research on discussion in Social Studies has shown that observed, Social Studies teachers (the American equivalent to the UK Humanities teacher) only used discussion in 10% of their lessons and that when they did it was of poor quality in that it was short and teacher dominated (Hess, 2004; Nystrand et al., 1998).

A search of the research literature in this field shows that there have been relatively few studies on the classroom dynamics of leading and teaching using discussion. In fact most of the literature on discussion in science pertains to the intricacies of discussions of socio-scientific issues but fails to deal with the matter of whether the discussion was open or teacher dominated.

After a comprehensive literature search by this researcher, not a single research paper dealing directly with the question of whether Science teachers hold *different* conceptual models of discussion when compared to those of Humanities teachers could be found. The one paper that did observe both Science teachers and Humanities teachers doing what they reported to be discussion with their classes showed that even when observing Social Science teachers, English, Languages and Art teachers handling discussion, 40% of the observed lessons formed an open forum for discussion with 60% of the lessons taking the form of either recitation or a lecture or a mixture of both (Alvermann *et al*., 1990).

What the Hess (2004), Nystrand *et al* (1998) and Alvermann *et al* (1990) studies show is that even Humanities teachers have trouble teaching using discussion. In order to understand the root of such disparity we need to take a closer look at the nature of discussion and to research why teachers who can articulate their conceptual understanding of discussion, fail to enact true discussion when they claim to use it frequently. Furthermore, understanding science teachers' thinking, in particular about discussion, is required if we can assume, that as with all teachers, their thoughts underlie their classroom action (Clark et al., 1986). If discussion is to be used to help develop pupils' scientific literacy through teaching them about the process of discussing issues of a socio-scientific nature, then teachers are a crucial variable in creating the necessary context.

If teachers only think of discussion as a recitative interaction between teacher and pupil, then recommendations for the increased use of discussion are doomed to failure. There is a clear need for additional insight into the uses of discussion particularly within the science classroom. This train of thought provides a focus for research especially since the new science curriculum as set out by *CfE* explicitly prescribes discussion of socio-scientific issues within Scottish science education.

4.3 Teachers' conceptual models of discussion.

The reporting style employed within this Chapter is descriptive in nature, throughout which the text is punctuated with exemplar comments from the teachers' interview transcripts. This method was chosen since it allows for a fuller and richer description of the range of views expressed by these teachers and allows the logical flow of the teachers' thinking to be followed.

In order to answer research question 2, all the teachers who took part in the semi-structured interviews were asked a series of common questions which were designed to elucidate their conceptual models of discussion. These were as follows:

1. *What is your understanding of what class discussion is?* Prompt: Give specific illustrations or images of discussion, either experienced or observed, which exemplify characteristics important to discussion.
2. *Can you describe an ideal discussion?* Prompt: Focus on specific events within an ideal discussion.
3. *Can you give a description of a failed discussion?*
4. *Can you list classroom activities which you use or could be used which incorporate discussion?*
5. *What do you think the educational purpose of discussion is?*

In addition to these core questions, science teachers were asked questions relating to their comfort levels when discussing controversial socio-scientific issues as well as questions relating to their views on factors which at present hinder such discussions. These questions were designed to gain an insight into practising science teachers' views on the use of discussion of socio-scientific issues in *CfE* (these questions help answer research question 5). Furthermore, all teachers were asked questions relating to their views on cooperative learning. These were designed to help answer research question 3.

The response to each of the core questions formed the basis for generating clearly defined conceptual models of discussion as described by this group of teachers. The response to each question also allowed for qualitative differences to be seen between each of the three teacher groups. However, the models described here are derived from the analysis of all of the interviews permitting the full spectrum of teacher views to drive the theory-forming phase of the analysis.

4.3.1 Teachers' conceptual models of discussion.

During the analysis phase of this part of the action research project, it became clear that teachers from different subject disciplines viewed discussion in a variety of different ways. Upon reading the interview transcripts, while listening repeatedly to the audio-taped interviews, it became evident that the teachers held multiple conceptions of discussion. However, experienced Humanities teachers were better able to articulate their models of discussion compared to their Science colleagues.

When reflecting on the interview transcripts, it was apparent that this group of Science teachers struggled to articulate what their understanding of discussion was. When directly questioned, most of the science teachers required extensive prompting and subsidiary questioning in order to unpack their ideas about discussion.

The data reveal that the eighteen teachers interviewed carried five distinct models of discussion. These emerged from the data during coding, categorising and the process of refinement using the transcripts as described in Chapter 3, section 3.6.2.1. The emergent models of discussion were: (1) discussion *as a teacher-mediated discourse*; (2) discussion *as open-ended inquiry*; (3) discussion *for the development of reasoning skills*; (4) discussion *as mediated transfer of knowledge to real-life contexts*; (5) discussion *as practice for democratic citizenship.*

The constituent characteristics reveal that there are differences between the three groups of teachers in terms of the percentage of teachers in each group who mention a particular characteristic of discussion when asked to describe what the educational purpose of discussion was (See table 4.1).

Table 4.1: *Characteristic components of discussion as mentioned by teachers in their semi-structured interview.*

Identified Characteristic Component of Discussion	Percentage of teachers who mentioned a characteristic			
	Experienced Science Teachers (n=6)	Newly Qualified Science Teachers (n=6)	Science Teachers Overall (n=12)	Experienced Humanities Teachers (n=6)
Development of social skills	83	67	75	50
Development of confidence	67	67	67	50
Development of communication skills	67	17	50	50
Development of listening skills	50	33	42	50
Development of thinking skills	33	50	42	100
Exposure to multiple perspectives	50	33	42	67
Assessment of knowledge	33	17	25	17
Formation of personal opinions	0	17	8	50

Table 4.1 shows that all the Humanities teachers saw discussion as a way to develop pupils' thinking skills compared to only 33% of experienced Science teachers and

50% of newly qualified Science teachers. However, 83% of experienced Science teachers and 67% of newly qualified Science teacher' saw discussion as a way to develop social skills. Furthermore, 67% of experienced Humanities teachers and 50% of experienced Science teachers saw discussion as a way to expose pupils to multiple perspectives. Worryingly, only 8% of the Science teachers and only half of the experienced Humanities teachers saw discussion as a way in which pupils could formulate their own informed opinions.

At this point it must be conceded that Table 4.1 represents a relatively crude method of identifying differences between the three different groups of teachers. Furthermore, just because a teacher does not mention a particular characteristic explicitly when asked does not mean that the teacher views that characteristic as unimportant. It is possible that an omission may be due to the teacher seeing another characteristic as more important than another. For example, Humanities teachers might see the development of social skills as unimportant since they may take the development of social skills for granted, so do not mention their development explicitly when asked. Over the next five subsections the different conceptual models of discussion will be described along with exemplar quotations from the teachers' interview transcripts.

4.3.1.1: Discussion as a teacher-mediated discourse.

Discussion as a teacher-mediated discourse could be described as a way in which teachers see discussion as a dialogue which they lead or control. With this model there is more pupil-to-pupil interaction than in a recitation style lesson. It also is conducted for a different purpose. For example, recitation is about questioning for the review of taught knowledge, whereas teacher-mediated discourse is intended to help pupils understand multiple perspectives which impinge on an issue being discussed to encourage a deeper understanding of the topic. This is exemplified by a comment from ExHT2;

> *You get to draw things out of them (the pupils). My job is to challenge the initial response and 'say well let's look at a little bit deeper'...see things from another's perspective, so it's a kind of discovering things through, in a way a metaphor. For example a metaphor can put things across in a way*

which say "x" statements can't, so sometimes a discussion is a good way of getting them to engage with an issue that they don't necessarily get first off and, you know, this gives them confidence in their own opinions and you can improve your relationship with them and make them aware that maybe people don't always agree but that there are many different ways to look at the same issue and discussion is good for that. **ExHT2**

What this statement shows is that the use of high order questioning is employed by the teacher to elicit deeper responses from the pupils to the line of inquiry in the discussion. Teacher mediated questioning allows more than one perspective to be introduced to the discussion, either from the pupils themselves or from the teacher. This model also allows the pupils to engage with an issue by providing a forum of views which they can follow in the context of the discussion. Thus the teacher is leading the pupils through the discussion to reach predetermined learning objectives while allowing pupils to interact more freely. This free interaction allows for pupil-to-pupil and pupil-to-teacher interactions to flow during the discussion under the teacher's direction.

The teacher's role is seen as that of a facilitator. ExST1 and 4 exemplify this by suggesting that;

…the teacher is really just facilitating, not necessarily giving their point of view but, really trying to gather from the class what their ideas are. **ExST1**

Sometimes as a teacher it's your job to facilitate them and explain it to the rest of the class "what they mean by that is…" if they can't quite express it themselves they're still coming up with the original idea and concept themselves. **ExST4**

The idea that the teacher helps to reflect and rephrase pupils' comments suggests that in this model the teacher is helping to clarify pupils' views and opinions in order to help the class understand points which may have been poorly communicated by a pupil. This suggests that the teacher is modelling communication skills which the pupils may wish to adopt. During this model of discussion the teacher is an active participant in the discussion whereby he/she moderates and directs the flow of interactions and thus maintains order. However, in this model the teacher is leading the discussion by directing and posing questions which are designed to expose the pupils to multiple perspectives, where the pupil often responds to both teacher-posed and pupil-posed questions. The teacher may or may not give feedback on the pupils' responses but the teacher's role in this conception of discussion is pivotal in shaping the direction and pace of the discussion.

4.3.1.2: Discussion as open-ended inquiry.

Discussion as open-ended inquiry is a model that teachers use to allow the discussion to flow, where they do not always direct it or evaluate pupils' responses. In this model the teacher interacts orally with his/her pupils as participants where both offer up their own opinions on the issue under discussion. The teacher is not there to maintain control of the discussion but acts as both a guide and possibly even a learner.

Full participation is encouraged and expected. ExST2 suggests that;

> *It's got to be a conversation where everyone in class, no matter what their ability, is able to get involved, at some level and also it's got to be so that they would actually feel confident and comfortable contributing something, no matter what it would be.* **ExST2**

This type of discussion can often turn out to be argumentative in nature. This generally occurs when the issue is controversial in nature or when the knowledge pertinent to such discussion is contentious. In addition, issues which contain widely varying perspectives lend themselves to this type of discussion.

> *I would think that discussion from a science teacher's point of view is about the pupils trying to look at evidence and forming their own opinions based on the evidence and being able to argue for and against their point.* ***NQST2***

By engaging with pupils in this way the teacher is modelling how to participate in open-ended inquiry. This model of discussion is facilitated by the provision of a safe and trusting environment in which pupils discuss the issue. As such issues tend to have with no clear solution and are held as controversial by diverse groups, classroom ethos is important to the success of the discussion.

> *Both parties have to be able to voice or give a viewpoint, if it's in my opinion discussion then you are never going to get a solution. Eh, if it's a proper discussion based on scientific evidence, then the evidence has to be prescribed by both parties, then it has to be examined, say "let's look at the way you examined that. Why did you examine it in that way?* ***ExST6***

In ExST6's comment, the issue of openness is touched upon in the context of interpretation of evidence where all participants have to be prepared to view the evidence with an open mind and not just from their own perspective. This issue of openness can be extended to evidence-based decision-making as exemplified by ExHT1's comment;

> *When we do medical ethics we have them in groups and they discuss a moral dilemma and they have to decide what they thought the doctor should do…Should they let someone continue to live in a certain state or should they allow them to die? They then have to collaborate with each other and come up with ideas and arguments for and against, to see if there was any consensus within the group.* ***ExHT1***

This suggests that in this kind of discussion, being prepared to be open-minded and willing to look at all the pros and cons of an issue is integral to its success. However, it is important that in open-ended inquiry the discussion is focused on a particular concept, an issue or question. ExHT3 extends this idea as follows:

> *We ask a question and we expect a variety of responses so, for example, you're asking a question on transport and congestion then the solutions also have a lot of problems associated with them, so what you'd expect is for the discussion to develop an answer which dovetails into all the problems associated as well where we can then bounce their ideas off of each other.* ***ExHT3***

In this regard, ExHT3 is suggesting that open-ended discussion is about helping to tease out the complexity involved in order to expose the pupils involved to the complexity of the issue and to the associated problems with finding an acceptable solution. This model exposes the pupils to the difficulties faced by people charged with coming up with solutions to everyday problems.

4.3.1.3: Discussion for the development of reasoning skills.

In this model of discussion the teacher frequently uses critical questioning in an effort to challenge pupils' opinions, ideas or beliefs. This model differs from recitation as the teacher is not seeking particular answers to questions posed but is concerned with deliberately challenging pupils' thinking. In addition, it differs from open-ended inquiry in that the teacher continues to ask specific questions for different purposes, such as requesting clarification of pupils' views or asking for more information, or by opening up a different perspective by posing a question. This can also be used to develop or challenge pupils' thinking or can be used to provoke a reaction from them.

This view is exemplified by the comment below;

> *Classroom discussion is… looking at possible misconceptions and asking pupils to discuss it with each other and raise it in a forum from the class, so that you can take what they have got and understand what they can do with it and where it's going. Challenge is the job of the teacher. To challenge what they have, be it a misconception or not so that they can build on it in a productive way. Now misconceptions fall down either because other people in the class, ideally or the teacher, will bring up a point whereby their logic falters and fails or your testing their previous knowledge against each other and against the situation that the teacher introduces to see if it works. What you're looking for is the best possible construct between the pupils and the teacher. The teacher might add to things that the pupils have introduced that the teacher might not have thought of. At the end of it what you've got is a forum of discussion whereby the best of all ideas come together and part of that is burning bridges that should not have been built in kids' minds based on complete fallacies.* ***ExST3***

ExST3 clearly feels that challenging misconceptions is best done through persuasion and logical argument using views from across the spectrum of the class. However, he also suggests that the role of the teacher in this is to stimulate and challenge the pupils' thinking. He also implies that there must be open-mindedness and a willingness to take on board other views both of the teacher as well as of other pupils. There must be curiosity on the part of pupils to engage and seek more information.

ExST3 put this view in the following terms.

> *You have to have enough character to be able to put up an argument and be able to accept the fact that it doesn't go as well as they thought or it doesn't work at all. But still have the curiosity and interest and the investment amongst other people to feel it's still worth while to take part.* **ExST3**

In this model, the teacher may adopt a "devil's advocate" approach by questioning everything that is said. This is useful when the teacher detects that pupils are biased or only have a shallow understanding of the issue under discussion which may lead to an opinion which is based on poor or weak reasoning. In order to stimulate pupils into questioning their own thinking, some teachers employ the deliberate tactic of making extreme statements designed to play on the pupils' values and their personal interpretations. This provokes a reaction which may increase pupil engagement in the discussion by touching a raw nerve as exemplified below:

> *Typically when we are doing the Scottish Wars of Independence, what I am trying to do is burst the 'Braveheart' bubble, so I am trying to provoke people into discussion by calling William Wallace the English Osama bin Laden and get them to discuss that. That usually riles people, so I am trying to get them to discuss their perceptions of this important man… I've got to be, if you like, an agent provocateur to get them to participate. I've got to make a ridiculous statement like, if I am doing votes for women, to provoke the girls into a reaction I'll say this is where it all went downhill, the end of civilisation as we know it when women started getting the vote. If I do that it provokes a response and I get more, wider perspectives.* ***ExHT4***

This quote suggests that sometimes it is necessary for the teacher to take an extreme standpoint in order to stimulate the pupils into expressing points of view. However, this approach leads to a degree of unpredictability and potential loss of control over the direction of the discussion, depending on the views expressed.

> *I don't think it [discussion] can be completely predictable from the start. It's organic, it is evolutionary and it has to be based on where they (the pupils) are coming from, the teacher has to get inside their logic and follow their logic to a point where it's defeated if it's no good or it's added to, to supplement the class knowledge if it is useful".* ***ExST3***

This model also allows teachers to develop the pupils' reasoning skills by questioning their thinking through the use of counter-balancing questions, thereby helping pupils to question themselves. This process may stimulate the pupils to reflect on their reasons for thinking the way they do, thus stimulating meta-cognition. This is exemplified by the following statement.

> *My role will be to… Say they give you an answer to a problem, I'd say 'very good that is a good solution to that problem, but what are the issues which arise from this solution?' Hopefully to try and get them to think about the other issues surrounding the problem being discussed. So it's to get them to give us all their ideas on that one particular area with myself leading them through the complexities in different directions.* **ExHT3**

The main aim of this version is to stimulate pupil thinking and to challenge rather than direct their reasoning. However, this model is also aimed at developing other skills such as listening skills as well as confidence building.

> *Within the classroom, discussion is a way of allowing the pupils to think out loud… They think out loud with other people and can hear what other people are saying, so it develops thinking skills; it develops their oral skills and their listening skills… They may say something that sparks off something in your head and you begin to think a little differently and that may spark off someone else and discussions like that can grow arms and legs.* ***ExHT6***

> *... It promotes higher order thinking but also it could be good because it promotes confidence in the individuals and it builds their social skills in either small groups or in larger whole class groups… They are becoming more confident and from that they're then learning skills of higher order thinking and will become more successful in learning.* ***NQST5***

4.3.1.4: Discussion as a guided transfer of knowledge to real-life contexts.

This model of discussion involves the use of knowledge already gained in the class to help resolve an issue with a real-life context, using generalised knowledge gained from school to help solve an unfamiliar problem. This involves the teacher guiding the discussion in order for the pupils to consider how their school knowledge could be used in their own life. The act of discussion allows the pupil to make connections between what they have learned in school to their own life in ways that perhaps other pedagogical approaches may not. Some teachers see this model of discussion as a way of preparing pupils for situations beyond the school boundaries as exemplified as follows:

> *…They are having to do projects and discussions in front of their peers or adults or whatever. You know that can be a worrying experience because we have had pupils before who have been going for interviews for medicine or vet school and it's a high level interview, but they don't have the social skills to be able to interact and show people what their actual understanding of the knowledge is, so I think it's important as well as making sure they have the academic side that they have to be able to have the confidence to be able to represent what they actually know because it can really pull them down in a situation where it is quite competitive like that. They need to be able to feel confident in themselves to be able to express their opinions.* **ExST1**

This extract illustrates the need for pupils to be able to show their understanding in an academic sense in addition to the social and interpersonal sense. ExST1 suggests that this ability to take knowledge gained within the school environment out into real-life context is an important part of pupils' development in intellectual and social terms. This suggests that this model is closely linked to that of discussion for democratic citizenship (see below). In a sense it is but, in the case of discussion of controversial socio-scientific issues within the science classroom, which also fits into this model, it is also different; particularly since the knowledge gained from within the science curriculum, when discussed in this context, becomes more real. Issues such as embryonic stem cells research and the therapeutic use of stem cells places the science knowledge within a social context, which could allow the pupils involved in the discussion to empathise with the people within the situation as presented, allowing pupils to see the effect that science can have on people's lives within the social domain.

However, some teachers indicated that pupils find this type of discussion difficult.

> *In geography a lot of the stuff that we discuss is about things that surround them [the pupils] so we assume that they have seen a lot of the things that we are discussing…The majority of the kids have an understanding of what your taking about…They are happy to give you factual information but when it comes to opinions they are not so keen on doing that.* **ExHT3**

These types of discussion require pupils to develop higher order cognitive processes in connection with the issue under discussion. This requires effort and can be seen as essential to the success of this kind of discussion.

> *Pupils have to participate for a good discussion to take place; they need to be motivated to be involved in the discussion.* **ExHT3**

The use of these thinking skills should increase pupils' motivation to learn more about the issue, thereby resulting in a deeper understanding of what is being discussed, allowing pupils to recognise the connections between topics and concepts rather than the simple comparison of facts. However, the issue itself can also be a motivating factor since some pupils may have a pre-existing interest in it or, in the case of medical issues, they may have first or second hand experience of what is being put forward.

4.3.1.5: Discussion as practice for democratic citizenship.

Classroom discussion is a powerful pedagogical tool for the practice of oral communication skills, listening skills and general behaviour in social and cultural terms. Therefore, in this model of discussion the pupils practise skills such as listening skills, communication skills and social skills, and manners such as turn-taking, allowing others time to express their views without interruption, etc… This type of discussion allows the pupils to practise the process of discussion itself. The following comments express the view that this model of discussion sees the practice of such skills as essential tools for participation as a citizen within a democratic society

> *I think that you need to develop social skills in pupils so that they can go outside a school and have a discussion about any topic and be able to use the knowledge that they've got but be able to have the social skills, as I say, to listen to other people and to value other people's opinion even if it's not exactly the same as their own because for some pupils that is a difficult thing for them to do… They need to be able to feel confident in themselves to be able to express their opinions.* **ExST1**

> *For me discussion is a really useful tool for learning… I tend to drift, listen or I'll take part… you encourage them to engage in the discussion by moderating it properly. I use it because the kids get to hear other people's opinions and in this day and age, in general in society, people just don't want to listen to other people's opinions because they have got their own and that's it. They are happy to force their opinion down your throat but will not listen, so as a side issue you have to teach the kids that someone may have a different opinion from you but that doesn't mean that they're wrong.* ***ExHT6***

These quotes exemplify the feeling among this group of teachers that discussion can also be a learning outcome in its own right. Engaging in discussion involves a social element that is not necessarily used just to teach subject-specific content. In these terms, discussion is a skill in itself and as such requires practice. This model of discussion in many respects is central to all the others in that without the communication skills or the ability to listen to other people's views, opinions and beliefs, discussion is doomed to failure.

4.3.2 How do these Conceptual Models of Discussion Inter-relate?

It is interesting to note that Science teacher's emphasis in discussion lies towards the development of social skills, whereas, Humanities teachers' emphasis in discussion lies towards the development of thinking skills, the exposure to multiple perspectives and the formation of personal opinions. However, how do the five conceptual models of discussion outline above fit together? Figure 4.1 outlines the manner in which the five conceptual models of discussion inter-relate.

It could be suggested that discussion as teacher-mediated discourse is a starting point for the practice of discussion for democratic citizenship, since the development of social skills, listening skills, communication skills and argumentation skills must first be acquired as a prerequisite to the engagement in open-ended inquiry for the development of reasoning skills and the transfer of knowledge to real-life contexts. It could be further suggested that these models of discussion form a developmental progression through which pupils must journey in order to develop and practise the necessary behavioural characteristics and cognitive skills which enable them to acquire the skills required for discussion within a democratic classroom.

Figure 4.1: *Scottish Teachers' Conceptual Models of Classroom Discussion.*

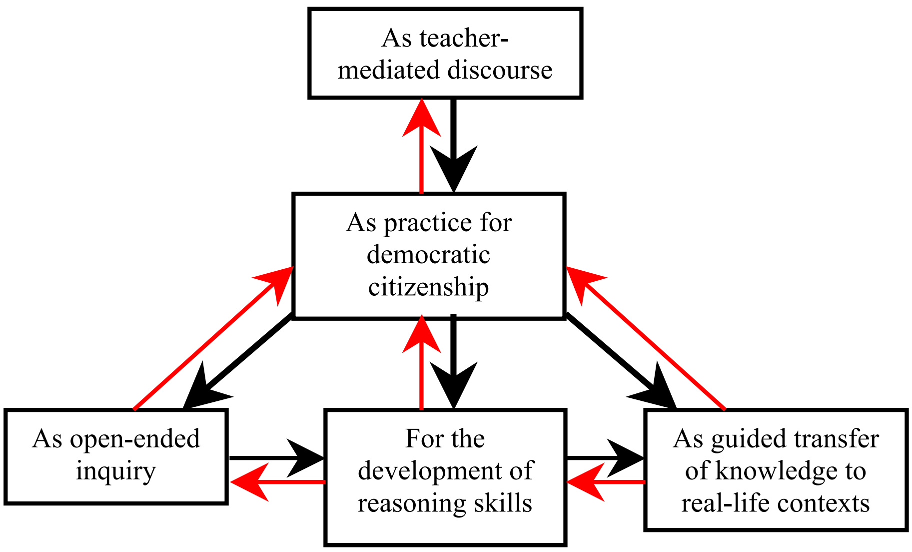


Figure 4.1 illustrates how these conceptual models of discussion interact together. Most forms of discussion within the classroom are to varying degrees, teacher-mediated. Normally it is the teacher who sets the parameters and context for

discussion and it is generally the teacher who initiates the first exchanges within any of the models of discussion. What makes discussion open-ended inquiry; for the development of reasoning skills; and a guided transfer of knowledge, is the willingness of the teacher to allow the pupils to take control of the discussion within differing contexts. It could be suggested that open-ended inquiry requires the teacher to relinquish most of the control of the discussion and as such, would be the most difficult of all the models for teachers to manage.

It is fair to say from the tone of ExHT6's last comment that, at present, the pupils that he has encountered lack the prerequisite listening skills and decorum of open-mindedness and willingness to accommodate differing views. This view was shared by the majority of the teachers within this study. However, one teacher's view showed the fragile nature of teaching using discussion in science as a result of a perceived lack of social, communication and listening skills.

> *In my experience, pupils, especially young pupils at this age group (13-14 years), just don't have the decorum, that sustained decorum required for a viable discussion. I have tried it plenty of times in PSE, I've tried it in Science and in Gaelic to an extent but there was too much engineering for the teacher to get it back on path as far. As I'm concerned it becomes a waste of time… then it becomes a teacher-centred lesson and that's how I feel time would be better spent doing something else.* **ExST5**

From this comment, it is clear that if science teachers are to engage in discussion within their classrooms, they must realise that it is predominantly an oral endeavour. Given that oral language weaves the very fabric of classroom culture, any attempt to develop the use of discussion within science education requires a major alteration to the classroom culture within the normal laboratory. Merely planning to do a discussion once or twice a term is insufficient preparation for the practice of the 'decorum' that is expected of the pupils.

As suggested earlier, teacher-mediated discussion is the first step for the acquisition and practice of social, communication and listening skills by pupils. Thus a teacher-centred lesson ultimately must be the starting point from which the teacher builds the pupils' confidence, social, communication and listening skills to the point where the teacher can begin to allow them to step forward into their position. The issue here is ultimately about control. Teachers must first learn to release their control of the discourse in their classrooms in order to allow pupils to realise their potential and, by extension, increase their participation within the discussion.

As Osborne *et al* (2002) points out, science teachers generally adopt a style which is closed and authoritative in nature, where the normal practice of the science teacher does not provide opportunities for interpretive and open discussion, since they tend to deal in well-established facts which are not open to question or interpretation.

It is this researcher's contention that teachers tend to perceive that they are under pressure to manage behaviour and cover course content and, as a result, they dominate the oral discourse of the classroom, while pupils in general accept this discourse as part of the ethos of the classroom and accordingly assent to the curtailment of their role within the discourse. It is the alteration of this position, particularly the roles of the pupils and the teacher within discussion, especially in the science setting that must be tackled if classroom discussion is to be encouraged and if pupils' development as culturally aware, critical thinkers is to be nurtured.

4.4 Teachers' comfort levels using discussion of controversial socio-scientific issues.

The suggestion that science teachers need to dominate and control the classroom discourse is linked to their level of comfort within the discussion process. When asked how comfortable they felt discussing issues which arise from contemporary science, such as controversial socio-scientific issues, there was a mixed response. For example, in the experienced science teacher group, all of the teachers expressed the view that they were comfortable discussing such issues. However, they then followed this comment with a proviso such as "it depends on the topic" or "I have no problem with that at all but on occasion when you have to discuss these issues it's all of a general nature" These comments suggest that the experienced science teacher group is not as comfortable discussing controversial socio-scientific issues as they say. One experienced science teacher, ExST1 commented as follows;

> *I would say that I would like to feel more comfortable than I actually am. I do like having discussions in science but there tends not to be time to do it. I have been teaching nine years now and for the time that you have to take in delivering learning outcomes in class, it's not something you know, your in your comfort zone, me talking to the pupils and then we do a quiz or a test and a lot of the time it's not involving their opinions, it's me telling them facts and then maybe finding some sort of fun way of learning. But I would* ***not*** *say that the majority of my teaching has been taken up discussing in-depth any science issues, so maybe some wee facts and things during lessons, but I would not say there has been an appropriate amount of time spent on it so, I would say that certainly it is something that I have not had a lot of experience doing then I would feel a wee bit apprehensive about doing it but certainly it's something I am quite open to doing".*

This comment extends the findings of recent Scottish research concerning the discomfort of Scottish Biology teachers concerning discussion (Bryce et al., 2004; Gray et al., 2006). Of the Science teachers questioned in this study only 8% were not comfortable discussing socio-scientific issues whereas 92% of teachers said that they were comfortable. However of these, 75% said that this depended on their level of subject knowledge and 67% said that this depended on the issue being discussed. Only two science teachers (ExST5 and NQST2) claimed to be very comfortable discussing such issues. Each of these teachers suggested that;

> *I keep abreast of topical items, so I don't have any qualms about broaching any new subject with them".* **ExST5**

NQST2 suggested that because she was interested personally in such issues, she felt very comfortable as this excerpt from her interview transcripts shows:

> ***NQST2****: I think probably because I'm interested in these things I feel comfortable in that it's because it's things that I feel are important; it's not just about teaching a curriculum, it's about*

awareness of what's going on around us and I think that the kids have to be aware of these things.

***Inv**: Do you think say, if we were to change the issue and I was to ask you to discuss the potential risks of mobile phone technology. How comfortable would you feel about going outside your subject knowledge?*

***NQST2**: I mean if you were talking about if, I had time, are you talking about going and doing it without any prior knowledge?*

***Inv**: No, how would you feel if it was coming up to that part of a course.*

***NQST2**: I would have no issue at all, not at all, I'd just go and prepare and I would make sure I was prepared and I knew the issues that were currently on the go. Definitely, I wouldn't have any problem with that at all.*

***Inv**: No issues at all?*

***NQST2**: I think the only issue might be… it depends on the class make-up. If it's a particularly challenging class that may limit discussion and maybe how far I would like to take it, whether I would like to have a lesson that's primarily a discussion, that would limit it.*

In this excerpt, NQST2 suggests that discussion of such issues is not something that she is particularly uncomfortable doing, provided that she has the time to prepare and assimilate the knowledge if she is not familiar with the subject area. This could be interpreted in the following terms: that as long as the teacher has the subject knowledge and is aware of some of the key arguments within the area to be discussed then he/she is comfortable discussing such controversial socio-scientific issues. This line of thought could also be interpreted that, as long as the teachers knows more about the subject being discussed than their pupils, then they feel comfortable.

In addition, it could be argued that Science teachers may shy away from discussion of socio-scientific issues due to a lack of subject knowledge about the issue being discussed. Furthermore, as such issues tend to emerge at the forefront of contemporary science it could be argued that it is unreasonable to expect Science teachers to keep up with new emerging science sufficiently to be able to discuss such issues especially if the science relevant to such issues is new and contestable. This train of thought leads to a number of questions such as: *Is this view a viable reason not to discuss such issues? Do discussions of socio-scientific issues require in-depth subject knowledge? Is this a view shared by Humanities teachers?*

In order to answer these questions, the experienced Humanities teachers were asked how comfortable they felt when discussing issues with some scientific content. Of the six Humanities teachers interviewed, four of them indicated that they felt very comfortable discussing issues with significant science content. ExHT1 suggested that in medical ethics they deal with a large level of scientific content;

> *In 4th year we've got medical ethics which very much has quiet a big scientific component in the sense of looking at genetic engineering and embryo research. On those sorts of issue, they do have a basic understanding of what the actual facts are and have a sense about that but, at the same time, we try not to focus on that too much, in getting too involved on what the actual science is because it is the moral perspective we are looking at it from.* **ExHT1**

This comment suggests that the science involved in such an issue, while important, is only one perspective and that the other perspectives which impinges on such issues allow people to engage in discussion. ExHT5 suggests that "It's not really a scientific question; it's more of a philosophical, ethical, moral type of question". Furthermore, ExHT6 suggests that he is comfortable even when his knowledge of the subject is not deep;

> *It depends; nobody likes to go outside their comfort-zone, so I would feel comfortable about it if I had some sort of knowledge of it but I would not be afraid for the kids who know more about it to take the lead. Just because I don't know much about a topic, doesn't mean I won't have a discussion about it at all because if some of the kids know more about it then brilliant,*

I'll learn something. If you don't like learning then you shouldn't be a teacher. **ExHT6**

This brings us back to the issue of control of the discussion. It appears that Humanities teachers see discussion as possible, regardless of the teacher's subject knowledge; that any issue is open for discussion since it is the perspectives through which the discussion is conducted that are important not just the objective facts pertinent to the issue being discussed. Humanities teachers seem to be happy to let their pupils lead discussion and are open to new perspectives.

The view of this group of Humanities teachers is that a lack of subject knowledge is no hindrance to discussion of any issue even issues with a scientific content. In addition, these humanities teachers do not feel that they need to know more than their pupils when initiating discussion as they are comfortable with them taking the lead. Furthermore, while they see subject knowledge as an important part of any discussion, when discussing socio-scientific issues they see the science as only one perspective, thus they feel more comfortable when discussing such issues because they are comfortable with the other perspectives (such as the moral, ethical, social, economic and political) and place the focus of the discussion on those perspectives.

4.5 Teachers' views on cooperative learning as an approach to discussion in the classroom.

All of the teachers interviewed were asked their opinion on cooperative learning as a pedagogical approach. It is interesting to note that all eighteen teachers had been for in-service training on the topic within the year prior to the start of the action research, with eleven of the teachers having attended a three day cooperative learning academy delivered by Canadian 'experts' through the sponsorship of the local education authority.

Upon analysing the responses there was a feeling among this group of teachers that cooperative learning was a good pedagogical approach with three ExST' rating it as 'excellent' and three rating it as 'good within limits'. All six NQSTs interviewed rated cooperative learning as 'good'. However, all six ExHTs interviewed rated it as ‘fine within limits’. This difference in view between the Science and Hhumanities teachers was evident in that Humanities teachers saw cooperative learning as a time consuming approach requiring more time in terms of planning and preparation of teaching materials as well as time in training the pupils on what their roles are as well as what the teachers’ expectations were compared to traditional approaches. Humanities teachers saw it as a method just like any other.

This view can be illustrated by the following quotes from the experienced Humanities teachers’ interview transcripts;

> *I think it’s [cooperative learning is] ok; I’ve got no problem with it at all; I do some of it already and I use it as and when I need it. It could be used more but I think there is a danger that you could use it too much. There are places where I use it but there are equally places where a more traditional teaching style is appropriate, it’s horses for courses.* **ExHT6**

Humanities teachers saw cooperative learning more as a management tool to help encourage discussion and as such saw its use as nothing new.

> *Cooperative learning isn’t particularly anything new; it’s just more formalized and more structured in that they work together and produce a joint outcome based on interdependence that’s much more formalized. But the actual process of teaching is not a great deal different; it’s just more formal… I’m not dismissive of cooperative learning, it definitely works and the kids like it but there are pros and cons to it. I am mostly quite enthusiastic about it as a method that can be used.* **ExHT5**

> ***ExHT3:*** *I like it because it does mean that every person in the group is ensured to participate… every kid gets involved, they are all part of the outcome so I do like it as at the end you can discuss it as a class, by seeing what everyone has done separately, then that information can spread more widely. I think it’s effective.*
>
> ***Inv:*** *Do you see cooperative learning as more of a management tool?*
>
> ***ExHT3:*** *Yes*

However, one Humanities teacher saw cooperative learning as restrictive in terms of the ability to cover ground (content) but that cooperative learning was useful when he wished to explore an issue in depth.

ExHT2: *I think that it works quite well like any other kind of strategy. I probably overdo the whole class discussion but again that is maybe due to the time element. I don't see classes for a couple of weeks; you want to be able to get as much done. Whereas group work might not get as much done but certainly you can go into more depth because the kids do feel more comfortable. You can't go as wide ranging if the teacher's not in charge. You can't suddenly draw on something that somebody said which was unexpected and say 'hang on there let's check this out'.*

Inv: *So it lacks flexibility?*

ExHT2: *A little bit. At the time, but it can work really well if the learning goals are much more focused.*

Inv: *So cooperative learning is restrictive?*

ExHT2: *Yes, because you can't talk about what you want. You need to give them very specific issues to talk about in a group discussion and then report back. That said, it can be used to cover stuff in depth. Perhaps you may not get the wide range but you can go further down the road of really trying to build knowledge.*

These experienced Humanities teachers saw cooperative learning as an approach which is time consuming and as such only use it where they see added benefit compared to their more traditional techniques. This opinion was echoed by three of the experienced Science teachers.

I don't think it's a panacea. I don't think it fits all situations. I think it depends on the class and it depends on the topic. If we had to go down the road of introducing cooperative learning at every stage of the game, two things would happen: teachers would be off ill with stress because it takes a lot of time and effort to do and development work is out the window… I *mean there is a place for it, but it does not fit all situations. The unfortunate thing is that the people that sit in ivory towers don't actually appreciate exactly what is involved and the physical demands of the job.* **ExST6**

In this quote, ExST6 views cooperative learning as a time consuming activity and worries about the effect that increased workload will have on teaching staff. However, ExST3 does see a place for it but worries about the need for checking the ideas generated by the pupils and questions the worth of some of the techniques used in cooperative learning.

Cooperative learning has its place and that place is in the generation of ideas, possibly the revision of ideas if you have got your source materials at hand. To divorce the cooperative learning from source materials would be a huge error. Things like graffiti board are an error. You need checks all the way. Within that you can't unload people and say you're now free to generate ideas that you are going to spread to other people with no checks at all. What you get is a hotchpotch of different levels of ideas all in one piece of paper which doesn't actually mean anything to anybody, it's nobody's culture and it's everybody's porridge. **ExST3**

The main critique that ExST3 levels at cooperative learning is the issue of the teacher being able to cover all the groups in the class adequately in the time available to be able to properly intervene when a misconception is exposed within the cooperative learning setting. This is seen as a possible weakness in the approach by this science teacher. The view that cooperative learning is of limited utility within science is also aired by science teachers who are more enthusiastic about its utility.

I think cooperative learning is fantastic but it doesn't apply to sciences all the way through the course. There are only certain areas where it will lend itself. I think as well that to do co-op learning you have got to do it properly, which again involves a lot of time. You've got to set up groups and you've got to have identifies and they've got to want to work together, and they've to want to collaborate to achieve the group goal. That in itself is time consuming; you're constantly referring them to the tasks but that involves you being particularly well planned ahead. You should be anyway but I think *particularly with co-op learning you have to really think 'what resources do I need, how am I going to integrate it, how am I going to plan it'.* ***ExST4***

One of the major concerns that this group of experienced Science and Humanities teachers return to is the issue of the time taken to plan and prepare a cooperative learning lesson. Within Science, time is short and the curriculum is packed with excessive content. If cooperative learning is to be used effectively, the development of teaching recourses would need to be factored into the planning and preparation time available. This means that teaching using cooperative learning must be targeted in such a way as to minimise the impact that increased planning and preparation time has on the management of the curriculum.

4.6 Summary.

Teachers use the phrase 'discussion' to cover a wide diversity of classroom interaction. Moreover, Science teachers hold a diverse range of conceptual models of discussion in much the same manner as their Humanities colleagues. Five conceptual models of discussion emerged from the research: (1) discussion *as a teacher-mediated discourse*; (2) discussion *as open-ended inquiry*; (3) discussion *for the development of reasoning skills*; (4) discussion *as mediated transfer of knowledge to real-life contexts*; (5) discussion *as practice for democratic citizenship.* However, Science teachers tend to emphasise discussion as practice for democratic citizenship, whereas Humanities teachers tend to emphasise discussion as open-ended inquiry and for the purpose of developing of reasoning skills.

In terms of comfort level when discussing controversial socio-scientific issues, Science teachers are not as comfortable as they initially report themselves to be. 'Comfort' seems to be conditional. They are more comfortable when they have enough knowledge of the science and key arguments relating to the issue being discussed. However, Humanities teachers are more than happy to discuss such issues regardless of their understanding of the content (the science) which impinges on the issue, as they place the emphasis on multiple perspectives of which science is only one.

Cooperative learning is seen by both Science and Humanities teachers as a useful tool for teaching using discussion. However, Humanities teachers see it as equally effective as other types of pedagogical approach to discussion. Both Humanities and Science teachers see cooperative learning as time consuming in terms of planning and preparation. Furthermore, they see it as less efficient in terms of their use of time.

Chapter 5: Pupils' views of Science & Technology and School Science.

5.1: Introduction:

This chapter describes some of the findings from the pupils' questionnaires and places the findings in the context of the overall action research. From the outset it was felt that in order to gauge the relevance of the subject matter to the pupils (and since bearing in mind Dillon's (1994) recommendation set out the need to consult the pupil as a criterion for the assessment of discussion) it was important to seek pupils' views on the cooperative learning strategy and to determine what they felt about science in general and about school science in particular.

As stated in Chapter 3, the pupil questionnaire was based on the Scottish version of the Relevance of Science Education (ROSE) questionnaire for three reasons;

1. The Scottish arm of this international survey was large, with 2757 pupil responses from 31 of the 32 Local Educational Authorities in Scotland. This allowed comparison of the school cohort to the Scottish ROSE (national) data. In addition, the Scottish ROSE study showed that there was no regional variation in pupil responses and that pupils in the Outer Hebridian Islands have similar likes, dislikes and attitudes to pupils in inner-city Glasgow.
2. The ROSE questionnaire format was relatively easy to analyse and interpret allowing for comparison of the S2 XHS cohort with the national data in order to provide evidence that the study cohort was not atypical.
3. The ROSE Questionnaire could be adapted to include a number of additional sections of questions relevant to specific aspects of the present study.

The data presented within this chapter is a selection of data from the pupil questionnaire relevant to the aims of the project. The remainder of the data from the questionnaire has been included in Appendix C for the sake of completion. It is important to note at this point that the Scottish arm of the ROSE study was given to S3 pupils (81.4% were 14 years of age with 12% being 13 years of age and 6% being 15 years old which equates to a mean age of 13.85). Whereas in this study the pupils targeted were a year younger in S2 (13.13 ± 0.34 years old).

5.2: Study Group Characteristics (Pupils and Teachers).

The S2 study group comprised 238 pupils of which 126 were male and 112 were female (53%:47%, male: female). The S2 pupils were split in 13 practical sections for Science. Four teachers took two sections each and five teachers took one section each. Nine Science teachers took part in the study: 3 Biology, 3 Chemistry and 3 Physics teachers.

Before focusing on the analysis of the pupil questionnaires, it was important to determine some basic characteristics of the S2 pupils in terms of their abilities in English reading and writing in comparison to Mathematics and Science. To this end, data was kindly provided by both the English and Mathematics departments to help assess each pupil's ability as determined by their 5-14 level at the end of S2. Figure 5.1 shows a stacked bar chart which compares English Reading and Writing with Maths and Science 5-14 Level for the S2 study cohort (n=238).

Figure 5.1: *Comparisons between S2 pupils 5-14 Levels in English (Reading and Writing) with Mathematics and Science.*

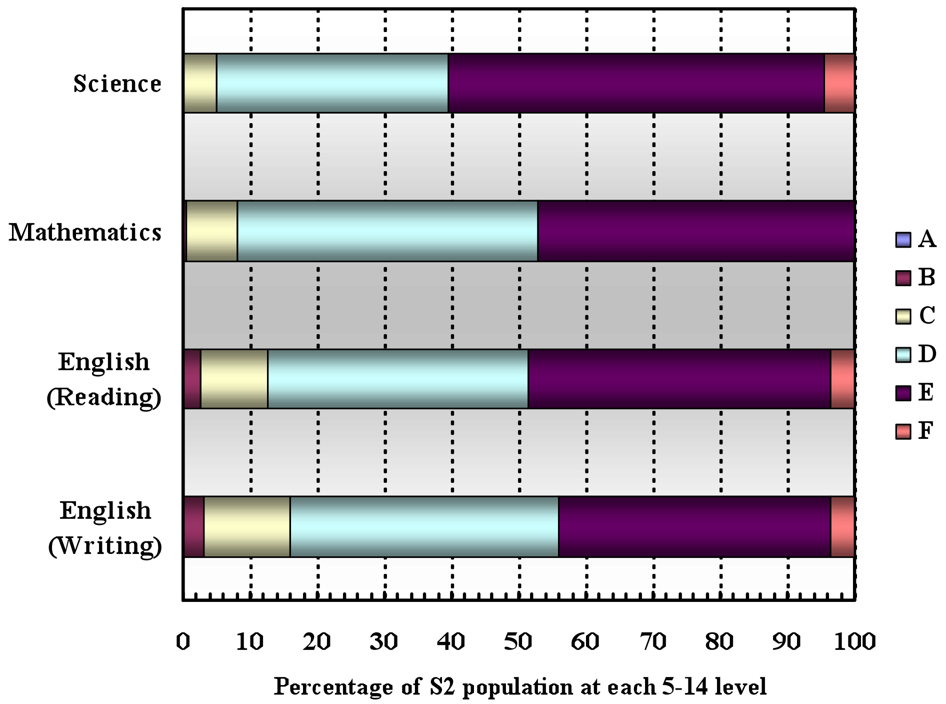


Table 5.1: *Percentage of S2 Pupils attaining each 5-14 Level in English (Reading & Writing), Mathematics and Science.*

5-14 level	English (Writing)	English (Reading)	Mathematics	Science
A	0.0	0.0	0.0	0.0
B	3.1	2.7	0.4	0.0
C	12.8	9.9	7.6	5.0
D	40.1	38.7	44.9	34.6
E	40.5	45.0	47.1	55.8
F	3.5	3.6	0.0	4.6

The data presented in Figure 5.1 and Table 5.1 indicate that the vast majority of S2 pupils attained levels D/E in English (Reading & Writing), Mathematics and Science by the time they reach the end of S2 with significant numbers of pupils attaining level E. It should be noted however, that a larger proportion of S2 pupils attained level E in Science (55.8%) in comparison to Mathematics (47.1%) and English, Reading & Writing (45% and 40.5% respectively).

These data suggest that the S2 pupils are generally less able in terms of writing by comparison with reading. In addition, 15.9% of pupils (38 pupils) were at level B/C for writing ability with 12.6% (30 pupils) being level B/C for reading ability. This is in contrast to Mathematics and Science where the percentage of pupils attaining a level B/C was 8% and 5% respectively.

5.3: Pupil Questionnaire.

In order to present the data contained within the returned surveys in as full a manner as is possible, the results from this part of the study are presented section by section and, where possible, comparisons are drawn with the ROSE data for Scotland.

5.3.1: Pupil Questionnaire Characteristics.

A total of 238 pupil questionnaires were issued. Of those, 204 surveys were returned (86%), of which 171 were completed in a valid form (72%). Thirty four pupils (14%) were absent on the day of issue and were not issued with the questionnaire on their return. Thirty-three surveys (14%) were rejected from the data set mainly due to inadequate completion as described in Chapter 3.

5.3.2: General distribution of responses to the S2 Survey.

The mean Likert score, averaged over all 107 topic items for all 171 pupils was 2.39 which compares well with that of the ROSE survey in Scotland which reported a mean Likert score, average for sections A, C and E of 2.40. As with the ROSE survey Scotland, the XHS S2 pupils showed a great deal of variation in their overall level of interest. Figure 5.2A shows the distribution of the mean scores for each pupil, together with the standard deviation of each pupil's scores across the 108 items of Sections A, C &E from the ROSE survey Scotland Figure. 5.2B shows distribution of the mean scores for each pupil, together with the standard deviation of each pupil's scores across the 107 items of Sections A, D and I from the S2 pupil cohort.

Figure 5.2: *Scatterplots of mean and standard deviation scores in Sections A, C & E from the ROSE survey Scotland and the corresponding sections A, D and I from the XHS S2 pupil cohort.*

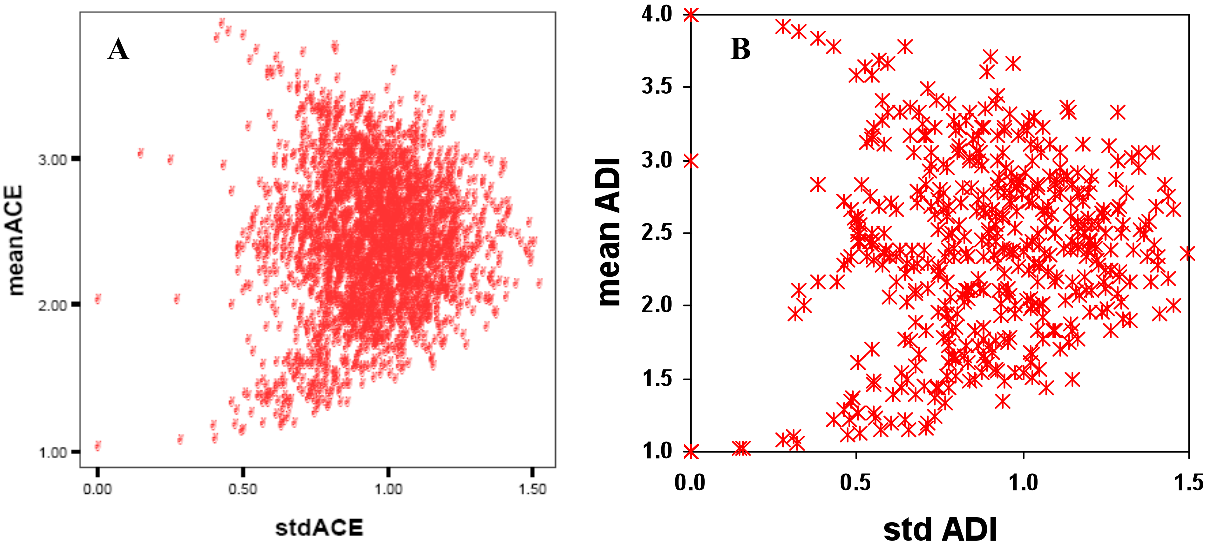


Figure 5.2A shows the mean verses standard deviation plot for the ROSE Scotland Survey and Figure 5.2B shows the corresponding data for the S2 pupil cohort from XHS.A mean score of 1 indicates strong lack of interest in the topic and 4 indicates strong interest in the topic.

In the ROSE survey one pupil responded '1' (strong lack of interest) for every topic. This also occurred in the S2 pupil cohort. At the other extreme in the ROSE survey one pupil's mean was 3.9, implying a great preponderance of '4' responses. This also occurred in the S2 study cohort. Figures 5.2A and 5.2B show that the vast majority of pupils spread their responses much more widely. The quite high standard deviation values signal that the full range of responses was used by most individuals. In terms of the mean scores, it is clear that there is a very wide variation in the overall interest levels of different pupils.

Figure 5.3: *Correlation between Sections A, C and E from ROSE Scotland with the corresponding Section A, D and I from the S2 pupil cohort Survey (XHS).*

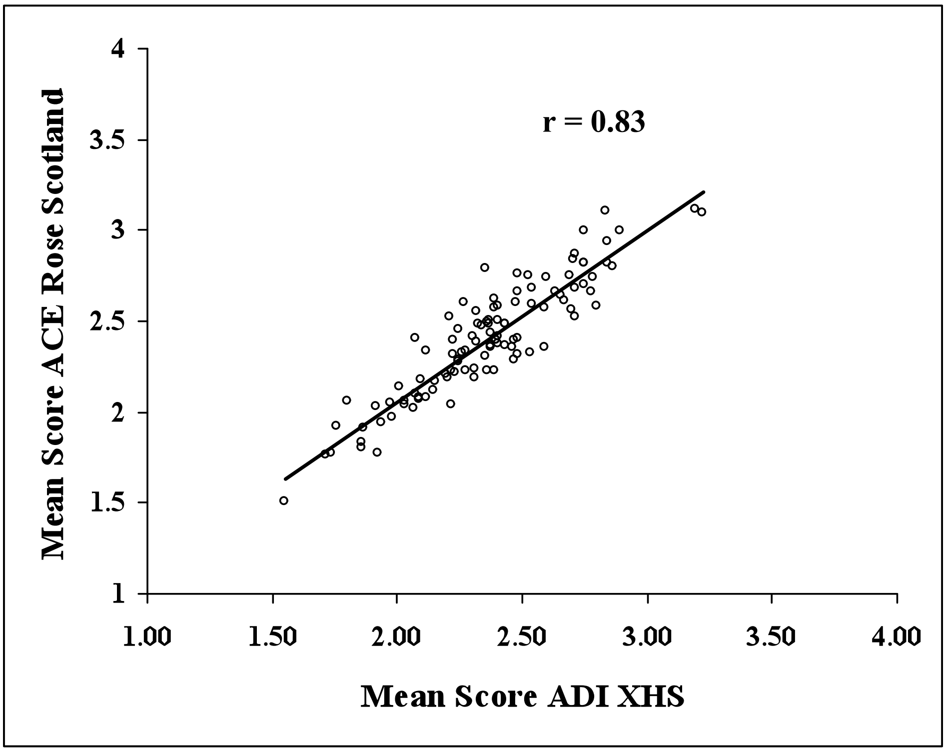


Figure 5.3 shows a strong positive correlation between the ROSE mean score for sections ACE with the mean score for sections ADI from the S2 pupil cohort from XHS.

The data presented in Figure 5.3 shows the there is a significant correlation (least square regression coefficient of r = 0.83) between the responses made by the S2 pupil cohort for the sections of the pupil questionnaire which asked pupils 'what I want to learn about' in comparison to the same sections in the Scottish ROSE questionnaire. This provides evidence to suggest that the S2 pupil cohort hold similar likes and dislikes in scientific topics to their peers across Scotland.

5.3.3: Review of responses to Section B 'Me and the environmental challenges'.

The responses to this section of the S2 survey can be grouped together under three categories, importance and global consequences, personal and national responsibilities, and animal rights and human intervention. Table 5.2 shows the mean Likert score for responses to items B1 to B18 and compares them to the corresponding mean Likert score from the ROSE survey Scotland.

Table 5.2: *Comparison between ROSE survey Scotland Data XHS S2 survey for Section B*

	Topic Item	Overall		Males		Females	
IMPORTANCE AND GLOBAL CONSEQUENCES		*ROSE Scotland*	XHS	*ROSE Scotland*	XHS	*ROSE Scotland*	XHS
B2.	Environmental problems make the future of the world look bleak and hopeless	*2.63*	2.63	*2.61*	2.67	*2.65*	2.58
B3.	Environmental problems are exaggerated	*2.21*	2.28	*2.27*	2.29	*2.15*	2.27
B4.	Science and technology can solve all environmental problems	*2.09*	1.90	*2.25*	2.02	*1.95*	1.78
B7.	We can still find solutions to our environmental problems	*3.02*	3.01	*3.01*	3.09	*3.03*	2.92
B8.	People worry too much about environmental problems	*2.42*	2.60	*2.53*	2.50	*2.32*	2.69
B9.	Environmental problems can be solved without big changes in our way of living	*2.44*	2.55	*2.44*	2.53	*2.44*	2.56
B14	I am optimistic about the future	*2.83*	2.71	*2.83*	2.81	*2.83*	2.61
PERSONAL AND NATIONAL RESPONSIBILITIES							
B1.	Threats to the environment are not my business	*2.01*	1.92	*2.08*	1.86	*1.94*	1.98
B5.	I am willing to have environmental problems solved even if this means sacrificing many goods	*2.22*	2.25	*2.22*	2.22	*2.22*	2.28
B6.	I can personally influence what happens with the environment	*2.26*	2.20	*2.26*	2.34	*2.26*	2.06
B10	People should care more about protection of the environment	*3.01*	3.01	*2.96*	3.12	*3.06*	2.89
B11	It is the responsibility of the rich countries to solve the environmental problems of the world	*2.61*	2.18	*2.69*	2.16	*2.54*	2.19
B12	I think each of us can make a significant contribution to environmental protection	*2.91*	2.77	*2.86*	2.80	*2.97*	2.74
B13	Environmental problems should be left to the experts	*2.20*	2.18	*2.24*	2.12	*2.16*	2.24
ANIMAL RIGHTS AND HUMAN INTERVENTION							
B15	Animals should have the same right to life as people	*3.02*	2.96	*2.88*	2.85	*3.14*	3.08
B16	It is right to use animals in medical experiments if this can save human lives	*2.14*	2.16	*2.33*	2.47	*1.97*	1.85
B17	Nearly all human activity is damaging for the environment	*2.23*	2.11	*2.19*	2.14	*2.26*	2.08
B18	The natural world is sacred and should be left in peace	*2.65*	2.74	*2.61*	2.83	*2.70*	2.66

In section B, the pupils were asked on a 4-point scale to indicate the extent to which they agreed with each item. The items grouped under the category *"Importance and global consequences"* indicate that the S2 pupils think that environmental problems make the future look bleak and hopeless (mean score 2.63 v 2.63 ROSE survey), but they are also optimistic about the future (mean score 2.71 v 2.83 ROSE survey). In addition, they do not believe that environmental problems are exaggerated (mean score 2.28 v 2.21 ROSE survey). Furthermore, they believe that Science can find solutions to the environmental problems (mean score 3.01 v 3.02 ROSE survey) but that science cannot find solutions to them all (mean score 1.90 v 2.09 ROSE survey). However, the S2 pupils think that people worry too much about environmental problems (mean score 2.60 v 2.42 ROSE survey).

The items grouped under the category "*personal and national responsibilities"* indicate that the S2 pupils strongly agree that threats to the environment are their business (mean score 1.98 v 2.01 ROSE survey) but as with the ROSE survey they are not prepared to sacrifice goods to help solve environmental problems (mean score 2.25 v 2.22 ROSE survey). In addition, they do not think that they can personally influence what happens with the environment (mean score 2.20 v 2.26 ROSE survey) but that people should care more about protecting the environment (mean score 3.01 v 3.01 ROSE survey). In contrast to the ROSE survey, the S2 pupil cohort does not think that it is the responsibility of rich countries to solve the world's environmental problems (mean score 2.18 v 2.61 ROSE survey).

The S2 pupils also believe that they can make a significant contribution to environmental protection (mean score 2.77 v 2.91 ROSE survey) which, on the face of it, is a contradiction of their view that they cannot influence what happens with the environment. However, this could be seen differently in that they may perceive that they can personally 'do their bit' to protect their local environment but that they have little influence over global environmental events.

The items grouped under the category *"animal rights and human intervention"* show that the S2 pupils agree with the ROSE survey respondents that animals should have the same right to life as humans (mean score 2.96 v 3.02 ROSE survey) and that it is wrong to use animals in medical experiments even if this can save a human life (mean score 2.16 v 2.14 ROSE survey). In the main, the S2 pupils' responses to Section B of the questionnaire correlate well with those of section D of the ROSE survey Scotland.

Figure 5.4: *Correlation between S2 responses to Section B of S2 Survey against Section D of the ROSE Survey Scotland.*

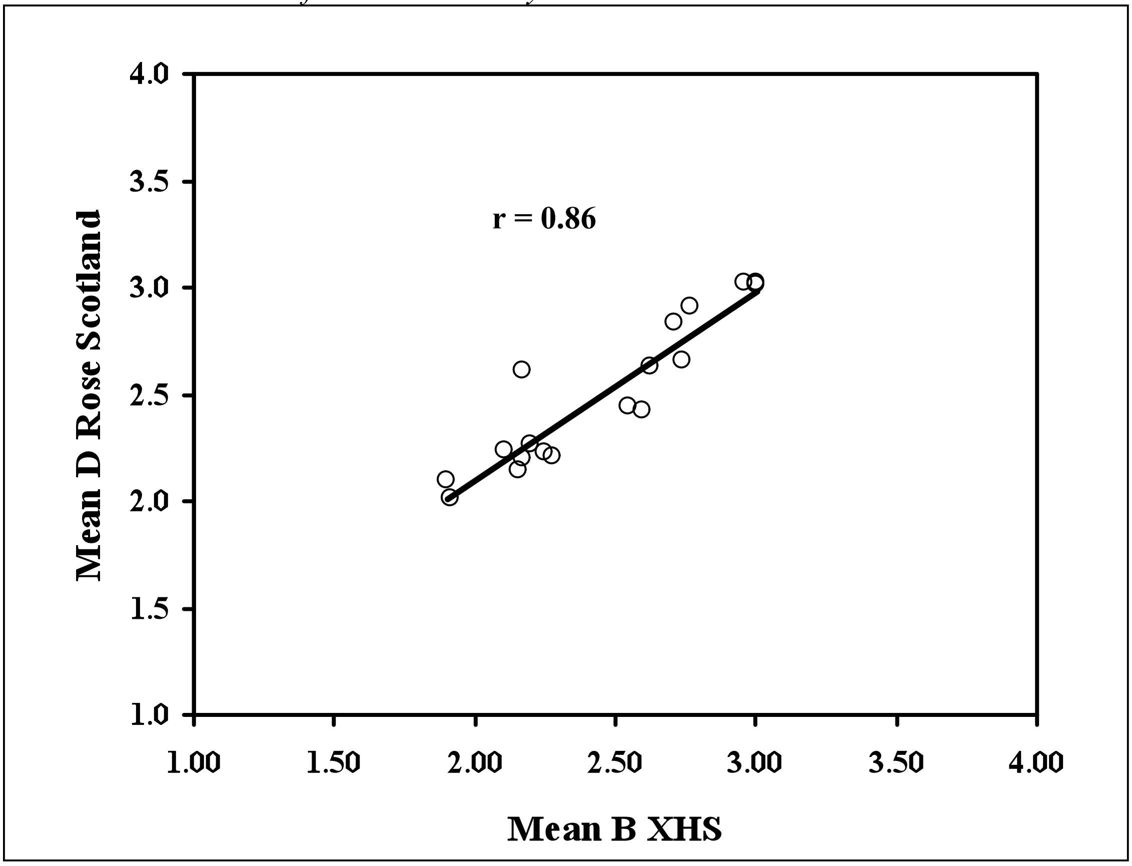


Figure 5.4 shows the correlation between the XHS S2 pupils' responses to Section B of the pupil questionnaire compared to Section D of the Scottish ROSE survey. There is a strong correlation (least square regression coefficient of r=0.86) between the Scottish ROSE data and that of XHS S2 which indicates that there is little difference in response between the two groups to these identical sets of questions.

5.3.4: Review of S2 Responses to Section C 'My opinion about Science and Technology'.

This section surveys pupil views about the importance and value of science as well as the impact of science and technology on society, and probes pupils' views on the reliability of science and of scientists. Pupils are asked, on the 4-point Likert scale, to record the extent to which they agree or disagree with each of 16 statements covering this ground.

***Table 5.3**: Comparison between Whole population mean Likert score for ROSE survey Scotland responses with S2 Study cohort responses to Section B.*

STATEMENT		ROSE Scotland			S2 XHS		
		mean	*SD*	% Agree	mean	*SD*	% Agree
	Number in group	2747			171		
C01	Science and technology are important for society	2.72	*0.99*	62.8	3.11	*0.93*	78.4
C02	Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc.	3.03	*0.91*	75.2	3.27	*0.74*	84.8
C03	Thanks to science and technology, there will be greater opportunities for future generations	2.89	*0.96*	69.4	3.18	*0.83*	80.1
C04	Science and technology make our lives healthier, easier and more comfortable	2.73	*0.95*	62.5	2.91	*0.95*	69.0
C05	New technologies will make work more interesting	2.77	*0.96*	64.6	3.15	*0.95*	82.2
C06	The benefits of science are greater than the harmful effects it could have	2.46	*0.91*	48.5	2.61	*0.97*	58.7
C07	Science and technology will help to eradicate poverty and famine in the world	2.31	*0.94*	42.0	2.37	*0.98*	45.3
C08	Science and technology can solve nearly all problems	2.06	*0.90*	29.5	2.11	*0.89*	33.9
C09	Science and technology are helping the poor	2.11	*0.90*	31.9	2.10	*0.88*	34.1
C10	Science and technology are the cause of the environmental problems	2.29	*0.90*	38.8	2.41	*0.91*	43.9
C11	A country needs science and technology to become developed	2.57	*0.95*	56.1	2.78	*1.02*	65.2
C12	Science and technology benefit mainly the developed countries	2.54	*0.98*	53.0	2.67	*1.08*	63.6
C13	Scientists follow the scientific method that always leads them to correct answers	2.12	*0.89*	31.6	2.12	*0.87*	31.4
C14	We should always trust what scientists have to say	1.78	*0.81*	16.9	1.75	*0.87*	19.4
C15	Scientists are neutral and objective	2.12	*0.83*	30.6	2.20	*0.89*	38.5
C16	Scientific theories develop and change all the time	2.74	*0.98*	64.1	2.91	*1.00*	77.8

For 14 of the 16 statements a high score response (indicating agreement with the statement) represents a positive view of science and technology. The mean Likert score of an individual's responses thus gives a crude measure of how positively that pupil views science as a whole. Form the S2 pupils responses the mean overall score (± standard deviation) was 2.60 ± 0.92, marginally to the positive side of the 'net neutral' value of 2.50. The mean scores for different pupils varied considerably, indeed across the entire possible range, though 92.4% lay within the central range from 2.0 to 3.0, with 69% of responses being above 2.50. So the survey shows a very wide range of opinions. This differs from the ROSE survey Scotland which reported a marginally negative mean overall score of 2.45 ± 0.92 with 70% falling within the central range from 2.0 to 3.0.

Confirmation that pupils on the whole considered each statement individually is provided by the standard deviation of the Likert scores provided by each individual: these values average 0.92, consistent with most pupils making use of the full 4-point scale. Whilst the 16 individual statements attract significantly different overall levels of agreement, it is also the case that there is significant diversity of opinion in all instances. The standard deviations in the Likert scores for each of the 16 items all lay between 0.71 and 1.00, so it is important to recognise that overall views reported below are not unanimous. The spread of responses is further reflected in the mean Likert scores for individual statements: these lay between 2.0 and 2.9, with the exceptions of C01, C02, C03, C05, (3.11, 3.27, 3.18 & 3.15 respectively) and C14 which had a mean Likert score of 1.75.

When S2 males were compared to S2 females, differences began to appear (see Table 5.4). For example, S2 males are more positive in their attitude to science and technology than S2 females (Item C01 mean score 3.30, 84.9% agreeing v 2.92. 72.9% agreeing). In addition, the S2 males are more optimistic about science and technology, with respect to greater opportunities for future generations (Item C03 mean score 3.35, 86.1% agreeing v S2 females mean score 3.01, 74.1% agreeing). Furthermore, when compared to the ROSE survey data, the S2 pupil cohort data show that the percentage agreeing with each statement for both males and females is on average different from the ROSE survey males and females by 7.87% and 6.62%

respectively. However, if the S2 sample size were larger it is probable that this difference may be reduced. Table 5.4 shows the comparison between males and females from the S2 pupil cohort with the corresponding data from the ROSE survey Scotland.

Table 5.4: *Comparison between male and female mean Likert score with % agreeing for ROSE survey Scotland responses with S2 Study cohort responses to Section B.*

STATEMENT		Males			Females		
		XHS mean	% Agree	ROSE Scotland (% Agree)	XHS mean	% Agree	ROSE Scotland (% Agree)
	Number in group	86		1277	85		1445
C01	Science and technology are important for society	3.30	84.9	66.1	2.92	71.8	59.7
C02	Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc.	3.24	83.7	73.8	3.29	85.9	76.6
C03	Thanks to science and technology, there will be greater opportunities for future generations	3.35	86.0	70.3	3.01	74.1	68.7
C04	Science and technology make our lives healthier, easier and more comfortable	3.02	74.4	64.9	2.80	63.5	60.4
C05	New technologies will make work more interesting	3.29	83.5	68.9	3.00	81.0	61.4
C06	The benefits of science are greater than the harmful effects it could have	2.55	53.6	53.9	2.67	63.9	43.7
C07	Science and technology will help to eradicate poverty and famine in the world	2.47	51.2	43.1	2.27	39.3	40.9
C08	Science and technology can solve nearly all problems	2.24	41.9	34.5	1.98	25.9	24.8
C09	Science and technology are helping the poor	2.26	42.9	34.5	1.94	25.3	29.6
C10	Science and technology are the cause of the environmental problems	2.50	46.5	40.3	3.32	41.2	37.6
C11	A country needs science and technology to become developed	2.95	69.8	60.5	2.60	60.7	52.1
C12	Science and technology benefit mainly the developed countries	2.76	69.0	55.4	2.58	58.0	51.1
C13	Scientists follow the scientific method that always leads them to correct answers	2.12	29.4	36.9	2.12	33.3	26.9
C14	We should always trust what scientists have to say	1.79	22.1	19.3	1.72	16.7	14.7
C15	Scientists are neutral and objective	2.27	44.7	34.7	2.14	32.1	27.0
C16	Scientific theories develop and change all the time	2.29	78.3	64.2	2.91	77.4	64.3

5.3.5: Review of S2 Responses to Section E 'My Science Classes' and Section L 'How I feel about Science in School'.

In both sections E and L, pupils were asked, on the 4-point Likert scale, to indicate to what extent they agreed with statements about their school science experience and how they felt about school science. Table 5.5 shows the overall S2 data and the data for both males and females in comparison with the overall ROSE survey Scotland data.

Table 5.5: *Comparison between XHS S2 pupil cohort mean Likert scores for sections E and L with the corresponding sections of ROSE Survey Scotland.*

	STATEMENT	ROSE Scotland	XHS Overall Mean	*SD*	XHS Male	*SD*	XHS Female	*SD*
E01	School science is a difficult subject.	2.25	2.49	*0.94*	2.37	*0.90*	2.61	*0.96*
E02	School science is interesting.	2.80	2.67	*1.04*	2.91	*0.98*	2.42	*1.05*
E03	School science is rather easy for me to learn.	2.35	2.37	*0.94*	2.51	*0.92*	2.22	*0.94*
E04	School science has opened my eyes to new and exciting jobs.	2.34	2.34	*1.09*	2.51	*1.07*	2.16	*1.08*
E05	I like school science better than most other subjects.	2.13	1.82	*0.97*	1.97	*1.05*	1.68	*0.88*
E06	I think everybody should learn science at school.	2.55	2.46	*1.15*	2.59	*1.12*	2.32	*1.18*
E07	The things that I learn in science at school will be helpful in my everyday life.	2.66	2.61	*1.06*	2.65	*0.99*	2.56	*1.14*
E08	I think that the science I learn at school will improve my career chances.	2.90	2.81	*1.05*	2.98	*0.96*	2.65	*1.11*
E09	School science has made me more critical and sceptical.	2.30	2.10	*0.97*	2.19	*0.96*	2.01	*0.98*
E10	School science has increased my curiosity about things we cannot yet explain.	2.59	2.62	*1.21*	2.84	*1.20*	2.40	*1.20*
E11	School science has increased my appreciation of nature.	2.31	2.31	*1.08*	2.34	*1.04*	2.28	*1.12*
E12	School science has shown me the importance of science for our way of living.	2.44	2.41	*1.04*	2.58	*1.00*	2.24	*1.05*
E13	School science has taught me how to take better care of my health.	2.45	2.65	*1.05*	2.60	*1.03*	2.71	*1.07*

Table 5.5 Continued

		Rose Scotland	XHS Overall Mean	*SD*	XHS Male	*SD*	XHS Female	*SD*
E14	I would like to become a scientist.	1.77	1.56	*0.95*	1.65	*0.99*	1.46	*0.89*
E15	I would like to have as much science as possible at school.	2.09	1.85	*0.96*	1.92	*0.95*	1.79	*0.98*
E16	I would like to get a job in technology.	1.96	2.01	*1.14*	2.62	*1.12*	1.40	*0.77*
L01	In Science, I would rather learn a lot about few topics than a little about a lot of different topics.	2.58	2.84	*1.09*	2.94	*1.06*	2.74	*1.11*
L02	Doing practical and experimental work helps me to understand science topics.	3.18	3.15	*0.94*	3.34	*0.85*	2.95	*0.99*
L03	Doing practical and experimental work with good, modern apparatus makes me want to study science.	2.88	2.81	*1.04*	2.92	*1.04*	2.69	*1.02*
L04	My School Science rooms are exciting places in which to work.	2.14	2.10	*0.97*	2.10	*0.95*	2.09	*1.01*
L05	If practical content of the course were increased it would give me grater enjoyment of Science.	2.77	2.79	*1.01*	2.88	*1.05*	2.69	*0.96*
L06	I found Primary Science interesting.	2.00	2.02	*1.03*	2.02	*1.03*	2.02	*1.03*
L07	Science at Primary School prepared me well for Science classes in Secondary School.	1.79	1.73	*0.97*	1.76	*0.98*	1.71	*0.96*
L08	I find Science in Secondary School more interesting than Science in Primary School.	3.05	3.06	*1.16*	3.31	*1.05*	2.80	*1.21*

Sections E and L probe pupil reactions to the science education they have experienced. They are asked to what extent they agreed with each of 24 statements. The first 16 questions (Sec E) surveyed their general views about their overall experience in terms of difficulty, interest, usefulness and educational impact. The remaining 8 questions (Sec L) gathered views about practical work and facilities and about the style and progression of the science curriculum over Primary School and the first two years of Secondary. Statements E1 and E3 investigate pupil views of the difficulty of science. Overall, the S2 pupil cohort were neutral as to the difficulty of school science with a mean Likert score of 2.49 ± 0.94 whereas the ROSE survey Scotland showed that across Scotland pupils thought that school science was difficult (ROSE mean score 2.25). However, S2 females found school science more difficult (mean score 2.61) than their male counterparts (mean score 2.37). The S2 pupil cohort did agree with the ROSE survey when it came to how easy they found science to learn with a mean score of 2.37 ± 0.94 (ROSE mean score 2.35). However, S2 males were again more positive about learning school science (mean score 2.51) than their S2 female counterparts (mean score 2.22)

Statements E2 and E5 investigated pupils' interest in and liking for school science. Overall, the S2 pupil cohort found School science interesting (mean score 2.67 ±1.04 v ROSE Survey Scotland mean score of 2.80). However, when asked if they liked school science better than most subjects, the mean score was more negative 1.82 ± 0.97 which is also more negative than the ROSE mean score of 2.13. S2 males are more interested in school science (mean score 2.91) than their female counterparts (mean score 2.42). Table 5.6 shows a cross-tabulation of responses for the S2 pupil cohort males and female for item E02 against E05.

***Table 5.6**: Cross-tabulation of Item E02 against E05 for S2 males and females.*

Sex			E05 I like school science better than most other subjects				
			Strongly Disagree	Disagree	Agree	Strongly Agree	Total
Female	E02 School science is interesting	Strongly Disagree	19 (22.4%)	0 (0%)	1 (1.2%)	0 (0%)	*20*
		Disagree	12 (14.1%)	8 (9.4%)	2 (2.4)	0 (0%)	*22*
		Agree	11 (12.9%)	16 (18.8%)	2 (2.4%)	1 (1.2%)	*30*
		Strongly Agree	1 (1.2%)	6 (7.1%)	2 (2.4%)	4 (4.7%)	*13*
		Total	*43*	*30*	*7*	*5*	*85*
Male		Strongly Disagree	10 (11.6%)	0 (0%)	1 (1.2%)	0 (0%)	11
		disagree	10 (11.6%)	1 (1.2%)	1 (1.2%)	0 (0%)	12
		Agree	14 (16.3%)	15 (17.4%)	7 (8.1%)	1 (1.2%)	37
		Strongly Agree	5 (5.8%)	4 (4.7%)	9 (10.5%)	8 (9.3%)	26
		Total	*39*	*20*	*18*	*9*	*86*

Ogawa and Shimode, of Kobe University in Japan, have suggested using these two questions to divide pupils into four categories:

i. **‘pro-science’**: (Specific priority group) those agreeing both that science is interesting both absolutely and relative to other subjects;

ii. **‘latent pro-science’**: (non-positive priority group) those disagreeing that science is interesting absolutely, yet who like it relative to other subjects;

iii. **‘apparent pro-science’**: (other priority group) those agreeing that science is interesting absolutely, but who nonetheless rate it low compared to other subjects;

iv. **‘anti-science’**: (Poor priority group) those disagreeing on both counts (Ogawa & Shimode, 2004).

A detailed analysis of the cross tabulation shown in Table 5.6 indicates that 45.9% of females and 24.4% of males were **‘anti-science’** (negative towards interest in science and liking science more than other subjects). Whereas 29.1% of males and 10.6% of S2 females indicated that they were **‘pro-science’** (interested in school science and liked science more than other subjects). When the data is further analysed it can be seen that 3.5% of S2 females and 2.3% of S2 males were **‘latent pro-science’** (not interested in school science but liked science more than other subjects). However, 40.0% of S2 females and 44.2% of S2 males indicated that they were **‘apparent pro-science’ (**interested in school science but that they liked other subjects more). When compared to the ROSE Scotland data, the S2 pupil group compare as follows in Table 5.7 :-

Table 5.7: *Comparison between ROSE Scotland cross-tabulation of Questions F2 and F05 with XHS S2 cohort cross-tabulation of Questions for E02 and E05.*

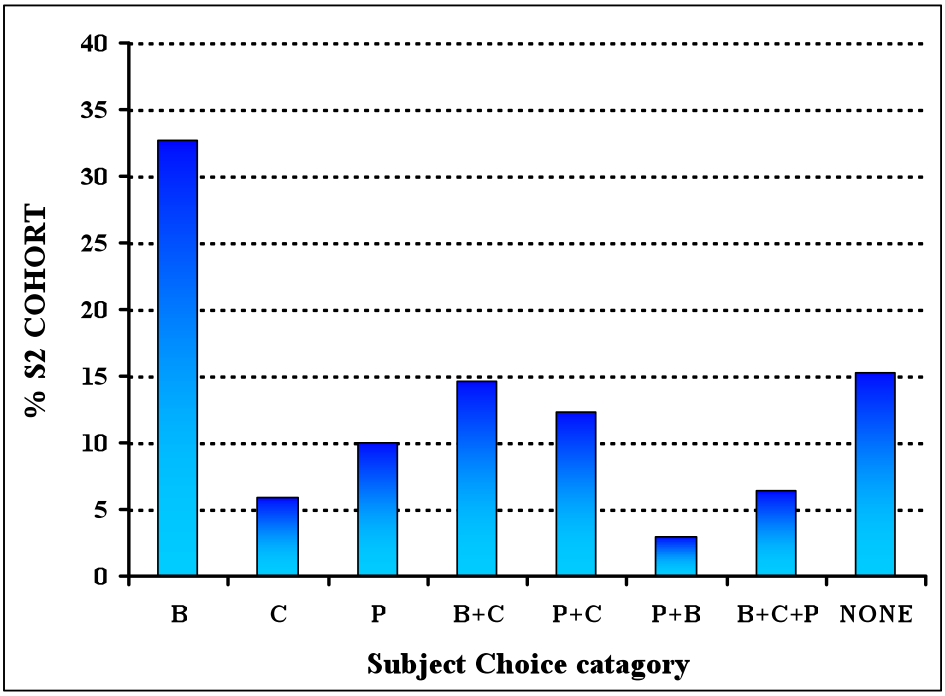
Study	Number	Gender	Pro-Science	Latent Pro-Science	Anti-Science	Apparent Pro-Science
ROSE Scotland	1449	Female	406 (28.8%)	42 (2.9%)	450 (31.9%)	512 (36.3%)
S2 Cohort	85	Female	9 (10.65%)	3 (3.5%)	39 (45.9%)	34 (40%)
ROSE Scotland	1282	Male	437 (35.3%)	65 (5.3%)	309 (25%)	425 (34.4%)
S2 Cohort	86	Male	25 (29.1%)	2 (2.3%)	21 (24.4%)	38 (44.2%)

These data are interesting as the pupils were asked in section H of the pupil questionnaire, *If given a **free choice** at the end of S2, which course choice would you pick from the following?* Table 5.8 and Figure 5.5 show the frequency of responses.

Table 5.8: *Range of Responses from the S2 study cohort to Section H*

	Frequency (n)	% of Population	Male (n)	% Male population	Female (n)	% Female Population
Biology	**56**	**32.7**	**20**	**23.3**	**36**	**42.4**
Chemistry	**10**	**5.8**	**6**	**7**	**4**	**4.7**
Physics	**17**	**9.9**	**16**	**18.6**	**1**	**1.2**
Biology and Chemistry	**25**	**14.6**	**8**	**9.3**	**17**	**20.0**
Physics and Chemistry	**21**	**12.3**	**17**	**19.8**	**4**	**4.7**
Physics and Biology	**5**	**2.9**	**1**	**1.2**	**4**	**4.7**
Biology, Chemistry and Physics	**11**	**6.4**	**6**	**7**	**5**	**5.9**
None of the above	**26**	**15.2**	**12**	**14**	**14**	**16.5**

Figure 5.5: *Percentage of pupils who would pick a science in 3rd Year if given a free choice*



The data show that in XHS, Biology is the most popular of all the Sciences, followed by Physics then by Chemistry. Interestingly, only 15.2% of pupils indicated that they would not take a science if they had a free choice. Furthermore, when items E02 and E05 are cross-tabulated, 17% indicated that they were not interested in school science and preferred other subjects to science. This strengthens the validity of the response to the survey as these data closely match each other. In addition, the data also reveal that while the proportion of the S2 cohort which can be categorised as anti-science is 35% and that, if given a free choice, only 15.2% would not choose a science in S3. That just over half of those categorised as anti-science would still choose a science in S3 is encouraging as this suggests that although they may not like science, they do see its relative importance to their education. These data indicate that in XHS, Chemistry is in decline by comparison with Biology and Physics.

Statements E04, E07 and E08 investigated the perceived usefulness of school science education for everyday life and career prospects. The S2 pupil cohort data show that S2 pupils do not think that school science has opened them up to new job possibilities. This is in agreement with the ROSE data (mean score S2=2.34 ±1.09 v ROSE= 2.34). However, S2 pupils think that what they learn in school science does help them in everyday life (mean score 2.61 ± 1.06 v ROSE =2.66). Furthermore, S2 pupils also think that what science they have learned will improve their career chances (mean score 2.81 ±1.05 v ROSE= 2.90). The data also indicate that males tend to be more positive about these three aspects than are females.

Statements E09 and E10 investigated whether pupils thought school science made them more critical, sceptical or curious. The S2 pupil cohort data indicates that overall S2 pupils from XHS think that school science has not increased their scepticism or made them more critical (mean score 2.10 ± 1.09 v ROSE mean 2.30) By contrast, the S2 data shows that the S2 pupils think that School science has increased their curiosity about things we cannot yet explain (mean score 2.62 ± 1.21 v ROSE mean 2.69)

Statement L01 asked whether or not pupils would prefer to study a few topics in depth or a little about lots of topics. The S2 pupils were in favour studying fewer topics but to a greater depth (mean score 2.84 ± 1.09 v ROSE mean 2.58). Statements L02, L03, L05 investigated the impact of practical work as perceived by pupils. The S2 pupils agreed with the statement "doing practical and experimental work helps me to understand science topics" with a mean score of 3.15 ± 0.94 which is comparable with the ROSE survey mean score 3.18. In addition, the S2 pupil cohort also agreed that "doing practical and experimental work with good, modern apparatus makes me want to study science" with a mean score 2.81 ± 1.04 and they further agreed that "if practical content of the course were increased it would give me grater enjoyment of Science" with a mean score 2.79 ± 1.01. It should be noted that the S2 cohort agreed with the ROSE survey data in that they did not find primary Science interesting (mean score 2.02 v ROSE mean score 2.00) and more worrying for primary science is that the S2 pupil cohort felt that primary science did not prepare them for Science classes at Secondary school (mean score 1.73 v ROSE mean score 1.79).

5.3.6: Review of Responses to section F 'Statements about Science'.

In this section of the pupil questionnaire the pupils were asked to choose one statement from each group of statements which most closely matched their view of science. In this section there were a number of statements (13a and b) which refer closely to statements in other sections of the questionnaire meaning that one could compare responses to these questions as a further means of detecting whether pupils were filling in the questionnaire consistently with their true feelings. Table 5.9 shows the range of responses to this section as the percentage of the S2 cohort who picked each statement

Table 5.9: *Range of response of S2 Study cohort to the Statements about Science Instrument.*

	Statement	**Overall**	**Male**	**Female**
1a	Science is a collection of true facts.	36.4	45.9	27.3
1b	Science is a procedure.	22.0	22.4	21.6
1c	Science is a world view.	41.6	31.8	51.1
2a	Science assumes cause and effect.	85.5	84.7	86.4
2b	Science assumes nothing.	14.5	15.3	13.6
3a	Science is independent of the culture.	43.9	41.2	46.6
3b	Science is affected by the language and culture it is conducted in.	34.7	37.6	31.8
3c	Scientific ideas are the stories that western scientists accept but have no special claim to describe reality over the stories of other cultures and people.	21.4	21.2	21.6
4a	Scientific ideas are true	14.5	16.7	12.5
4b	Scientific ideas are testable but can never be entirely proven.	77.9	76.2	79.5
4c	Scientific ideas are only relevant for western thinkers and only pertain to the western world view.	7.6	7.1	8.0
5a	The scientific method is a loose procedure for making observations about the physical world.	29.1	29.8	28.4
5b	The scientific method requires that reproducible tests be conducted.	70.9	70.2	71.6
6a	Scientific thinking is logical and linear and does not involve intuition.	16.2	17.6	14.8
6b	Scientific thinking is a combination of logic and intuition.	73.4	75.3	71.6
6c	Scientific thinking is primarily intuitive.	10.4	7.1	13.6
7a	Conclusions drawn by scientists are true.	11.0	9.4	12.5
7b	Conclusions drawn by most scientists are influenced by political pressures.	24.3	25.9	22.7
7c	Conclusions drawn by scientists are provisional and may be revised as more data become available.	49.7	49.4	50.0
7d	Conclusions drawn by scientists may not be relevant for other people.	15.0	15.3	14.8
8a	Theories can be proven.	83.2	81.2	85.2
8b	Theories can only be disproven.	16.8	18.8	14.8

Table 5.9 continued

	Statement	Overall	Male	Female
9a	Theories are effective models for describing reality.	37.6	36.5	38.6
9b	Theories are just stories.	21.4	22.4	20.5
9c	Theories are based only in facts.	41.0	41.1	40.9
10a	The community of scientists is open and inclusive to anyone.	31.2	34.1	28.4
10b	The community of scientists requires successful completion of rigorous training to join.	59.5	62.4	56.8
10c	The community of scientists is open to only specific demographic groups.	9.3	3.5	14.8
11a	If I choose to, I could become a scientist.	36.4	40.0	33.0
11b	If I tried to become a scientist, I might not succeed.	49.1	48.2	50.0
11c	I am a scientist.	14.5	11.8	17.0
12a	Scientists would be completely accepting of me if I became a scientist.	23.8	23.8	23.9
12b	Scientists would mostly accept me as one of them, maybe a few would not.	47.7	46.4	48.9
12c	Scientists would never fully accept me into their ranks.	12.8	14.3	11.4
12d	The ranks of scientists will always be closed to me.	15.7	15.5	15.9
13a	I think that science would be a good career path for me.	29.7	31.8	27.6
13b	I think that science wouldn't be a good career path for me.	70.3	68.2	72.4

From the S2 pupil cohort overall, 41.6% of pupils think that science is a world view. However, 36.4% see science as a collection of true facts. There is a gender difference within this data in that 51.1% of girls think that science is a worldview (*v* 31.8% boys) whereas 45.9% of boys see science as a collection of true facts. In addition 84.7% of boys and 86.4% of girls think that science assumes cause and effect. Furthermore, 46.6% of girls and 41.2% of boys think that science is independent of the culture in which it is conducted.

In terms of the S2 pupils' understanding of the nature of science, it is encouraging to note that 77.9% of the year group think that scientific ideas are testable but can never be entirely proven. However, 70.9% of S2 pupils see that the scientific method requires reproducible tests be conducted, with only 29.1% thinking that science is a loose procedure for making observations about the physical world. The S2 pupils also see scientific thinking as a combination of logic and intuition. However, fewer S2 pupils (49.7%) see scientific conclusions as provisional and may be revised as more data becomes available.

Interestingly, 41% of the S2 pupils see scientific theories as being based only on facts with 37.6% seeing that theories are as effective models for describing reality.

However, 21.4% of the S2 pupils think that theories are just stories. Worryingly, only 29.7% of the S2 pupils see science as a good career path for themselves. This statistic is reinforced by the fact that a similar statement (E14) in Section E was very negative with a mean Likert score of 1.53 ± 0.95, suggesting that most of the S2 cohort would not see science as an attractive career. However, 36.8% of the S2 pupils thought that if they chose to they could become a scientist with 49.1% believing that if they tried that they might not succeed.

5.4 Summary.

The majority of the S2 cohorts participating in this research had attained the 5-14 levels D-F in both English writing and reading by the end of S2, with the S2 being better in terms of reading compared to writing. The Scottish ROSE survey data set, which is the largest national data set in this International study, allowed for the comparison of the XHS S2 cohort's questionnaire responses with the national data. What this comparison shows is that the XHS S2 pupil cohort data set studied as part of the action research project was highly comparable with the National data set. This indicates that the S2 study group represented a typical pupil group whose opinions on the environment, science and technology, school science etc… did not differ from the national data.

Looking more closely at the S2 pupil questionnaire, there was a quantitative difference in views held by S2 males and females. Most notably, 45.9% of XHS S2 females could be categorized as being anti-science compared to 24.4% of XHS S2 males. When one looks at what XHS S2 pupils think about their school science, in general they are neutral about the difficulty level of school science. However, XHS S2 pupils prefer other subjects to studying science. When asked if they were given a free choice of different science subjects, only 15.2% of the S2 pupils indicated that they would not pick science in third year. In general, XHS S2 pupils see science as important for society. However, only 29.7% of the S2 pupils see science as a good career path for themselves.

Chapter 6: Action Research Findings: Teachers' and Pupils' Views, Together with Research Observations.

6.1 Introduction.

This chapter describes the findings from three rounds of action research utilising a cooperative learning approach to the teaching through discussion of climate change and global warming in small groups. Findings from each of the three rounds of research are outlined and where possible compared. The findings are derived from classroom observation, pupil questionnaires, semi-structured teacher interviews and semi-structured pupil-group interviews.

6.2 The Action Research.

6.2.1 Post-lesson semi-structured Teacher interviews.

6.2.1.1 Time taken to teach the discussion lesson series over the three rounds of action research.

In each of the post-lesson semi-structured teacher interviews over all three rounds of action research, the first question was: *How long did it take in periods of teaching time to teach the discussion lesson series*? The first thing to note was that the total number of periods allocated to the teaching through discussion of climate change and global warming using cooperative learning was different in each round of the action research. The first round lesson series was scheduled to last for *three* teaching periods; for the second round, *seven* teaching periods; and for the third round, *ten* teaching periods. The mean ± standard deviation number of periods taken to teach the climate change and global warming discussion lesson series was 5.6 ± 1.2 periods for the first round, 9.5 ± 0.9 periods for the second round and 10.9 ± 1.3 periods for the third round of the action research. This corresponds to an 83.1% over-run in the allocated time for the first round of the action research; a 35.7% over-run in time for the second round; and a 9.2% over-run in time for the third round.

It could be argued that the decrease in the overrun in time taken to deliver the lesson series is due to the increase in time allocated to the teaching of the discussion.

However, it must be remembered that more content was added to the lesson series at each round, so in terms of allocation of time to deliver the lesson series, each round was comparable in terms of the length of time allocated to teach the content. What is encouraging is that the time taken decreased as the teachers became more familiar with the materials, the subject being taught and the cooperative learning approach being used.

What is clear from the post-lesson teacher interviews is that the amount of preparation and planning that went into the lessons prior to the teaching had significantly increased over the course of the research. For instance, the production time for materials and worksheets used in the first round lesson series was approximately 25 hours, with all the work being done by the researcher. This time included the time taken to find data useful for constructing a data interpretation worksheet and information required to make up the pupil information sheets, write the MP statements and construct the decision-grid.

For the second round of the action research, the time taken to prepare and plan the second round lesson series took approximately 42 hours, with the work being divided between the researcher and two science teachers. This included the time taken to modify the worksheets, compile and evaluate a list of suitable websites which could be usable in the pupil research lessons and evaluate the DVDs to be used in the lesson series and construct the DVD evaluation sheet.

For the third round lesson series, the time taken to prepare the materials and plan the lessons increased to approximately 150 hours split between six science teachers. The majority of this time was taken up by one teacher (approx 75 hours) who learned how to cut and edit video form DVD and embed video clips into PowerPoint which was used to focus the arguments being put forward in the DVDs, an Inconvenient Truth and The Great Global Warming Swindle. In addition to this, the website list was updated and evaluated and the lesson plans updated (see the accompanying CD-ROM for a detailed copy of all the materials used).

At classroom teacher level, the time taken to plan how they were going to teach individual lessons also increased over the three rounds of action research. For example, in the first round teachers reported doing on average 3 hours of lesson preparation prior to the teaching of the lesson series. For the second round, the average preparation time went up to 6 hours of individual preparation, mainly taken up be the teacher watching, evaluating and becoming familiar with the four DVDs used in the series, as well as becoming familiar with the ladder of feedback technique. However, for the third round of action research, the time taken for the individual teacher preparation reduced to 3 hours which was mainly taken up by running the PowerPoint presentation and becoming familiar with the card sorting activities associated with it.

6.2.1.2 Teachers' Views on lesson one in all three rounds of action research.

After this initial question, the post-lesson semi-structured teacher interview questions looked more specifically at each of the lessons in turn. In the first round of action research, the lesson series was broken down into three lessons. Lesson one involved the pupils, in groups, brainstorming what they knew about global warming and the greenhouse effect, completing a KWL grid and presenting a poster describing both the global warming and the greenhouse effect.

The teachers thought that this lesson was generally successful. The following extracts give exemplar comments from the teachers:

> *The KWL grids, I've used before and they are good for getting the kids to think and then tell you what they already know. The brainstorming part worked well although there was one group who were unsure what to do, but then it was maybe a lack of experience working like this. They seemed to get it at the end. As I went round the groups they seemed to have similar ideas, so there must have known something from maybe primary school or from previous science.* **NQST4**

Four of the teachers commented that they found it difficult to get round all of their class groups as they had to spend a lot of time with some groups trying to combat misconceptions and misinterpretations of the task. At this point one must define the term misconception as it pertains to the context of this thesis. The expression is taken to mean a preconceived notion, a non-scientific belief, naive theories, mixed conceptions, or conceptual misunderstandings where the person holding the misconceptions is unaware that their idea is incorrect. Thus throughout this thesis, the term 'misconception' is used to refer to pupils' conceptions that are different from scientific conceptions. However, one could argue that the misconceptions discussed throughout this thesis are nothing more than a lack of knowledge.

All of the science teachers interviewed mentioned the appearance of a common misconception surrounding the role that the ozone layer plays in global warming. What the pupils were referring to was the depletion of the ozone layer. The pupils seemed to think that the hole in the ozone layer, which is caused by increasing levels of Chlorofluorocarbons (CFCs) in the atmosphere, adds to global warming. This researcher would argue that the literature on misconceptions or alternative conceptions suggests that the term misconception is more appropriately applied in this case. This misconception is discussed in more detail later in the thesis but ExST2's comment exemplified the teachers' views.

> *I think that it [lesson 1] went well. The only thing that I would say [was that] there was a lot of confusion on the ozone layer... a complete misconception. I spent a lot of time going around the groups trying to explain why this had nothing to do with the greenhouse effect."*

All teachers reported that they had to stop most of their groups when this misconception occurred and explained why the hole in the ozone layer had nothing to do with global warming and the greenhouse effect. However, the success of this intervention was patchy as the misconception came through in the first round end-of-topic test essays. This misconception was also discussed with the pupils in the pupil group semi-structured interviews. The intervention also had an effect on the quality of the information displayed in the poster presentations as the teachers spent less time viewing the successful completion of the task set because they were spending their time combating the ozone layer misconception. Overall, the teachers felt that this lesson was the most successful and the one that, in their opinion, the pupils enjoyed the most.

In the second and third rounds of action research, the KWL grids were replaced with a 'graffiti board' method of assessing pupils' prior knowledge. Most of the science teachers felt that this change was good and that the technique helped them to assess their class group's knowledge more efficiently. However, one teacher did not like the technique stating that he thought the graffiti board method was "unstructured and incoherent". ExST3 further added that "the graffiti board suffers from the need to check what the pupils are writing; you can't just say to pupils 'Now you are free to generate ideas' that will be to spread to other people without checks at all. What you get is a hotchpotch of different levels of ideas all on one piece of paper which doesn't actually mean anything."

6.2.1.3 Teachers' views on lesson 2 of the first and second rounds of the action research.

In this lesson the 'analysing greenhouse gas data' worksheet provided a focus. What was clear from the interview transcripts was that most of the science teachers felt that this lesson was a struggle for the pupils. A number of issues arose from the post-lesson interviews on this lesson. One teacher suggested that the pupils from his class saw this lesson more as a maths lesson rather than a science lesson which he felt affected their attitude to the lesson.

> *...they would say 'this is maths, we don't do maths, this is science'. That was their attitude... look at the kind of maths input, look at the graphing. They had no appreciation of line graphs, of scaling and subsequently they haven't learned anything from it. They still can't scale a graph, they still don't know about axes*. **ExST5**

This comment is rather worrying as pupils at this stage should be able to do these kinds of simple mathematical tasks. However, problems with pupils not being able to scale graphs are not new to science teachers. Another teacher was concerned that the pupils were confused about how to draw the graph;

> *...for the first graph in the worksheet, generally the graph was okay but the usual problems cropped up, drawing a bar graph instead of a line graph, even although we went through it, not knowing which side to put the axes on. The first one wasn't too bad; they weren't sure what was meant by describe*

the pattern or trend so I had to explain that, but there was a lot of time spent even just going over the first graph and how to plot it. **ExST2**

This quote from ExST2 suggests that the pupils in her class struggled to complete the graph in task 1 and that she spent a lot of time explaining the vocabulary. She indicated that they should have known these words. However, she did indicate that the current science course does not support the assimilation of such vocabulary.

It is something they should know but it is not necessarily the case, but when you think about it, when you look at the (science) course we teach them, it is not something that comes up, the only topic where it does come up is Heat where we do the cooling curves, but they coped well once I explained the things to them what the pattern or trend meant…. **ExST2**

Another teacher suggested that the shape of the graph paper also caused problems for the pupils:

ExST4: *I think one of the things was the graph paper for example caused the kids a bit of a problem. I had to spend time, and I had the student in with me as well, so it was quite good in a way as I could really help the pupils to come up with a way to draw the graph, even although they have had a lot of exposure to drawing graphs. It was just because of the way the graph paper was; it was small.*

Inv: *Because it wasn't square?*

ExST4: *Yes and they are not used to that. They would ask 'how do I fit that in' and what confused them was when it was going up in 50s, then it went from 1950 to 1980 and 1990. That threw some of them wee bits; also as the* CO_2 *went up, the numbers were hard for them.*

One of the teachers suggested that pupils with greater maths ability were better able to cope with the demands of the worksheet compared to pupils with lower maths ability;

…what I found was that the kids who were in the higher maths class were straight in there, but the kids perhaps with a lower ability in maths were

> *unsure about the graph. Looking at the graph that was drawn, there was still confusion about scales and a line graph in general. I got two or three bar graphs to start with but again it got to the point where I just put it up on the board and never told them the answer. Instead I asked them to look at the years and look at the numbers and think about the intervals between them.* **NQST4**

In terms of answering the questions which followed each graph-drawing task, the science teachers suggested that the pupil responses were mixed with some pupils being able to answer the questions straight away, but that most pupils struggled with the question. NQST4 made a comment which generally sums up what all the science teachers said about the questions.

> *…it was pretty much a mixed bag because some of them could see straight away but again you might find that these are the kids that are in the better maths classes…One of the questions which asked about a pronounced trend, they were trying to look over a ten year period, they weren't looking at the whole thing so they might have been missing out some of the questions because they couldn't read the graph properly.* **NQST4**

In general the science teachers were unsure as to the success of this lesson since the level of teacher intervention was high. ExST4 made a comment that summed up what this group of teachers thought.

> *I don't know how much they took away from this lesson. I think that it was good that they were exposed to some data instead of just talking about it but did they learn anything? I don't know. I think we learnt more than they did in that they struggle to draw and interpret graphs.* **ExST4**

In terms of the success of this lesson from a cooperative learning perspective, most of the science teachers indicated that this lesson did not work as well as the first lesson. They suggested that this type of lesson would better be done using a more traditional approach.

ExST6 commented that

...this lesson would have been more successful in terms of pupils learning if I taught it using a more traditional, dare I say, more normal approach. The lesson itself was good but the tasks required a more subtle approach where I would have pointed out the differences and scaffolded their learning more directly.

In the second round of action research, the teachers felt that the revision to the 'analysing greenhouse gas data' worksheet made it smoother to deliver. However, the same issues were seen in terms of the pupils' inability to scale the graph, draw a line graph and interpret what the data in the graph was saying. ExST2 commented that:

...the same problems with scaling and drawing the graph came up again this year compared to last year's group. I think that some of the issues that we see in this lesson need to be tackled across the board, not just in Science and Maths. **ExST2**

However, a number of the teachers suggested that this year's group were more prepared to try the worksheet before asking for help, with ExST1 commenting that

...this year group seemed to make a better fist of the worksheet than last year's lot. I can't explain why, but last year I seem to remember having real trouble running around the groups; you know, helping the pupils to think about scaling the graph and explaining why the years went along the x-axis but this year I seemed to be doing a lot less of that. That's not to say that I didn't do a fair bit of that this year but it didn't seem to be as frantic. **ExST1**

Looking more closely at the individual questions in the worksheet, most of the teachers suggested that, as in the previous round, they spent a lot of time helping the pupils to interpret the graphs in the light of the question. As with the first round, the science teachers felt that this lesson was the least successful cooperative learning lesson in the second round series.

6.2.1.4 Teachers' views on lesson 3 of the first round of the action research.

The majority of the science teachers interviewed thought that this lesson was an ideal way to round off the lesson series commenting that they saw it as the whole point of the series. However, one teacher suggested that he thought that this type of lesson had no place in science as it was more social science. He did not think that science was the place to discuss things like carbon tax.

> *…the class did not get the concept of using a decision-grid to help come to a decision on the carbon tax proposals; they were totally disinterested. It got to a point where they didn't really care, what the politics of it was or the fact that carbon footprint is important, or even carbon emissions might result in the next generation suffering… I personally would not have done the third lesson as I wouldn't have brought politics into it, not with second years, it wasn't valuable.* **ExST5**

However, ExST2 commented that:

> *I think that it [politics] has to be tackled in the science classroom as the science can't be divorced from the more social aspects of the topic. I mean the whole point of doing this was to show the kids that science has an input into such issue and that it can be an important part of the solution as well."*

ExST4 concurred with this sentiment by suggesting that:

> *…if you want people to be responsible citizens then they must understand that in science we don't just go out and do an experiment and that's it; It's not just an experiment in isolation. We cannot teach science without relating it to everyday life… I suppose it's really about taking the topic forward to show them what do we do with the information, now that we have it? It's about the next step; it's about getting them to think of the problem; and what can be done to solve it. For me, it's getting them to a finishing point.* **ExST4**

NQST4 suggested that even although he accepted that the third lesson was not really within the domain of science, it was science in context and as such it was just as valid to do this kind of lesson in science as it was in Modern Studies.

There are no right or wrong answers to the question of whether this lesson should be done in science. What I would say is that, granted it's not strictly a science lesson but it is science in context. What they have done previously is science, and as such they should be in a position to comment on such issues. **NQST4**

Looking more specifically at different aspects of the lesson, some of the science teachers indicated that the pupils found using the decision-grid difficult to complete even after they explained to them how to use it. Others commented on the fact that the pupils found it difficult to pick out differences between the three MPs' statements.

I think some of the pupils found that they couldn't decide or distinguish what was a positive aspect and what was negative…when they went to vote, a lot of them looked to see which one had the most positives rather than looking at the three positions and weighing up each as a whole, although they seemed to enjoy it. **ExST4**

Ultimately this lesson was seen as a successful endpoint to the series despite the difficulty that some pupils had when deciding which MP's proposal to vote for. Most teachers commented that they felt that this type of lesson links science well into citizenship education.

6.2.1.5 Teachers' views on the success of the cooperative learning approach and teaching through discussion after all three rounds of action research.

After the first round of action research, the majority of science teachers were of the opinion that the use of cooperative learning for the discussion of global warming and climate change was moderately successful. Most of them thought that the 'analysing greenhouse gas data' worksheet lesson was the least successful cooperative learning lesson, with most of them agreeing with ExST6's comment that this would be better suited to a more traditional approach. However, the majority commented that this was a useful first step towards more open and inclusive discussion in science.

After the second round of action research, the teachers felt that this round was more successful in terms of cooperative learning but was full of technical issues which made the lessons less coherent than in the first round. They felt strongly that this could have been better managed and wanted a group of teachers to further develop the teaching materials to iron out the technical difficulties in preparation for the third round of action research.

At the end of the third round, the teachers felt that it was better, with teachers commenting typically that:

> *I felt that overall it was a better layout this year. There was more time for the important parts of the topic, such as discussion, and less time spent on the parts where the pupils lose interest quickly.* **NQST5**

Even one of the two most negative science teachers' comments were surprisingly positive about the success of the third round of action research:

> *It was definitely more enjoyable to teach this year. Pupil brainstorming and [the] initial discussion session was much more successful and I would say the pupils themselves were more positive in examining one another's pre-concepts and opinions. In general, pupils were keen to understand the underlying principles of global warming and how it affects their environment, despite some of the ideas being quite big and political."* **ExST5**

In terms of general comfort level all the science teachers agreed that they were now much more comfortable both with the cooperative learning approach and with handling the discussion of controversial socio-scientific issues such as global warming and climate change issue.

> *I feel much more comfortable with the content and the pupils seem more confident and comfortable with the style of learning. I think that the basic format of these lessons is perfect now for the requirements of CfE. Cooperative learning is a suitable method for this set of lessons. I don't think that these lessons would work if they were purely teacher-led.* **NQST1**

The most reticent of all the science teachers (with respect to this action research), ExST7 commented that:

> *This year was, for me, the least painful in trying to cover the topic. The lessons went much more smoothly as most problems from last year in particular were dealt with. The 1st year through there was too much paperwork and not enough for the pupils to work on independently. Last year, in my opinion, was a disaster. Some of the practicalities of the lessons particularly having 4 DVDs running in one class at the same time had been ill thought out. Most of the recommended websites were not suitable for S2 pupils. After last year I was not looking forward to doing this topic again. However, this year I quite enjoyed most aspects of the project. Pupils' behaviour was much better as things ran more smoothly. The video clips lessons were good and the pupils really seemed to enjoy working on the presentations. I have found it useful in that it has shown me what aspects of cooperative learning I am comfortable using and what aspects don't work for me.* **ExST7**

This comment is interesting as this particular teacher commented at the start of the research that "…in my classes I don't do discussion, I tell them what they need to know and that's it" (ExST7, 2006). It also shows that when doing this type of research, it is important that reticent teachers are convinced of the utility of the cooperative learning approach to discussion through the provision of evidence that it *can* work. Admittedly, ExST7 was open-minded enough to try it first before dismissing it, but after three rounds of action research even she is more comfortable handling discussion using cooperative learning than she was at the beginning. This suggests that with an open-mind, and a willingness to try, even the most 'difficult' science teacher can be convinced of the need to change their practice.

The teachers were asked at the end of the third round to comment specifically on the discussion element of the lessons over the three rounds of research. ExST3 commented that;

> *…the debate was excellent, much better than expected, but my class were used to a discussion-based approach to each topic. However, the group work did not work well as peer status is critical in this age range and random allocation to groups (for fairness) removed control from friendship groups.*

Intra-specific rivalry in groups reduced group effectiveness despite each member being given clear tasks. Inter-group rivalry in terms of Tajfel's minimal differences research showed groups voted down the achievement of competitors to maximise their own relative worth. **ExST3**

ExST3's comments suggest that the discussion worked well but he thought that the ladder of feedback approach to group processing and peer assessment did not work with this age group. However, NQST4 commented that:

I had two different experiences whilst teaching this topic due to the two different classes that I taught. One class was made up of only 9 pupils compared to the second class which had 20 pupils. This had an effect on how well the topic actually went. I felt that the larger of the two classes actually benefited more from the work in terms of discussion within the class. There was a greater variety of opinions and more discussion/debate on some of the aspects. I was unable to say why this was so but smaller class size certainly made a difference to the discussion. **NQST4**

The issue of class size making a difference to the extent to which discussion thrives in the class is interesting. In some respects this might be why ExST5's comments on the success of the discussion in the first and second rounds was more negative since his class size in the first round was 8 and in the second round was 6 but in the third round the class was larger with 12 pupils.

Teachers were asked to comment on what they thought the pupils gained from the experience of discussing climate change and global warming. All of the teachers commented that the pupils gained experience of how to take part in a discussion, analyse arguments and appreciate that decision making in such issues is not as straightforward as it seems. Below are four examples of the types of comments that teachers made to this question.

ExST3 commented that:

They gained the ability to comprehend opposite arguments, strengths and weaknesses of arguments, form a balanced and informed opinion and express this to a wider group. They also gained an appreciation, if not an *understanding of statistical analysis, interpretation, and the difficulties of making a judgement without reference to complex variables.* **ExST3**

ExST7 commented that:

Pupils did seem to enjoy the topic, particularly working at the presentations. It was a chance for some of the less academic pupils to show other skills that they have. For example, one boy who is not keen on written work really enjoys art and design, so he was happy to work on the poster and made a good job of it. It improved the confidence of some pupils who, although are not particularly good at science, are very knowledgeable about IT and were in a position to help other more able pupils for a change. **ExST7**

NQST4 suggested that:

I would say that about 80% of pupils enjoyed the overall experience of the project. It took them the first three or four lessons to become comfortable with what was asked of them, which I put down to the fact that this was the first time many had taken part in such an open, pupil-orientated set of lessons. Over the piece it became obvious that pupils I had previously perceived to be quiet and introverted soon became outspoken and more confident in themselves. There were occasions when I had to stop all group work due to the fact there were some common misconceptions within almost all of the groups. At this point I resorted to the more teacher-led approach to clarify some issues. If I had not then this would have had a major impact on some of the concepts to be discussed at a later date. **NQST4**

ExST5 commented that:

They [the pupils] were given the opportunity to develop skills of scientific inquiry and investigation, using the internet and text books; they developed skills in the accurate use of scientific language relating to Global Warming. They were able to recognise the impact that sciences make on my life, the lives of others, the environment and on society. They were able to develop an understanding of the Earth's resources and the need for responsible use of them, working towards expressing opinions and making decisions on social, moral, ethical, economic and environmental issues based upon researched *material, developing their scientific literacy in processing relevant data and preparing a presentation for whiteboard and an audience of their peers.* **ExST5**

Finally, the teachers were asked: *How useful have you found the action research project in preparing you to teach the new experiences and outcomes of the new CfE Science outcomes?* In answer to this question the majority of science teachers commented that the project was an extremely valuable experience. NQST4's comment sums up what the science teachers felt about their experience of teaching this lesson series:

This topic, and the pedagogical approaches used to teach the topic, have greatly helped me prepare for the coming changes. The topic itself fits exactly with what has been asked of us for the Topical Science strand of CfE. It means we are already a huge step ahead of other schools within the authority. The use of co-operative learning as a means to deliver the climate change outcomes will also stand us in good stead for what approaches. It helps pupils fulfil the four capacities as well as making a difference to the actual delivery of lessons within the classroom. **NQST4**

6.2.2 Classroom Observation.

Classroom observation in this research served a number of different purposes. It provided a mechanism through which the researcher could check whether discussion was taking place (as opposed to recitation using the criteria set out by Dillon, 1994). It also allowed the researcher to observe the teaching of discussion using cooperative learning to check how it was being applied and whether this was in a consistent manner by the teachers involved. It allowed triangulation to occur as the researcher could use critical incidents observed and recorded in field notes as discussion points in both the teacher and pupil group post-lesson semi-structured interviews. Lastly, they allowed the researcher to observe the use and application of the teaching materials developed for this series of lessons, in order to assess difficulties in their use first hand.

6.2.2.1 Assessment of discussion throughout the action research.

As stated in Chapter 2, recitation is a predominant feature of classroom discourse (Larson, 2000), particularly within science. This situation has led to a classroom culture where ideas are rarely, if ever, challenged. In order to implement the use of more open forms of classroom discourse such as discussion, it is important that one can distinguish the difference between recitation and discussion. Chapter 2, section 2.6.3 discusses criteria set out by Dillon (1994) which were useful as an assessment tool for the evaluation of teaching through discussion. They provided a fairly objective method for establishing that the transition from a recitation-style towards open discussion had been successful. These criteria include: the predominant speaker, typical exchange, predictable sequence, overall pace, the questions posed, the answers given, and the evaluation of the answer. It should be noted at this point that the focus of these observations was the typical exchange and overall pace as a detailed analysis of other characteristics of discussion was too difficult to observe reliably *in situ,* given the multiple purposes of the lesson observations. However, the predominant speaker could also be assessed aggregating the different typical exchanges.

The observation schedule used allowed the observer to tally up the typical exchanges in the lesson by putting a tally mark in a column for either teacher-to-pupil (T-P), pupil-to-pupil (P-P) or pupil-to-teacher (P-T). The pace of the exchange was marked in a column for fast (F) or slow (S) and the number of each counted for each typical exchange noted. Table 6.1 shows the overall distribution of typical exchanges for the first, second and third rounds of action research.

Table 6.1 *Percentage distribution of observed exchanges over the three rounds of action research.*

	Typical Exchange (% of total)		
Round of Action Research	**teacher-to-pupil**	**pupil-to-pupil**	**pupil-to-teacher**
First	33 ± 6	40 ± 8	27 ± 5
Second	25 ± 4	44 ± 4	31 ± 4
Third	24 ± 5	40 ± 4	37 ± 4

These data show that over the three rounds of action research the typical exchange in the observed lessons was between pupil-to-pupil and pupil-to-teacher which suggests that the predominant exchange in the classroom discourse had shifted from a teacher dominated to a more pupil-centred discourse. However, when one looks at the pace of these exchanges, the pace is fast suggesting the questions posed were predominantly low order. Table 6.2 shows the distribution of the pace of these exchanges across the three rounds of the action research.

Table 6.2 *Percentage distribution of pace of typical exchange across the three rounds of action research.*

		Typical Exchange (% of total)		
Round of Action Research	**Pace**	**teacher-to-pupil**	**pupil-to-pupil**	**pupil-to-teacher**
First	*Fast*	63.5 ± 10.2	73.1 ± 6.4	77.2 ± 8.8
	Slow	36.2 ± 10.2	26.9 ± 6.4	22.8 ± 8.8
Second	*Fast*	55.2 ± 7.7	65.6 ± 8.3	74.2 ± 9.6
	Slow	44.8 ± 7.7	34.4 ± 8.3	25.8 ± 9.6
Third	*Fast*	59.7 ± 7.7	67.3 ± 8.0	74.1 ± 8.9
	Slow	40.3 ± 7.7	32.7 ± 8.0	25.9 ± 8.9

It should be noted that the % of total denotes the total of exchanges within that type of typical exchange. For example from Table 6.1, 33% of the typical exchanges in the first round of action research were teacher-to-pupil exchanges. In Table 6.2, 63.5% of those exchanges were fast and 36.2% were slow.

Table 6.2 shows that the pace of exchange in the observed lessons is predominantly fast with most of the questions being a mixture of low order on task questions from teacher-to-pupil; technical exchanges typically inquiring what to do from pupil-to-teacher; and a mixture of quiz questions from teacher-to-pupil or from pupil-to-pupil. What is encouraging is that the percentage of slow exchanges from teacher-to-pupil increased over the three rounds of action research which shows that as the teachers became more familiar with the issues and with the cooperative learning approach, the use of higher order questions increased, a trend which is mirrored in both the pupil-to-pupil and pupil-to-teacher exchanges.

Using the criteria set out by Dillon (1994), it is fair to say that over the period of the action research these lessons could be described as discussion lessons, since the pattern of typical exchange is pupil-centred rather than teacher-dominated. However, the majority of exchanges were fast indicating that although the aim of using discussion was achieved, more work needs to be done to slow the exchanges down to encourage more time for thought. A possible reason for the high proportion of fast exchanges is that the pupil group studied as part of these lessons were young and unfamiliar with both the cooperative learning approach being used in the science context and were unfamiliar with the style of teaching adopted by their science teachers. This could possibly have been somewhat disorientating for them as it was a radical departure from the normal classroom discourse. In addition, most of the pupil-to-teacher exchanges were questions relating to procedural matters such as 'what do we do next?'. It was obvious that these pupils were highly dependent on their teacher for direction and they noticed that the teacher had taken a step back.

It was clear to this researcher that the pupils were taking some time to adjust to the change in style. However, by the end of the lesson series each class observed had became more comfortable with this style of lesson. In addition to this, it is worth noting that in the first round observations there was a palpable sense of apathy across the S2 cohort which was not present in the second or third round S2 cohorts. This apathy was not exclusive to lower ability pupils.

6.2.2.2 Assessment of the application of cooperative learning to the discussion.

Over the three rounds of action research it was clear to this researcher that each of the teachers involved in the research had become increasingly comfortable with the cooperative learning approach. It is important to note that although probationary teachers involved in the research came and went between the rounds of research, there was a core of eight permanent science teachers who taught classes in each of the three rounds of the research. From the observations made in the first round, those eight teachers who had all been on a three day cooperative learning academy run by the local authority were putting into practice all the key elements of the learning-together method of cooperative learning. It was observed that all of the science teachers tended to concentrate on four of the five key elements of cooperative learning in the first round. These four elements were individual accountability, positive interdependence, face-to-face interaction and social skills. However, individual accountability and positive interdependence were observed more frequently in each lesson with each teacher reminding the class at the start and periodically throughout which social skills were to be focused on and practised in each lesson.

One element which was least frequently observed was group processing. The main way that the teachers practised group processing was by having short plenary sessions to bring discrete sections of the lesson together before moving on. In the first round, only two classes that were observed had problems in terms of disruptive behaviour. Both classes were taught by the same teacher (4 observations out of 24). However, these two classes had been problematic in terms of discipline all year. On a number of occasions during these observed lessons, behaviour had started off well with both classes and slowly got worse to the point where a number of sanctions had to be given. These lessons were, in the opinion of this researcher, unsatisfactory and more indicative of the classroom teacher's inability to control the class rather than the fault of the cooperative learning approach, but what these failed lessons indicate is that if the class teacher does not have the respect of the class normally then the extra pressure of teaching using a more open form of pedagogy can make the situation worse in terms of control for the teacher.

On the whole, the behaviour of the classes during the lessons was very good. In fact most of the classes observed work very well together and each lesson had a real buzz of activity. This left the observer with the feeling that the classes entered into the lesson series in an open manner and with a willingness to 'give it a go'.

However, in the second round of action research it was obvious that the teachers were more proactive within each lesson compared to the previous round. Most of the teachers had rearranged their rooms to suit the cooperative learning approach and had developed different strategies for forming groups. In the second round there were more technical difficulties, in so far as the lesson utilising the four DVDs on climate change and global warming sometimes wouldn't run on certain computers and the volume became a problem with five groups watching the DVDs at the same time. With the help of the science technicians and flexibility in terms of rooms this difficulty was overcome. In general, the behaviour of the second round S2 cohort was very good and the apathy observed in the first round of the action research was not present in the second.

In the second round lesson series, the use of the five elements of the learning-together method of cooperative learning was more even with each teacher making an effort to use group processing more. This was facilitated by the teacher's use of the ladder of feedback. However, as in the first round, the teachers concentrated heavily on the elements of social skills, individual accountability and positive interdependence. Face-to-face interaction was assured by the teachers in that they had all rearranged the seating so that group members could face each other.

In the third round of action research, the teachers were completely familiar with the cooperative learning approach and it was observed that their confidence in facilitating the discussion had grown. A key feature of this round was the nature of the interactions that each teacher had with pupils. It was observed that the teachers had visibly backed off and seemed more content to patrol the room only becoming involved when invited, when they noticed that a group was struggling with a task, or to inquire about the group's progress. In the opinion of this researcher the teachers seemed to be more willing for their pupils to take control of the pace. Interestingly, the teachers made more use of an on-screen timer and stuck to the time management of the lessons more rigidly. The pupils in the third round S2 cohort genuinely seemed to enjoy the discussion more in that round than in the previous rounds, but again this observation was based on the fact that their behaviour was very good, there was very little observed off-task behaviour, and the running of the lessons was by far the smoothest of all three rounds of the research.

In the third round of the action research, the teachers again infused the five main elements of cooperative learning into their teaching, again with positive interdependence, individual accountability and social skills being most heavily drawn upon.

6.2.2.3 Lesson-specific events observed in each round of action research.

In the first and second rounds of action research, there were three lessons whose content overlapped with each other. In the third round, two lessons overlapped with those in the first and second round. So it is only proper to look at these areas of commonality first. The first lesson of each round was designed to bring to the fore the pupils' existing understanding of global warming, the greenhouse effect and climate change. However, it became apparent during these observations that a large number of pupils (in each S2 cohort from all three rounds) held the misconception that the hole in the ozone layer played an important part in global warming. This gave the teachers a major problem as they tried to get round each group in the class. In a number of classes (four observed by the researcher) the teacher stopped all the groups and went to the whiteboard and directly lectured to the class about why the ozone layer was not involved in the greenhouse effect and how this did not contribute to global warming. In the first round, 9 lessons were observed in which this misconception surfaced. The same misconception appeared in the graffiti boards in the second and third round of action research but when this happened the teachers spoke to groups individually rather than stop the work of the groups and lecture to the whole class. On a few of the graffiti boards the pupils scored out the ozone comment in recognition that the comment was erroneous.

In the first and second round of the action research, 16 lessons featuring the analysing-greenhouse-gas-data worksheet were observed. One thing that was clear from all these lessons was that large numbers of pupils struggled to scale the graph in task 1. The teachers spent a lot of their time explaining to individuals within the groups how to scale a graph. When it came to answering the question on the worksheet, it was clear that pupils in both rounds were looking to their teacher to tell them the answer rather than try to answer the questions themselves. However, the teachers did not give the pupils the answers; to their credit they forced the pupils to discuss their thoughts and come to an answer for themselves. In the second round, the pupils did seem to be more motivated to complete the tasks in the worksheet as groups but a number of groups required the teacher to probe their logic and confirm their thinking before they answered. It became clear during the observation of the analysing-greenhouse-gas data worksheet lessons that the teachers needed to give the pupils more thinking time in order that they could take on board what the data was saying. In addition, if they were given more time to discuss each question in their groups then perhaps some of the difficulties in answering the questions could have been resolved. This point was brought up with the pupils in the pupil-group semi structured interviews and more specifically by item J07 in the pupil questionnaire.

In the first and second rounds of the action research, the pupils were asked to consider three MP statements regarding proposals for a carbon tax. In this lesson, the pupils were given three MP statements and they were asked to look them in their groups and compare each proposal using a decision-grid (see appendix G). The pupils then had to feed back to the class what their group's thoughts were regarding each statement and as a class they were asked to vote for which proposal they preferred. A total of six of these lessons were observed in the first round and three in the second round. It was clear that the pupils in the first round had difficulty with this lesson, as a sizable minority of pupils in each observed class questioned why they were doing this, with some pupils commenting that they had been doing something similar in Modern Studies. This notwithstanding, the pupils seemed to find evaluating each of the MP statements on carbon tax and comparing the pros and cons of each proposal problematic. In a number of observed lessons, the teachers spent a lot of time going around groups helping pupils to pull out specific points in the statements which they could use for comparison.

During these observations, the teachers were evidently reluctant to press the pupils to actively read the statements critically. Rather than scaffold the group's thinking, the pupils would just passively listen to the teacher pointing out areas of the statement that they should look at. This defeated the purpose of the lesson in terms of the literacy outcome for the lesson, where pupils were expected to read the statements closely and pull out key points.

Each teacher explained how to use the decision grid extensively. However, the pupils were confused since, (again) a sizable minority did not understand what was meant by the terms of comparison in the context of the statements. For example, the pupils were asked to compare the statements in terms of their effect on economic growth, cost, fairness, the ability to reduce CO_2 emissions, and the ability to promote energy efficiency. However, some of the pupils did not understand what economic growth was and therefore not surprisingly found it difficult to understand what was meant by fairness in this context. All of the teachers spent a lot of their time going around the groups explaining what these terms meant in this context, but once explained the pupils seemed to get to grips with the task.

In three of the observed lessons, it was obvious that the teacher's manner had an effect on the outcome of the lesson. In one lesson, the teacher seemed apathetic and didn't seem (to this researcher) to be putting in an effort to bring the lesson to life. By way of contrast, in two lessons it was obvious that the teachers had put in a tremendous effort to make the lesson exciting and interesting. In one, the teacher made the lesson into a role play lesson where each statement was debated in a mock debate in the House of Commons. Prior to this, the group task was to read the statements carefully and discuss each one in groups, then the teacher randomly assigned three people to read the statements in the House and open up the House to questions. This was enthusiastically taken up by the class and it occurred to this researcher that this class was a great deal more enthusiastic in this lesson compared to the previous observed lesson (lesson two, analysing-greenhouse-gas-data worksheet). In the other lesson, the teacher set up a similar style of lesson but he took up the 'do nothing' argument and in the House of Commons debate played the devil's advocate role, questioning everything. The pupils in this group did not seem to be fazed by this and seemed to pick up the challenge, judging by the forthright manner in which they replied to his questions. It was interesting to observe that different teachers approached the teaching of this lesson in very different ways and that the teacher's attitude to the subject matter considerably affected the style and feel of the lesson.

In the second round of the action research, these lessons were observed three times with different teachers. These lessons were observed to be closer to the House of Commons debate in style, as planned. The pupils again were fully engaged in the lesson. However, this time round the pupils seemed to be more comfortable with the format in that the negative grumblings as to the place of this lesson in science was not picked up by the researcher. The pupils also found isolating the key elements of the political statements easier but again they found the decision-grid difficult in much the same way as the first round S2 cohort did.

One lesson in the second round stood out as different from the first round. This lesson, designed to carry over two teaching periods, involved the pupils splitting into their cooperative groups and watching one of four DVDs. In total, five of these lessons were observed. Each cooperative group was issued with an evaluation sheet which posed key questions that the pupils had to answer while watching the DVD programme. This part of the lesson suffered from technical difficulties. For example, some of the DVDs did not play on the lap top computers, the volume was either too low or too high, and the pupils found it difficult to concentrate on their task for distractions. However, most of these problems were overcome by a combination of either the teachers thinking on their feet and technical support from the science technicians. When these issues were overcome the lesson proceeded well. The second part of this lesson required the groups to feedback to the class what they had learned from the DVD that they watched and how they answered their questions. This part of the lesson proceeded well without any problems. What was interesting was that, looking across the five lessons observed, there were differences in what each group observed from the individual DVDs. The cooperative groups did not seem to have any difficulty in answering their questions.

In the second and third rounds, pupils were set tasks in their cooperative groups of researching an aspect of global warming using the internet. After the pupils had completed their research, they had to plan and deliver a mini-lesson to the class the following day using either a poster, a story board or as a PowerPoint presentation. In the second round, four of these lessons were observed with six observed in the third round. In both rounds, the pupils went about this task with enthusiasm and found a lot of information from the internet. However, when the pupils presented their PowerPoints the quality of the presentations was highly variable. For example, rather than presenting a narrow range of information derived from their research question, most of the cooperative groups presented as much information as they could on the broad area surrounding their research question. This led to the presentations being overly long in parts and lacking in focus. What was interesting was the skill that most of the groups had in producing their PowerPoint presentations, but they seemed to neglect important details to be presented by putting too much emphasis on things like animations and sounds - a case of high gloss and no substance, a sentiment raised by some of the teachers in their post-lesson interviews.

The presentations were peer-assessed using the ladder of feedback but the quality and balance of the feedback given to the groups was variable. In the second round observations, the feedback was very partisan in that the pupils found it difficult to criticise their friend's group presentations. In the opinion of this researcher, this type of peer assessment technique requires a level of maturity, practice and experience which did not seem to be present in this year group. However, in the third round observations the teachers placed a greater emphasis on the criteria used in the assessment and intervened if the assessment was unfair or biased. This made the peer assessment more constructive and less biased but not all the teachers placed enough of an emphasis on the assessment criteria. In those classes the observed result was a more biased and unfair assessment of the group's efforts.

6.2.3 Pupil Questionnaire: Section J Data.

6.2.3.1 Review of Responses to Section J in the pupil questionnaire: The Global Warming Discussion Lessons.

In this section of the S2 pupil questionnaire, the pupils were asked to indicate the extent of their agreement with each item on a 4-point scale. The items statements in this section are characterised under the headings: engagement with the issue, accessibility of materials, the co-operative learning approach, and the relevance of Science. Table 6.3 shows the summary data for section J responses overall, and separated for males and females.

Table 6.3 *Summary data for S2 Survey responses to Section J.*

STATEMENTS		Overall		Male		Female	
		Mean	SD	Mean	SD	Mean	SD
ENGAGEMENT WITH THE ISSUE							
J01	I enjoyed the discussion on global warming	2.35	0.97	2.45	0.94	2.25	0.99
J08	The global warming issue was of interest to me before these lessons	2.28	1.10	2.33	1.11	2.16	1.09
J09	The discussion has changed they way I think about global warming and climate change.	2.52	1.10	2.51	1.10	2.53	1.10
J10	I found this discussion boring	2.37	1.08	2.24	0.99	2.51	1.15
J11	I would like to discuss other topics such as using animal in medical research and embryonic stem cell research in my science class.	2.39	1.16	2.22	1.10	2.55	1.20
J15	I feel that I understand more about greenhouse gases and global warming after these lessons	2.69	1.09	2.73	1.10	2.65	1.08
ACCESSIBILITY OF MATERIALS							
J02	I found the discussion on global warming hard	2.14	1.05	1.99	0.93	2.29	1.14
J05	There was enough information provided for my group to successfully complete the tasks set in each lesson	2.81	1.03	2.87	1.06	2.75	1.00
J06	The information was easy to read and the language level was suitable for my year group	2.74	1.05	2.80	1.08	2.67	1.03
THE CO-OPERATIVE LEARNING APPROACH							
J03	The discussion on global warming gave me the chance to express my own opinions	2.43	1.03	2.44	1.05	2.42	1.02
J04	Everyone in my group took part equally in the lessons	2.77	1.06	2.72	1.09	2.81	1.04
J07	Working in groups made the question in the worksheets easier to answer	3.07	1.05	3.02	1.08	3.12	1.02
J13	These lessons were different from my normal science lessons.	3.00	1.07	2.93	1.13	3.07	1.01
J14	I like working as part of a group.	3.15	1.05	2.98	1.14	3.33	0.93
J16	During the group discussion I was able to ask my teacher for help and advice	2.87	1.09	2.73	1.14	3.01	1.02
THE RELEVANCE OF SCIENCE							
J12	This discussion helped me to see how science is relevant to my life.	2.40	1.07	2.45	1.03	2.35	1.11

When one looks at Table 6.3, it is encouraging to note that these S2 pupils are generally positive about what they have learned about climate change and global warming from their discussions. When asked in item J15 about the extent to which they agreed with the statement 'I feel that I understand more about greenhouse gases and global warming after these lessons', the overall mean Likert score was 2.69 ± 1.09 with males being more positive (2.73 ± 1.10) than females (2.65 ± 1.08). In addition, these S2 pupils did not feel that the discussions on global warming were hard (overall mean 2.14 ± 1.09). Males felt that the discussion on global warming was less hard than the females (male mean= 1.99 ± 0.93 versus female mean= 2.29 ± 1.08). The main thing to note is that these S2 pupils saw these lessons as different from what they were used to experiencing in science (item J13, overall mean=3.00 ± 1.07; male mean= 2.93 ± 1.13; female mean= 3.07 ± 1.01). When one looks more closely at the percentage of pupils who took a particular view, there is an indication of how much the experience affected them in terms of their enjoyment of it. Table 6.4 shows the cross-tabulation of items J01 and J10

Table 6.4 *Cross-tabulation of items J01 against item J10 for S2 Males and Females.*

Sex			J10 I found this discussion boring				
			Disagree	Slightly Disagree	Slightly Agree	Agree	Total
Female	J01 I enjoyed the discussion on global warming	StronglyDisagree	5 (5.9%)	3 (3.5%)	4 (4.7%)	14 (16.5%)	26
		Disagree	2 (2.4%)	10 (11.8%)	3 (3.5%)	5 (5.9%)	20
		Agree	6 (7.1%)	16 (18.9%)	4 (4.7%)	6 (7.1%)	32
		StronglyAgree	5 (5.9%)	2 (2.4%)	0 (0%)	0 (0%)	7
		Total	18	31	11	25	85
Male		StronglyDisagree	4 (4.7%)	2 (2.3%)	2 (2.3%)	9 (10.5%)	17
		Disagree	4 (4.7%)	6 (7.0%)	12 (14%)	2 (2.3%)	24
		Agree	7 (8.1%)	21 (24.4%)	8 (9.3%)	0 (0%)	36
		StronglyAgree	8 (9.3%)	0 (0%)	0 (0%)	1 (1.2%)	9
		Total	23	29	22	12	86

The data in Table 6.4 show that 41.8% of S2 males and 34.1% of S2 females enjoyed the global warming discussion and did not find it boring. However 29.1% of S2 males and 30.6% of S2 females found the global warming discussion boring and did not enjoy the experience. By way of contrast 18.6% of S2 males and 23.5% of S2 females did not enjoy the discussion but were not bored by the experience. In addition, 10.5% of S2 males and 11.8% of S2 females, found the discussion boring but enjoyable. These data tell us is that looking only on the mean Likert score as a measure of what the pupils are thinking is, at best, a crude tool for summarising the pupils' voice. With this in mind, it is valuable to look at the percentage of pupils who expressed a view for each item in order to better appreciate what the data reveal. Figure 6.1 shows a stacked bar chart of the overall S2 responses to Section J of the pupil questionnaire, with Figure 6.2 and 6.3 showing the stacked bar charts for males and female respectively.

Figure 6.1 *Stacked bar chart showing the overall percentage of XHS S2 pupils' response to each item in Section J of the pupil questionnaire.*

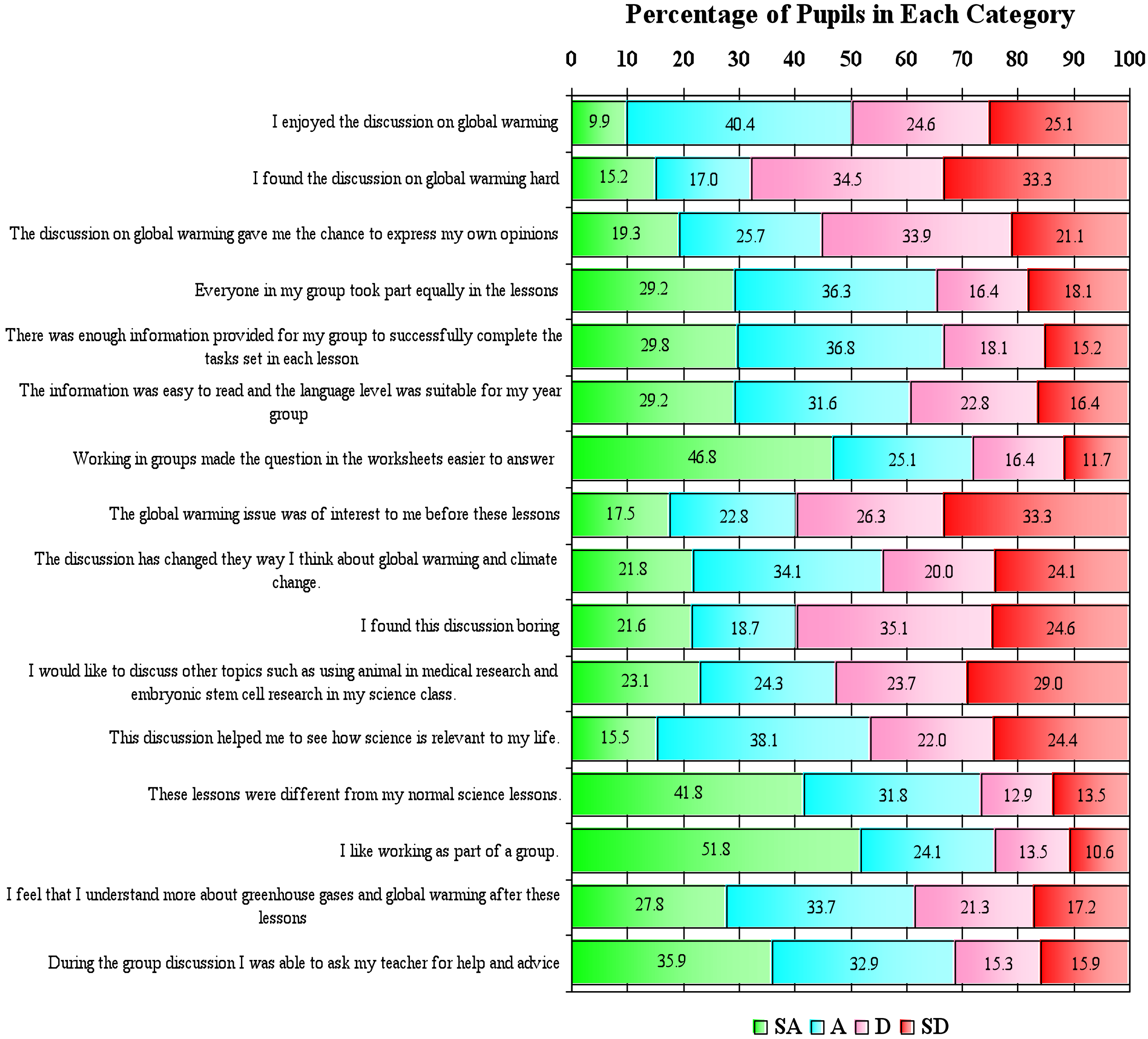


Figure 6.1 shows the overall percentage of S2 pupils who expressed their view on items J01 to J16 in section J of the pupil questionnaire. Item J01 starts at the top. Note that SA=strongly agree, A=agree, D= disagree, SD= strongly disagree.

These data show that overall 50.3% of the S2 pupils enjoyed the discussion on global warming and 59.7% did not find it boring. Interestingly, 59.6% of S2 were not interested in the issue of climate change and global warming prior to these lessons. However, in terms of discussion in general, only 45% of S2 felt that during these discussions they were given the chance to express their own opinions. This is worrying since the whole point of using discussion is to give pupils an opportunity for everyone to express their opinions. On a brighter note, 61.5% of these S2 pupils agreed that they felt that they understood more about greenhouse gases and global warming after these lessons with 53.6% of the S2 pupils agreeing that this discussion helped them to see how science was relevant to their life.

In terms of the materials used, overall 66.6% of the S2 pupils felt that there was enough information provided for their group to successfully complete the tasks set in each lesson with 60.8% of the S2 pupils agreeing that the information was easy to read and the language level suitable for their year group.

In terms of the cooperative learning approach used by the teachers to facilitate the discussion, 65.5% of the S2 pupils felt that everyone in their group took part equally in the lessons, with 75.9% of the S2 pupils indicating that they liked working as part of a group. Also, 68.8% of the S2 pupils felt that they were able to ask their teacher for help and advice during the group discussions with 71.9% of S2 pupils indicating that working in groups made the questions in the worksheets easier to answer. However, 52.7% of the S2 pupils indicated that they disagreed with item J11 *'I would like to discuss other topics such as using animals in medical research and embryonic stem cell research in my science classes'*.

The data from the mean Likert score showed that there was a difference in opinion between males and females. How these differences balance out in percentage terms is shown in Figure 6.2 and Figure 6.3.

Figure 6.2 *Stacked Bar Chart of the percentage of XHS S2 Male responses to Section J of the S2 pupil questionnaire.*

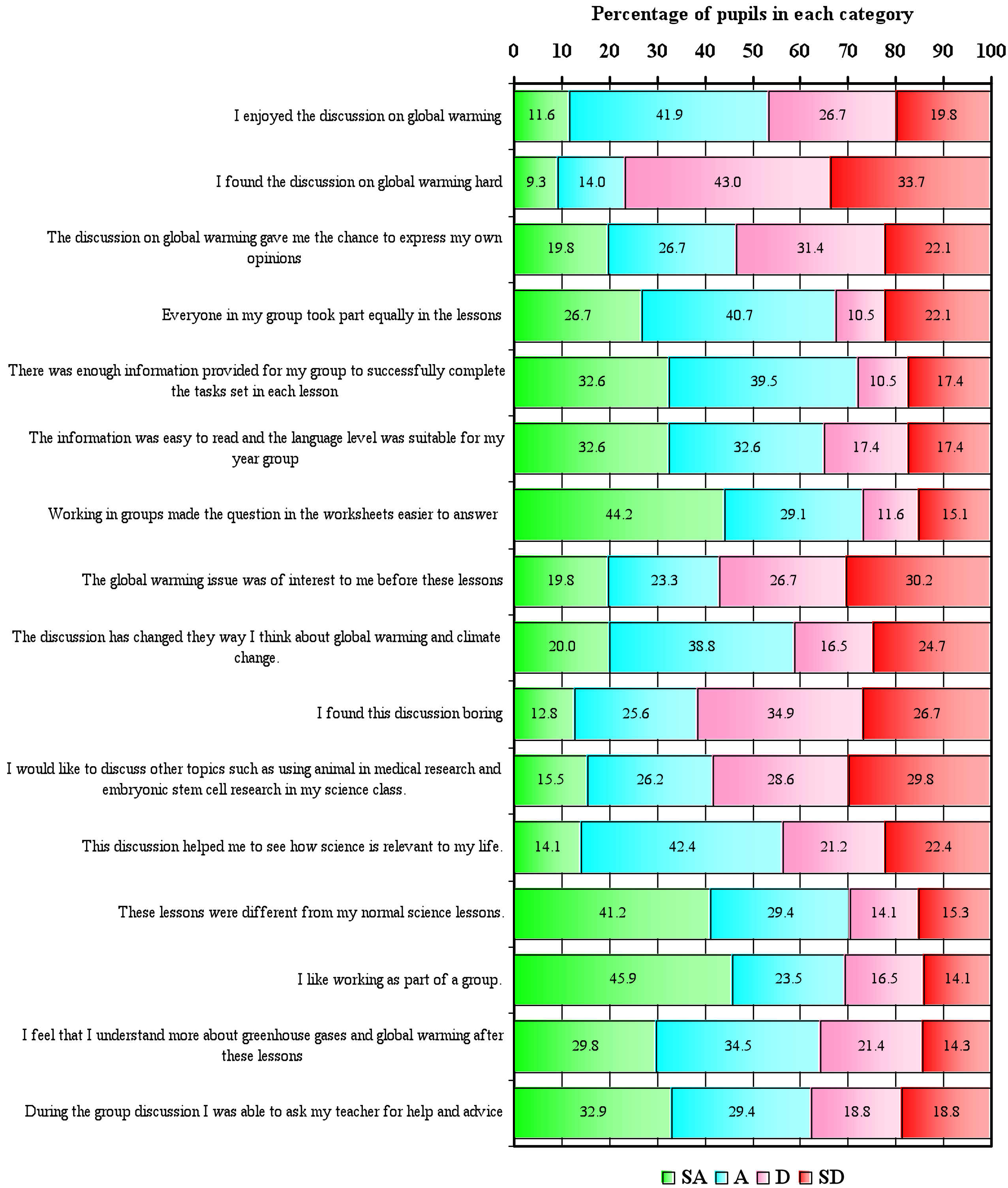
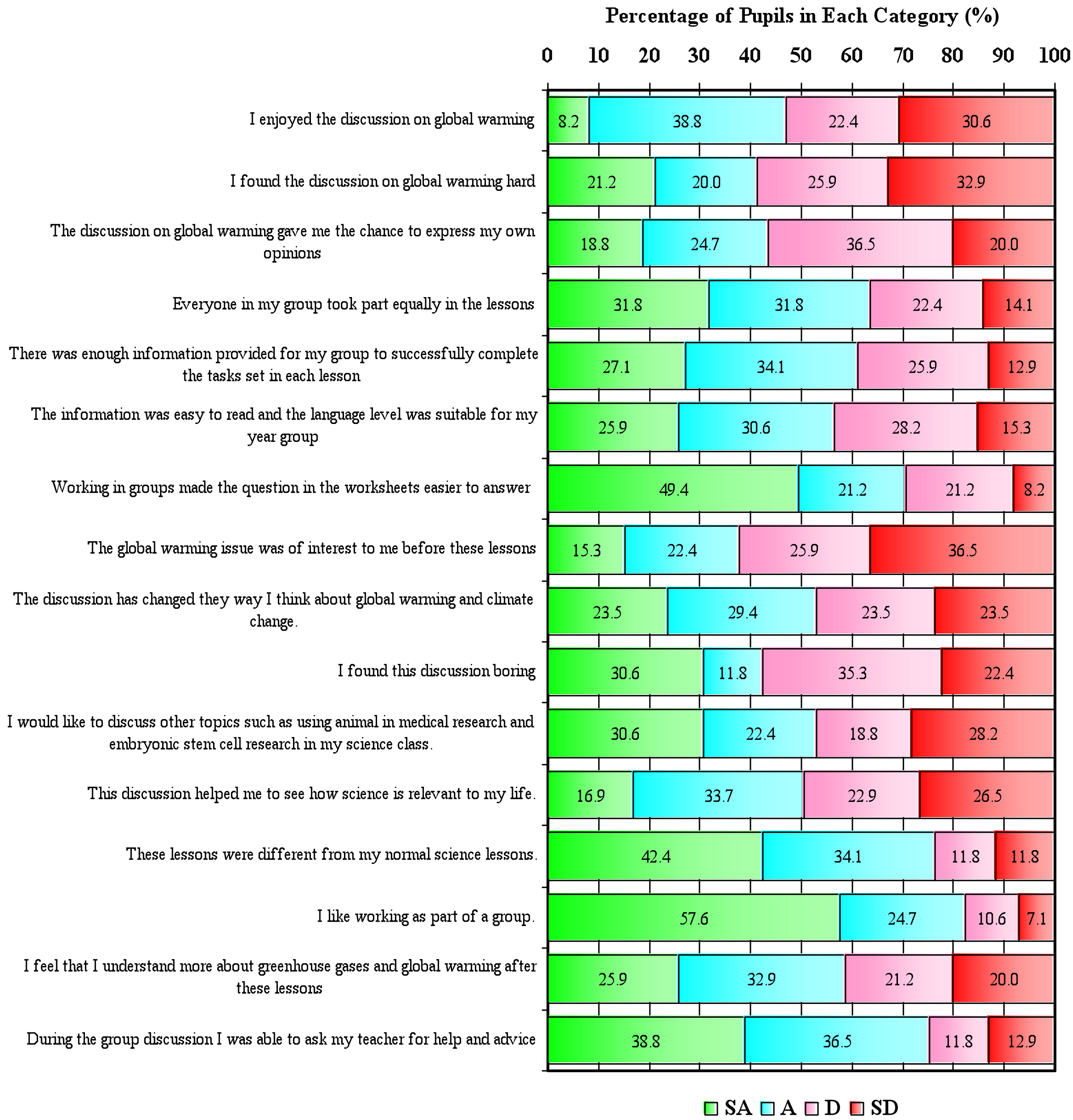


Figure 6.2 shows the overall percentage of male S2 pupils who expressed their view on items J01 to J16 in section J of the pupil questionnaire. Item J01 starts at the top. Note that SA=strongly agree, A=agree, D= disagree, SD= strongly disagree.

Figure 6.3 *Stacked Bar Chart of the percentage of XHS S2 Female responses to Section J of the S2 pupil questionnaire.*



Legend:

Figure 6.3 shows the overall percentage of female S2 pupils who expressed their view on items J01 to J16 in section J of the pupil questionnaire. Item J01 starts at the top. Note that SA=strongly agree, A=agree, D= disagree, SD= strongly disagree.

The data from Figures 6.2 and 6.3 illustrate differences between S2 males and females in their views on the climate change and global warming discussion lessons. For example, 53.5 % of males enjoyed the discussion compared to 47.1% of females.

Also, prior to the series of discussion lessons on climate change and global warming 62.4% of the S2 females were not interested in the topic compared to 57% of males, with less males (38.3%) finding the discussion boring than females (42.4%). More males (64.3%) than females (58.8%) agreed that after these lessons they felt that they understood more about greenhouse gases and global warming. But 58.8% of S2 males and 52.9% of S2 females expressed the view that the discussion had changed the way they thought about the issue. Interestingly, females were more interested in discussing other issues such as use of animals in medical research and embryonic stem cell research than males (41.7% males versus 52.9% of females agreeing with item J11).

In terms of the accessibility of the materials used, there were differences in perception between S2 males and females. For example 41.2% of S2 females thought the discussion on global warming was hard compared to 23.3% of the S2 males, with 27.9% of S2 males and 38.8% of females expressing the view that there was not enough information provided for their group to successfully complete the tasks. In addition, more females (43.5%) felt that the information was hard to read and the language level too difficult for their year group compared to the S2 males (34.9%).

In terms of the cooperative learning approach, 82.4% of S2 females liked working as part a group compared to 69.4% of S2 males, with roughly equal numbers of males (53.5%) and females (55.5%) concurring that during the discussion they felt unable to express their own opinions. In addition, 67.4% of S2 males and 63.5% of females agreed that everyone in their group took equal part in the lessons with 73.3% of S2 males and 70.6% of females agreeing that working in groups made it easier to answer the question in the worksheet. Furthermore, more females (75.3%) felt that they could ask their teacher for help and advice during the group discussion compared to males (62.3%).

6.2.4 Post-lesson Series Pupil-Group Semi-structured Interviews.

The post-lesson series pupil-group semi-structured interviews were used as an opportunity to ask the pupils about their experience of the lesson series and as a way to probe a cross-section of each S2 cohort about their views on the cooperative learning approach, discussion in general and about critical incidents observed during the series. In an effort to present the findings from these pupil-group interviews in a consistent manner, the findings are presented under headings derived from key questions posed during the interviews and discussion points observed during lessons. The total number of pupil-groups interviewed in each round of the action research was six, resulting in a total of 18 pupil group interviews over the whole. Each pupil group comprised of five randomly chosen pupils from a class which had been observed by the researcher over the course of the series. The findings from this part of the research include extracts from the group interview transcripts, throughout which the researcher is denoted by the code **Inv,** the pupils within the group as **P** with a number.

6.2.4.1 Pupils' views on the materials used in the topic.

One of the findings from the teacher post-lesson interviews was that most of the teachers felt that the pupil materials used in round one required differentiation as some of the vocabulary was felt to beyond the pupils. However, when the pupils were asked what they thought of the language levels in the worksheet, they reported that they thought that the language was suitable. The following extract talks about the language level used in the analysing-greenhouse-gas-data worksheet from the first round:

> **Inv:** What did you think of the language level in the questions?
>
> **P1:** In what way?
>
> **Inv:** Was it too high for you?
>
> **P1:** No
>
> **Inv:** So you understood what was meant by the phrase 'most pronounced trend'
>
> **P4:** Yes

P3: I didn't understand what that question was asking but I just asked the teacher to explain what it meant and she told me and I got on with it. That's their job isn't it? If I don't know what a word means I just ask the teacher or if I am in English I look it up.

It is clear from this extract that the pupils do not see language level as a hindrance to their learning as they see it as the teacher's job to explain the language so that they can learn new words and thereby extend their vocabulary. This is in contrast to the teachers' comments that the language level used in the materials was too difficult for this year group. The difference in perception of difficulty level may seem unimportant, but it highlights an important problem faced by Science teachers. Differentiation of language for the sake of it can dangerously reduce pupils' opportunities to accumulate new words and meanings and stifle their pupils' vocabulary.

In the first and seconds rounds, the pupils were asked about what they thought of the analysing-greenhouse-gas-data worksheet. The pupils in both rounds said that they felt that the graph drawing tasks were relatively easy. However, this perception is at odds with the observations made during those lessons and from analysis of the worksheets (sees Chapter 7). One pupil suggested that this task was easy commenting that:

I was doing something similar in Maths the period before we had science, so I thought it was ok **S2 pupil in the First round**

In the first and second rounds, pupils were asked to discuss issues surrounding a proposed Carbon Emission Bill and two alternatives and were asked to vote for the proposal they preferred and why. As part of this lesson the pupils had to use a decision-grid to help them analyse the statements. The teachers felt that the pupils struggled with this task. However, the pupils felt that the decision grid was relatively easy to use and commented that they thought that it helped them to see the difference between the three MP statements. It could be argued that the difference in how the pupils perceive difficulty compared to their teachers may stem from the pupils' expectation of help from the teacher. This suggests that the pupils expect the work they are set to be difficult but with the help of the teacher they may be confident of learning from the experience.

In the second round, the pupils were asked to watch and evaluate four DVDs and feedback the information that they had found out. The pupils all agreed that this lesson was difficult, commenting:

> *I found it difficult to concentrate on our video because of the noise from the other groups. The one I watched was an Inconvenient Truth and I thought it was boring which didn't help.* **S2 pupil from the second round**

The technical difficulties mentioned by the pupils were also commented on by the teachers. However, these difficulties were fixed for the third round. In the third round the number of DVDs was reduced and the video clips focused around key questions to help the pupils focus in on the task. The pupils said that this lesson was good but a bit repetitive because the two hypotheses covered much of the same ground.

> *...the PowerPoint with the video clips was ok but I thought that they seemed to repeat themselves, one even used a clip from the other which I thought was strange.* **S2 pupil from the third round.**

This comment highlights the fact that some of the pupils did not understand that the video clips were trying to convince them of the merits of one hypothesis over the other. Also, as the pupil comment states, one of the video clips from the Great Global Warming Swindle used a clip from the Inconvenient Truth to point out a flaw in Al Gore's argument (in an Inconvenient Truth). This suggests that the arguments in this lesson were too subtle for this age group of pupils.

6.2.4.2 Pupils' views on the cooperative learning approach.

The pupil groups were asked to comment on the cooperative learning approach used by their teachers to teach the climate change and global warming discussion lessons. In the course of their responses it emerged that all the pupil-groups agreed that they liked the cooperative learning approach to group work but some of the pupils felt that they did not like working in the groups that they found themselves. This was a recurring theme in all three rounds of action research. The following extract from a group interview from the first round typifies the type of comments made by pupils during the interviews throughout the rounds of action research:

> **Inv:** What did you think of the cooperative learning approach to group work?
>
> **P1:** It was good because I was in a group with friends.
>
> **P3:** My group didn't work so well because I didn't have anybody in my group that I was friendly with.
>
> **Inv:** So the group dynamic made a difference to your enjoyment of the group work?
>
> **P2:** I like working in groups but not with people that I don't like or who I don't get on with, so I didn't want to work with them so I didn't.
>
> **P3:** I kind of held back, but if I was in with people you know it's better.

One of the issues that the pupils raised was that they did not like being randomly assigned to groups, with some of the pupils being highly critical of being allocated to groups where they did not have a friend or where they did not like the other pupils in the group. These pupils did not accept that they should learn to work with others, even if they did not particularly like the others in the cooperative group. Interestingly, the majority of pupils who felt into this category were girls but the majority of boys reported that they would work with anyone.

In the second round of action research, most of the pupil-groups interviewed claimed that they liked the group work but that they felt that some people in their groups did not contribute as much as they thought they should, resulting in them reducing their effort to compensate. The following extract from a second round group interview exemplifies the sentiment felt by some pupils

> **P2:** Some people in my groups didn't want to work and sometimes misbehaved so I thought why should I bother if they aren't going to.
>
> **Inv:** So you slowed down or reduced your input according to the effort of the other pupils in your group?
>
> **P2:** Yes, because it's not fair that they [other pupil in group who is free loading] get to do nothing while we do all the work.

This issue suggests that the teachers were perhaps not applying individual accountability as diligently as they might have since this element would have highlighted the problem quickly and resulted in their intervention to rectify the problem before it got out of hand.

In the third round, one pupil felt that their teacher would stop their group work too much to ask for people to explain what they were doing in their groups

> *In our class our teacher seemed to stop the class every five minutes to ask for person number one in group eh… two what did your group find… It was a bit over the top. I thought that we needed more time to discuss which card went under each heading in the table.* **S2 pupil in third round**

This suggests that some of the teachers had tried to compensate for this as in their own post-lesson interviews they commented that they had become conscious of those pupils in some groups not pulling their weight.

When asked more specifically about their normal experience in science compared to what happened in these lessons, the pupils commented that the global warming lesson (in all three rounds) were very different from the type of lesson that they were used to in science. This was corroborated by responses to item J13 in the pupil questionnaire. When asked in what way these lessons were different, they all said that they differed from their normal lessons by the fact that they had to pull together to complete their work, whereas normally they worked individually. Also, most of the pupils said that in these lessons there was a lot more talking about the tasks with others and there was less bookwork.

In the first round of the action research, there were two class groups who made specific comments about their peers' behaviour. In particular they made reference to their teacher's inability to control the behaviour of one or two individuals whom they said affected their concentration levels. The following extract from one of these class's group interviews exemplifies the class group's feeling.

> **Inv:** Did you feel that working in groups distracted you?

P1: Yes, because we were talking a lot.

P2: Yes, in some groups there were people who didn't want to work and misbehaved.

Inv: So, in your opinion you felt that some groups didn't work.

All Pupils: Yes.

Inv: Could you explain why this was the case?

P1: Yes, she could have controlled the class a bit better. Certain people misbehaved but the whole class got punished.

Inv: Was the class behaviour worse when doing the global warming discussion topic?

P1: No, it was better because we had two teachers in the room.

P2: But when you [the observer] left the room it got out of hand.

P3: The girls listened but the guys were not good.

P4: The same people caused the problems as usual, they should have been excluded.

Inv: Do you think that the disruption in your class prevented you from getting into the global warming discussion?

P1: Yes, because it was all stop start, stop start.

P3: I felt there was not enough time to do it because the disruption dragged on.

P4: I thought the discussion could have been good but when the teacher started shouting at us I just switched off.

Inv: So, the class behaviour affected your enjoyment of the discussion?

P2: Yes, our class was the worst in the year.

P1: I felt sorry for the five girls in the class who tried to get on with the work.

The behavioural aspect of the classes in the action research was good, however as mentioned earlier, there were two classes that were observed to be poorly behaved. The extract above suggests that in the pupils' opinion, the teacher's inability to control the class had a detrimental effect on the discussion. In the view of this researcher, the truth probably lies in between this position. It was obvious from observation classes that the teacher had difficulties with a number of challenging pupils. However, these pupils would have caused a problem for even the most experienced of teachers. But the pupils suggest that the behaviour was only bad when the observing researcher left the room. So one might question whether the pupils in this class were deliberately trying to wind up the teacher to avoid work. Or were there genuine issues with this teacher's competence? This question is beyond the scope of the present research. However, it shows that cooperative learning, like any other pedagogical approach, is only as good as the compliance of the pupils in the class will allow it to be.

6.2.4.3 Pupils' views on the global warming discussion.

The pupils interviewed in all three rounds expressed mix views on the global warming discussion. In the first round of the action research the pupils indicated as stated previously, that they saw these lessons as very different from their normal science lessons. However, three of the first round pupil-groups commented that they felt that the discussion was rushed and that they would have liked more time during the lessons to discuss the tasks within their groups.

> **Inv:** So you liked the discussion?
> **P1:** Yes, but we needed more time to discuss things and our teacher pushed on.
> **Inv:** Did you get the opportunity as a group to discuss the questions?
> **P2:** We only go 5 minutes to do each question and some of them were big questions. I thought we needed more time to discuss our answers before we wrote them down.
> **Inv:** So you felt rushed?
> **P3:** Definitely.

This comment is interesting as the pupils are suggesting that they felt that they could have done better if they had been given more time to take in the information and discuss their thoughts.

In terms of their enjoyment of the global warming discussion, again the pupils expressed mixed views with some saying that they liked it, some saying it was okay or good, but some also saying that they found it boring. This pattern echoed across all three rounds of action research. Looking more specifically at individual lessons, all the pupil-groups said that they enjoyed the first lesson as it helped them to focus on what they already knew and helped them to think about what they thought was going on in general terms. One group of pupils suggested that they liked the poster presentation part of the lesson. However, in the first and second round interviews, the pupils said that they felt that the analysing-greenhouse-gas-data worksheet lesson was more like a Maths lesson stating that:

> …it wasn't as good as the first lesson but it was okay we draw graphs in Maths so it wasn't difficult. **S2 pupil from the first round**

This matter was also referred to by a number of the teachers. It highlights the fact the S2 pupils see skills like graph drawing as Maths and do not realise that all subjects, but particularly science, use graphs to help convey a sense of the meaning for the numbers that are generated.

In the first and second round, the pupils enjoyed the lessons which involved discussion of the political use of the science knowledge. The pupils in both rounds felt that this lesson closely resembled lessons that they had experienced in Modern Studies. They also expressed the view that they understood that this type of lesson was still important and should be done in science as well as Modern Studies.

> **Inv:** Do you feel that this type of lesson was appropriate for a science lesson?
> **P2:** It was still about global warming but it was different.
> **P3:** It was different from the other stuff.
> **Inv:** Do you think that this type of lesson helps you to see how science is relevant to your life?
> **All pupils:** Yes.

6.2.4.4 The pupils' response to the ozone misconception.

During the pupil-group interviews the pupils were asked about the appearance of the ozone misconception in relation to the greenhouse effect which was mentioned by the science teachers in their post-lesson interviews and observed by the researcher in his observation of the lesson. The following extract summarises what the pupils said:

Inv: I noticed that time and again in your class and in others that pupils mentioned the ozone layer in their KWL grids and posters. Where did this information come from?

P1: I heard it on the TV and in the news.

P2: Yes, it was on the TV a lot when I was at primary school.

Inv: Ah, but did you hear about it from primary school?

P1: No, we did very little science at my primary school.

This group of pupils claimed that they heard about the ozone layer from television programmes and the news when they were at primary school but were not taught about the depletion of the ozone layer in primary school science. However, another group of pupils suggested that they had been taught about it at primary as exemplified by the following interview extract:

Inv: One issue came out of the observation of the first lesson was a misconception about the ozone layer. Where have you been exposed to information about the ozone layer in the past?

P3: The news and primary school.

Inv: What have you been taught? Can you explain to me what you think the ozone layer is and how it is connected to global warming?

P3: The atmosphere, but I don't know how its connected.

Inv: So, you know there is an ozone layer, do you know what it does?

P3: It prevents harmful rays.

Inv: What harmful rays?

P4: From the sun, like heat.

Inv: Do you think that the hole in the ozone layer has been adequately explained to you in the past?

P3: No, I just sort of heard it.

Inv: So, it has just sort of filtered its way in? Where do you think it has come from?

P3: From the news and stuff.

It is clear that the ozone misconception has made its way into the students' thinking of the greenhouse effect by diffusion from the media such as from television programmes and newspaper reports and possibly even from primary school science.

However, what is more problematic is the fact that the pupils do not understand how the depletion of the ozone layer works, or what ozone's function in the atmosphere is or how it might be linked to the greenhouse effect. This is a good example of how pupils' naïve conceptions of what they think they know about the greenhouse effect can conflict with what they are being taught. It is important to remember that all pupils in all three rounds of the action research had previously been taught in first year science about the greenhouse effect and global warming as part of the combustion topic at the end of S1. The pupils should therefore at least have been aware of what the greenhouse effect was and that the ozone layer (which is not mentioned by either the science course or the geography course in S1 or S2) has nothing to do with the greenhouse effect. However, this misconception still crept in.

6.3 Summary.

Over the course of the action research the teachers who took part steadily became more comfortable delivering the lesson series on climate change and global warming using cooperative learning. This group of science teachers also felt that participation in the project had helped to prepare them for the challenge of *CfE.* The teachers intimated that the discussion took more time to plan and prepare for but that, over the course of the action research, the time taken to deliver the lesson series decreased.

Using cooperative learning, this group of science teachers successfully made the transition from a recitation style to a more open discursive form of classroom discourse. However, the teachers felt that although the cooperative learning approach was helpful in managing small group discussion, it was not suited to teaching data analysis and interpretation. Some teachers felt that this type of lesson required a teacher-led approach as some of the data used in the analysing-greenhouse-gas-data worksheet was difficult to interpret without targeted scaffolding around key points.

The pupils in general felt that these lessons were very different from their normal science lessons and enjoyed them. However, during the pupil-group interviews the pupils commented that they thought that the learning materials used in these lessons were suitable in terms of language and difficulty level. They also commented that they thought that the cooperative learning approach helped them to answer the questions posed since they could discuss the questions with their fellow pupils. However, they did suggest that the lessons were rushed and that they could have done with more discussion time. The teachers suggested that the language level of the materials was too high for this age group, indicating that the language needed differentiated to help pupils understand it better. This suggests that there are differences in perception of what is difficult with respect to language and content between teachers and pupils.

One misconception arose from the teaching of these lessons over the three rounds of action research and was concerned with the role played by the ozone layer. The pupils were confused as to the role that it played in global warming, reckoning that the hole in the ozone layer let the heat in with some thinking that the ozone layer was affected by CO_2 and other greenhouse gases, resulting in increased global warming. The teachers reported that they had a hard time combating this misconception. The pupils reported during their group interviews that they had picked this up from the media, particularly television, however a few pupils indicated that they had learned this in Primary school.

Chapter 7: Action Research Findings: Pupils' Class work.

7.1 Introduction.

This chapter describes findings derived from the pupils' class work carried out during each round of the research. In particular the findings described here help to corroborate and evidence some of the points highlighted in the post-lesson teacher semi-structured interviews, pupil-group semi-structured interviews and classroom observations. The data presented also help triangulate findings within and between rounds of the action research.

7.2 Pupils' class work from three rounds of action research.

In this section the output of pupils' work from the three rounds research is described. In the interests of pupil anonymity all work shown in this chapter has had reference to names removed. For the sake of brevity, only a small proportion of pupils' work is shown to illustrate points referred to by either the teachers in post-lesson interviews, or by the researcher as seen in observed lessons. All other pupil work is summarised in terms of whole year group performance in specific tasks for each round of action research.

7.2.1 KWL grids from the first round of action research

The KWL (three columns which set out what pupils think they **know** about a topic, what they **want** to know about a topic and what they have **learnt** about the topic) grids yield information on what the pupils know about global warming and greenhouse gases and the greenhouse effect as a concept. When one looks more closely at the content in the returned KWL grids it is interesting to note that of the 236 returned grids, 83 mention the misconception of the ozone layer (35%). Figure 7.1 shows an example of a KWL grid that mentions this misconception.

Figure 7.1 *Example of a pupils KWL grid.*

KWL Worksheet. Global Warming Lesson 1.

Name: ______ **Class:** ______ **Teacher:** ______

In the KWL grid below write down 5 things that you know about greenhouse gases and global warming.

In the KWL grid below write down 5 things that you need to find out more about greenhouse gases and global warming.

At the end of the topic write done 5 things that you have learnt about greenhouse gases and global warming

K: What do you know about Greenhouse gases and Global warming?	W: What do you need to find out more about?	L: What have you learned about Greenhouse gases and Global warming?
Polar ice caps are melting.	Polar bears	If the ice caps melt Polar bears could become endangered,
Temperatures are rising in lots of places.	Why are temperatures rising?	Greenhouse gases are harming the atmosphere and the ozone layer which makes it warmer.
Climate Change is largely to blame for global warming	How can we avoid global warming?	By saving energy by turning off all electrical appliances when not being used and not taking the car on some journeys.
~~..~~ CO^2 omissions are ~~...~~ polluting the air.	What has the sun got to do with global warming?	Gases are released from the sun that harm the earth.
Water levels are rising .	~~Why are they rising?~~ What will happen if they rise?	Some countries such as Holland and Bangladesh will end up under sea level.

This example of a pupil's KWL grid shows how the ozone layer misconception has made its way through this pupil's thinking. The pupil states that greenhouse gases are harming the atmosphere and the ozone layer which make it warmer. The worrying thing is that the L column was filled in by the pupils at the end of the lesson series. This is a good example of the insidious nature of misconceptions.

7.2.2 Pupil poster presentations from the first round of action research.

As part of lesson one in the first round of the action research, the pupils were asked to produce a poster presentation which explained the greenhouse effect and global warming. Figures 7.2 and 7.3 show examples of pupil group posters which were presented to the class.

Figure 7.2 *Example number one of a pupil group poster explaining the greenhouse effect and its contribution to global warming.*

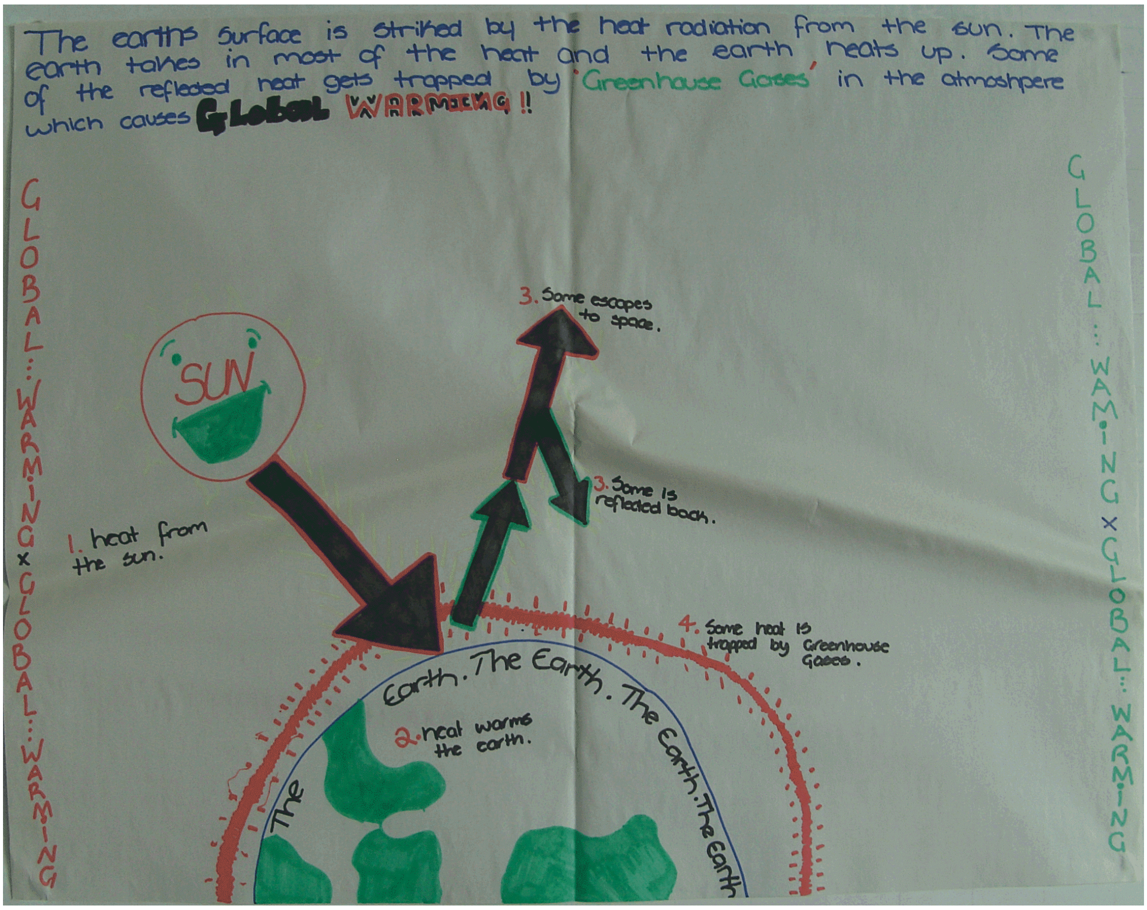
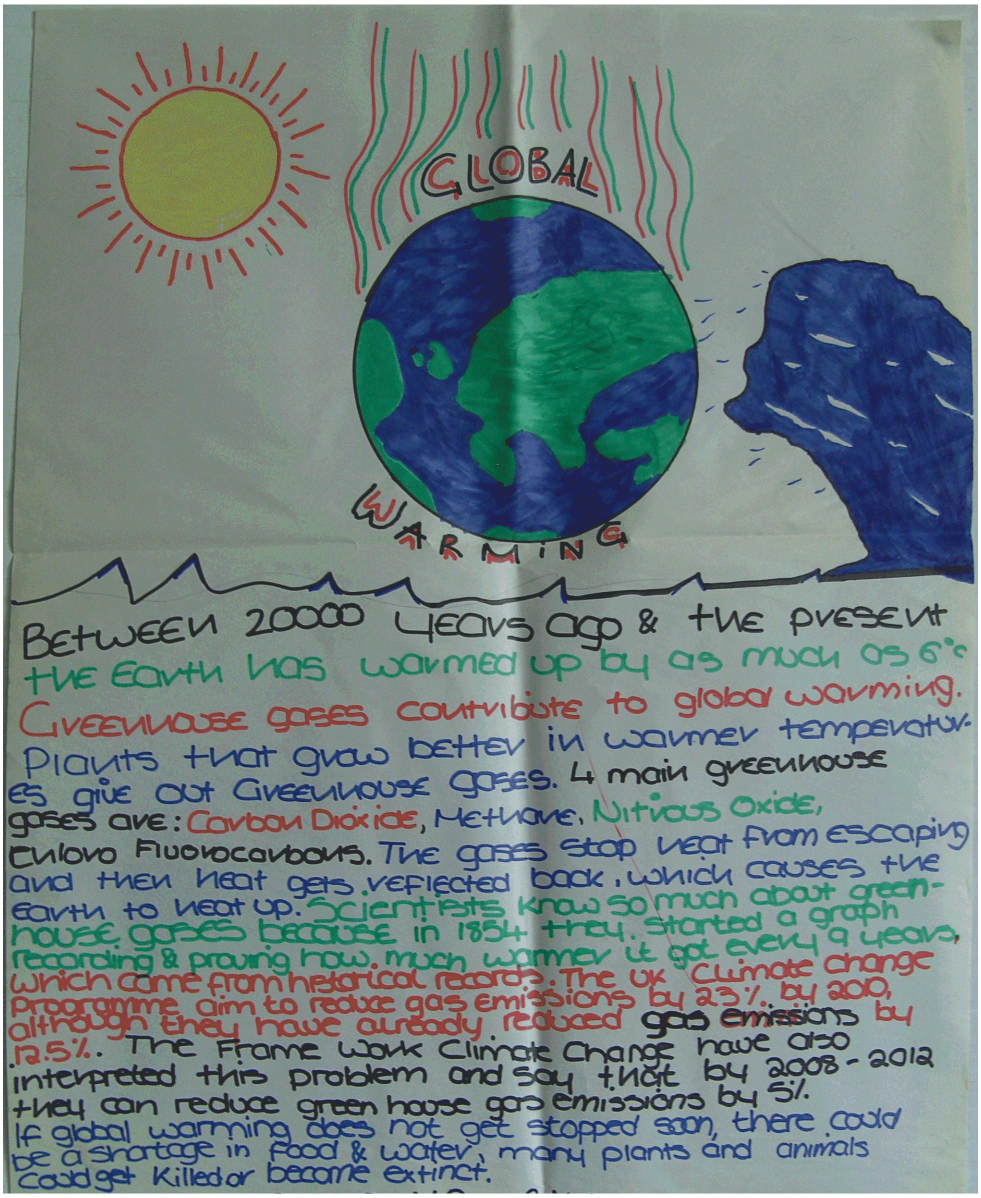


Figure 7.2 shows that the pupils in this group grasped most of the concept of the greenhouse effect but, on closer scrutiny, it is evident from the illustration that this group of pupils did not grasp the fact that for greenhouse gases to trap the heat, point 4 on their illustration needs to be above point 3 (some heat is reflected back). This shows that although the group could write a few sentences about the greenhouse effect, they could not represent that understanding graphically.

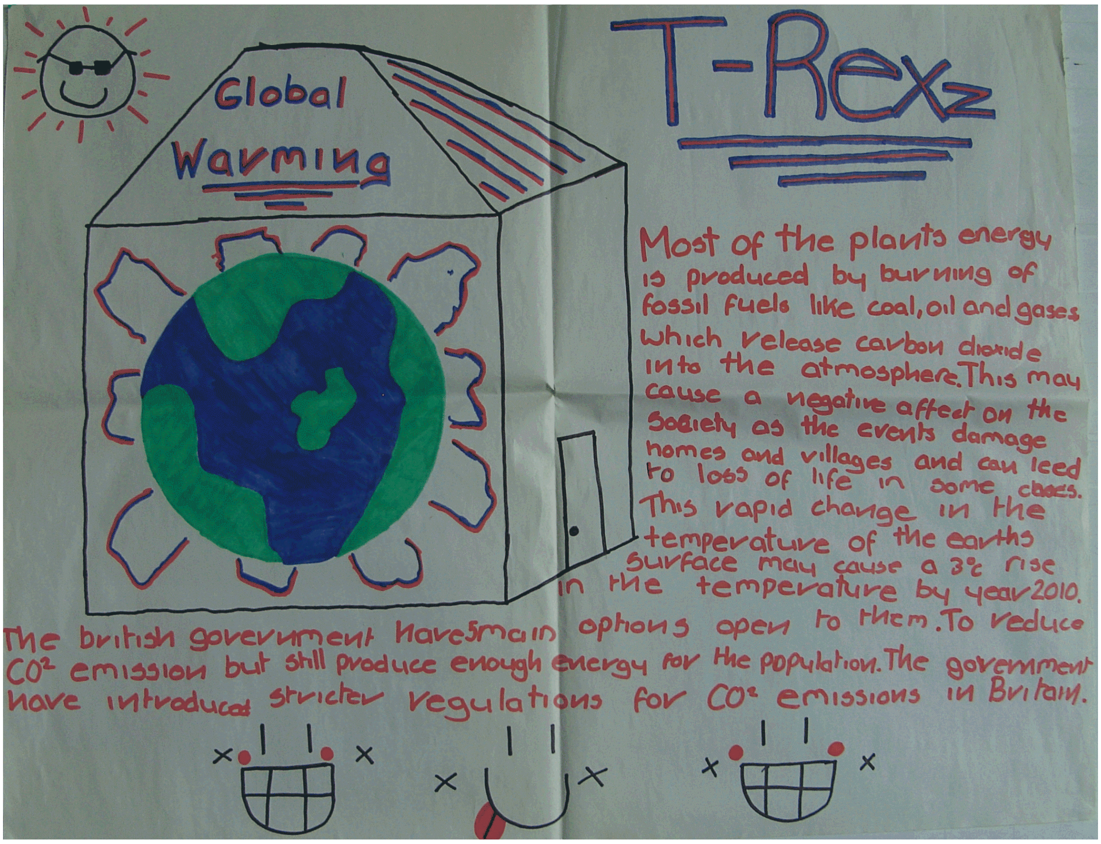
Figure 7.3 shows an example of a group poster which did not attempt to illustrate the point. This group's poster gives a written account of the greenhouse effect.

Figure 7.3 *Example number two of a pupil group poster which describes the greenhouse effect and its contribution to global warming.*



This group possibly did not understand what their brief was as they have not made any attempt to explain what the greenhouse effect is and how it contributes to global warming. Furthermore, the text reveals that the pupils are confused since they indicate in the poster that plants that growing in warmer temperatures give out greenhouse gases. This shows that this group basically expressed what they knew about global warming in the poster without reference to the task asked of them. Figure 7.4 shows another group's poster which illustrates a similar point that the pupils interpreted the task as a way to show what they knew about the issue without completing the task set.

Figure 7.4 *Example number three of a pupil group poster which describes the greenhouse effect and its contribution to global warming.*

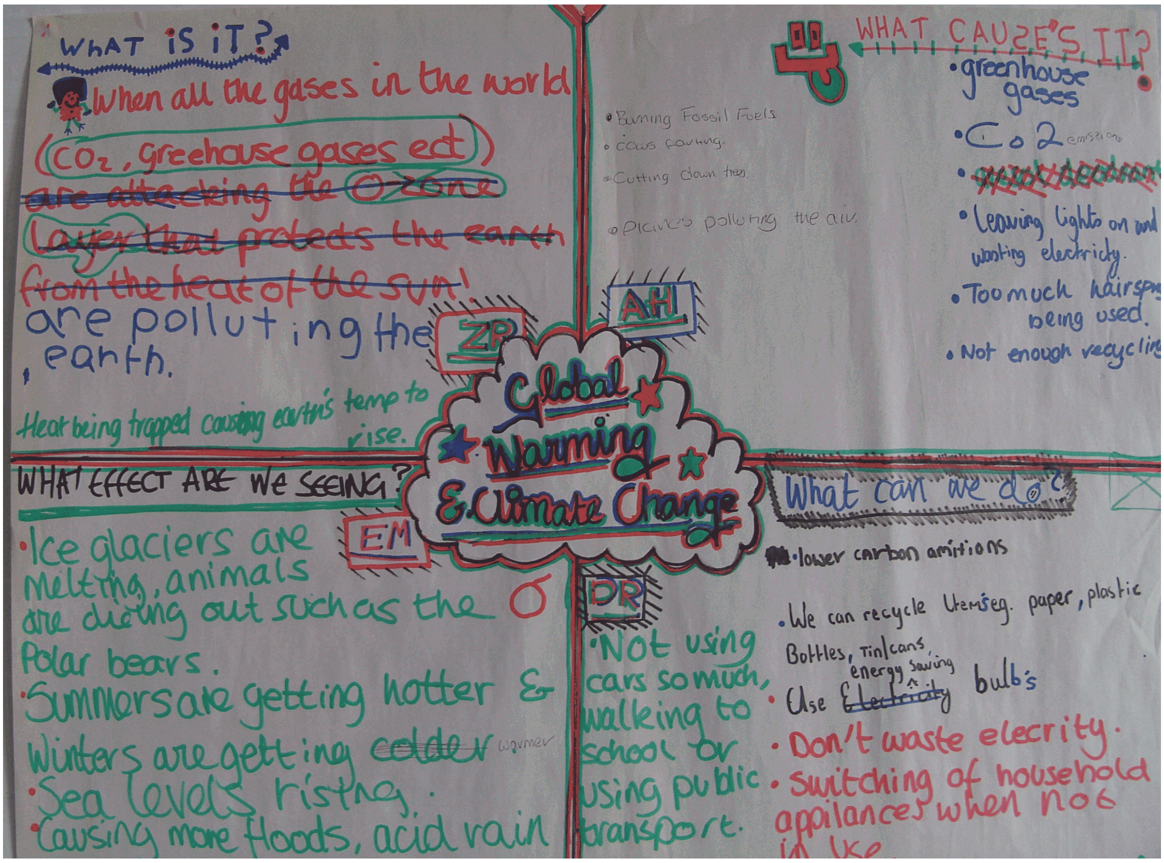


Of the 65 posters returned at the end of the lesson series, 13 posters (20%) were similar to Figures 7.3 and Figure 7.4. The distribution of such posters showed that only two classes did not have such a poster but that all the other classes had at least one group who interpreted the task in such a way. On the whole this task was successful in that it showed that the majority of the pupils in this S2 cohort could explain the concept of the greenhouse effect and how it contributes to global warming. However, it also showed that the teachers found it difficult to get round all of the groups sufficiently to prevent the groups from going off task.

7.2.3 Pupil group graffiti boards from the second and third rounds of action research.

In the second and third rounds of action research the pupils were asked to complete graffiti boards which asked four questions on global warming and climate change: What is it? What causes it? What effects are we seeing? and What can we do? Figure 7.5 and Figure 7.6 show examples of these graffiti boards from the second and third round of action research respectively.

Figure 7.5 *Example number one of a pupil group graffiti board from the second round of action research.*



From Figure 7.5 it can be seen in the top left hand panel (What is it?) that the ozone misconception appears but has been scored out later. This group thought that CO_2 and other greenhouse gases attack the ozone layer. They also think that the ozone layer protects us from the heat of the sun. This figure confirms the report by NQST4 that he stopped his groups and attempted to combat this misconception.

Figure 7.6 *Example number two of a pupil group graffiti board from the third round of the action research.*

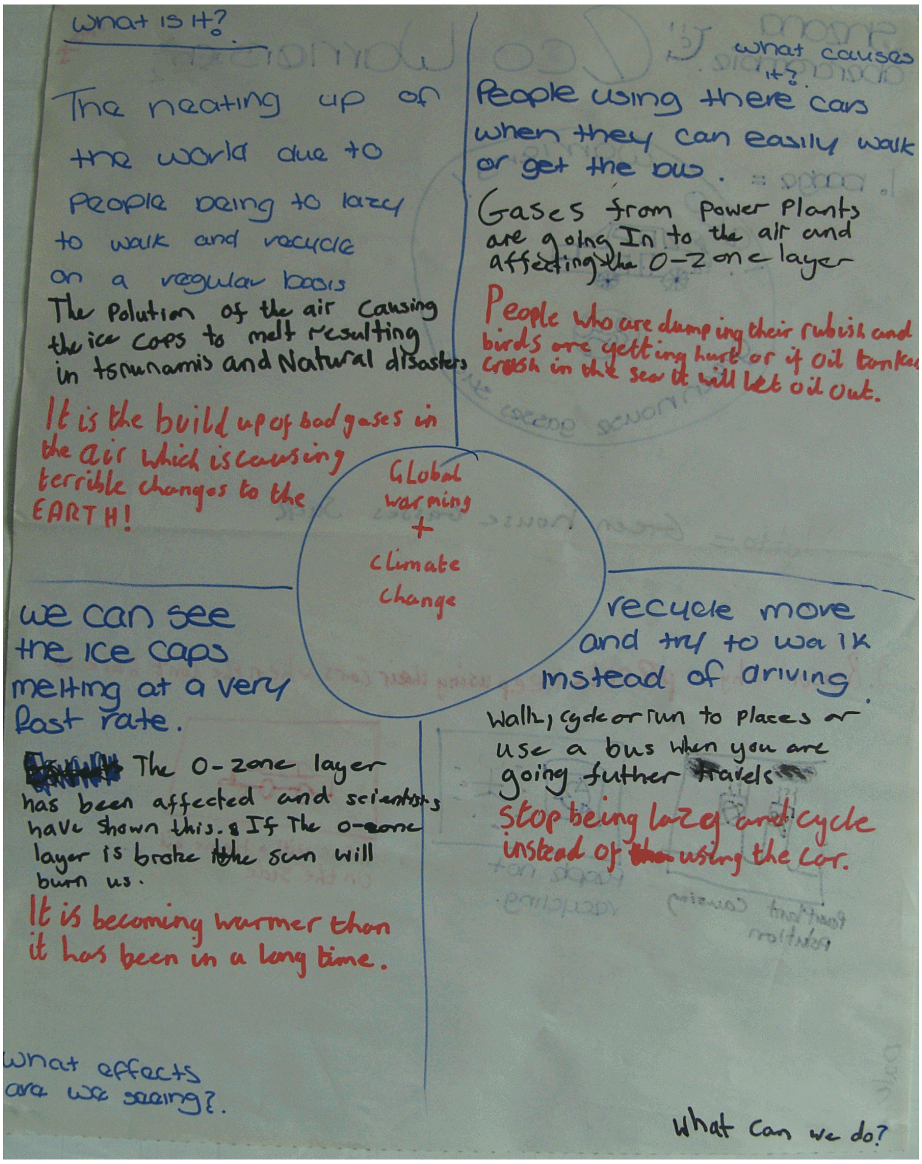


Figure 7.6 also shows another variation on the ozone layer misconception. This time the misconception appears in the bottom left panel (What effects are we seeing?). This group understood that the ozone layer protects humans from too much sunburn but again this has nothing to do with global warming. These two examples indicate that the S2 pupils did not understand that sunburn is caused by exposure to ultra-violet light from the sun and that heat energy comes from the infra-red radiation of the sun. This is concerning since all of the S2 cohorts from all three rounds of action research had just completed a topic on Heat energy and therefore should have known the difference between ultra-violet and infra-red energy.

7.2.4 Analysing greenhouse gas data worksheet from the first and second round of action research.

The analysing greenhouse gas data worksheet was designed to fulfil a number of learning outcomes which cut across the curriculum from the new science experiences and outcomes through to the Literacy and Numeracy experiences and outcomes. In particular, the analysing greenhouse gas data worksheet meets the requirements for the Numeracy across the curriculum experiences and outcomes at the second, third and fourth level for the Information Handling strand, Data Analysis topic which states:

> Having discussed the variety of ways and range of media used to present data, I can interpret and draw conclusions from the information displayed, recognising that the presentation may be misleading.
> **MNU 2-20a**
>
> I can work collaboratively, making appropriate use of technology, to source information presented in a range of ways, interpret what it conveys and discuss whether I believe the information to be robust, vague or misleading.
> **MNU 3-20a**
>
> I can evaluate and interpret raw and graphical data using a variety of methods, comment on relationships I observe within the data and communicate my findings to others.
> **MNU 4-20a**

These learning experiences and outcomes involve pupils demonstrating graph drawing skills such as correctly scaling, labelling and plotting a line graph. In addition to this, subsidiary questions involve the pupils demonstrating their understanding and interpretation of the graphical information as well as probing their understanding of the conclusions drawn from the data. In particular, question 2 (c) focuses on asking pupils to critically analyse the data to decide whether it supports the hypothesis that increasing greenhouse gas emission are responsible for the 0.5°C increase in observed temperature during the past 110 years . These learning outcomes also fit neatly into outcomes for the development of scientific literacy since a key component of scientific literacy involves the development of the pupils' ability to evaluate, interpret and draw valid conclusions from data.

With these learning outcomes in mind the analysing-greenhouse-gas-data worksheet was designed to help develop and practise this key element of scientific literacy. In the first round of the research project (2007), the worksheet was divided into two tasks which involved drawing graphs. Task 1 involved drawing a line graph using data from a table provided and answering two questions based on the graph. Task 2 involved drawing another line graph which was superimposed onto another graph to complete a graph with two y-axes, followed by six questions relating to the information contained in the graph. The entire set of subsidiary questions in the analysing-greenhouse-gas-data worksheet required more than one word answers. Thus, the worksheet also tested the pupils' ability to frame a written response to the question, hence literacy across the curriculum outcomes could also be assessed within this worksheet. The Literacy across the curriculum experiences and outcomes, Reading strand, Understanding, Analysing and Evaluating topic states;

> To show my understanding across different areas of learning, I can:
>
> - Identify and consider the purpose, main concerns or concepts and use supporting detail
> - Make inferences from key statements
> - Identify and discuss similarities and differences between different types of text.
>
> **LIT 3-16a**

In addition, the Writing strands, Organising and using information topic states;

> By considering the type of text I am creating, I can independently select ideas and relevant information for different purposes, and organise essential information or ideas and any supporting detail in a logical order. I can use suitable vocabulary to communicate effectively with my audience.
>
> **LIT 3-26a / LIT 4-26a**

In the second round of the action research project (2008) the analysing greenhouse gas data worksheet was modified to reflect teachers' views from the evaluation process at the end of the first round of action research. The graph paper in task one was redesigned to make it square rather than rectangular. In addition, Question 2 (a) and (b) were modified to introduce a tick box answer grid to make the answering process less literacy-dependent. Furthermore, Questions 2 (e) and (f) were dropped as the teacher felt that these questions were too conceptually difficult for pupils at this stage in their development. The teachers felt that these modifications would make the worksheet more focused on data handling and analysis as well as more accessible to a broader ability range.

7.2.4.1 Pupil Scores and Distribution from First and Second Round of Action Research.

The pupil responses to the analysing-greenhouse-gas-data were marked using a standardised marking scheme which was compiled by a group of experienced science teachers from the science department of XHS. All of these teachers were SQA markers and annually attended markers meetings. They used this experience to inform the production of the marking scheme. All worksheets for both rounds one and two of the action research project were marked by the researcher. To maintain consistency of marking, a cross-section of 30% of the worksheets from each round were cross-marked by the principal teacher of Chemistry and S1/2 Science from XHS. Utilising this process, none of the cross-marked papers were queried as inconsistent with the marking scheme for either the first or second rounds. The total number of marks available in the first round version of the worksheet was 15 marks. The total number of returned worksheets was 214, of which the mean ± standard deviation score for the first round S2 cohort was 6.37 ± 2.36 (42.4% ± 15.7). The total number of marks available for the second round version of the worksheet was 11 marks. The total number of returned worksheets was 182. The mean score was 5.6 ± 2.2 (51.0% ± 20.04). Figure 7.7 shows the distribution of marks for the first round S2 cohort. Figure 7.8 shows the distribution of marks for the second round S2 cohort.

Figure 7.7: *Distribution of scores for the S2 pupils' responses to the analysing-greenhouse-gas-data worksheet from the first round.*

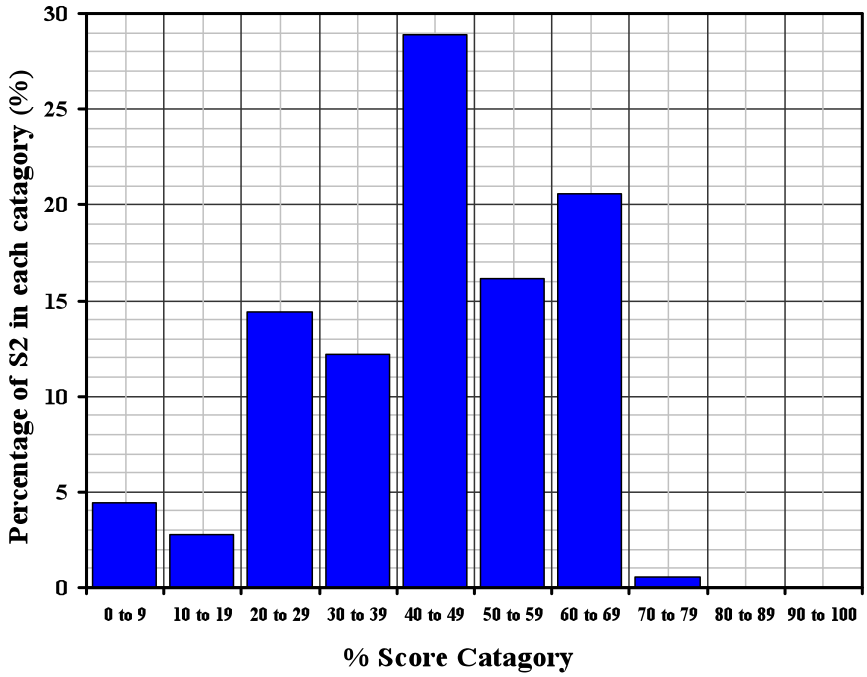
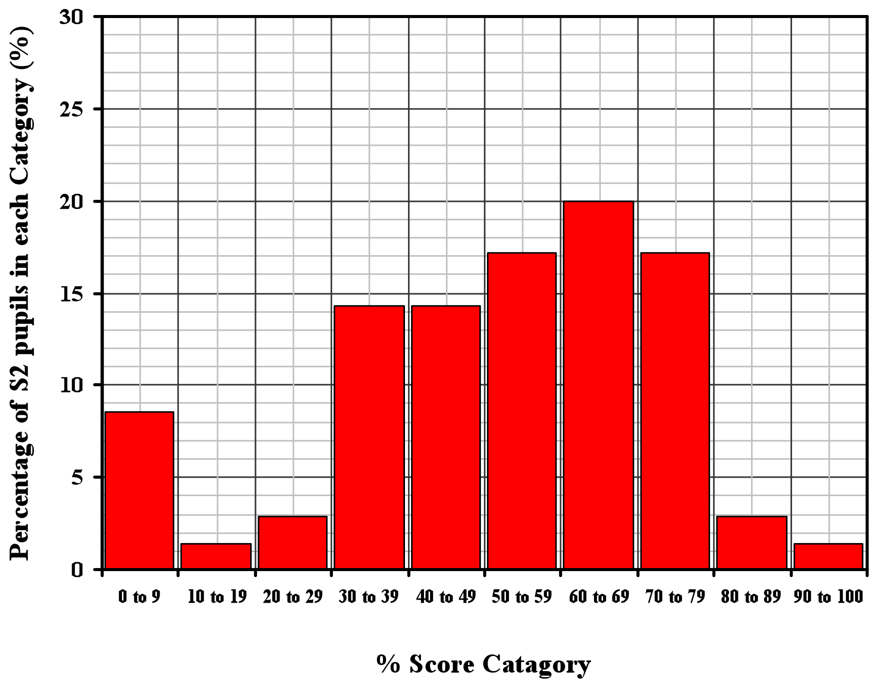


Figure 7.8: *Distribution of scores for the S2 pupils' responses to the analysing-greenhouse-gas-data worksheet from the second round.*



When the distribution of the percentage of pupils found in each % score category are compared (Figure 7.7 compared to Figure 7.8), it can be seen that the changes made to the analysing-greenhouse-gas-data worksheet had made it more accessible to more pupils since a higher proportion of pupils were able to attain a higher percentage score. However, looking more closely at the analysis of individual items from the worksheet we can see similarities and differences in the way the S2 pupils from each round of the research responded to each item. In addition, the question of accessibility of the items to the lesser-able pupil is seen to be more complex. Table 7.1 shows a detailed breakdown of the percentage of S2 pupils in each round of the action research who scored 0, 1, 2 or 3 marks depending on the item.

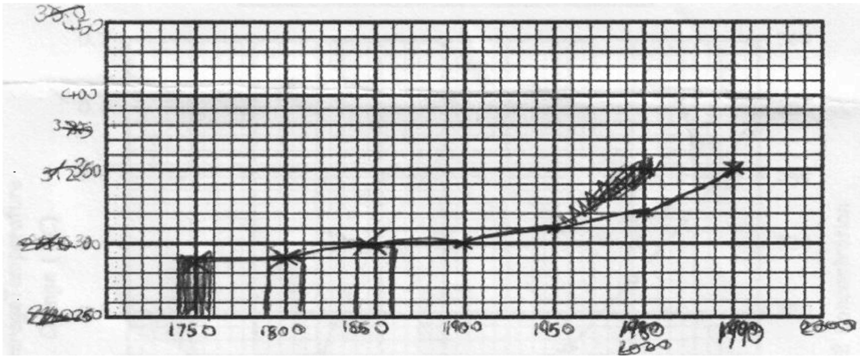
Table 7.1: *Matrix of Pupil Responses to each Item in the Analysing-Greenhouse-Gas-Data-Worksheet.*

% Pupils Scoring the marks in each item								
Score	**0**		**1**		**2**		**3**	
Worksheet Item	**Round 1**	**Round 2**	**Round 1**	**Round 2**	**Round 1**	**Round 2**	**Round 1**	**Round 2**
Task 1	17.2	14.3	20.0	37.1	31.1	31.4	31.7	17.1
1(a)	53.9	21.4	46.1	78.6	-	-	-	-
1(b)	29.4	28.6	70.6	71.4	-	-	-	-
Task 2	25.6	48.6	74.4	51.4	-	-	-	-
2(a)	15.0	51.4	85.0	48.6	-	-	-	-
2(b)	14.4	47.1	85.6	52.9	-	-	-	-
2(c)	47.8	54.3	42.8	32.9	9.4	12.9	-	-
2(d)	73.3	57.1	26.7	42.9	-	-	-	-
2(e)	91.1	-	8.9	-	-	-	-	-
2(f)	100.0	-	0.0	-	-	-	-	-

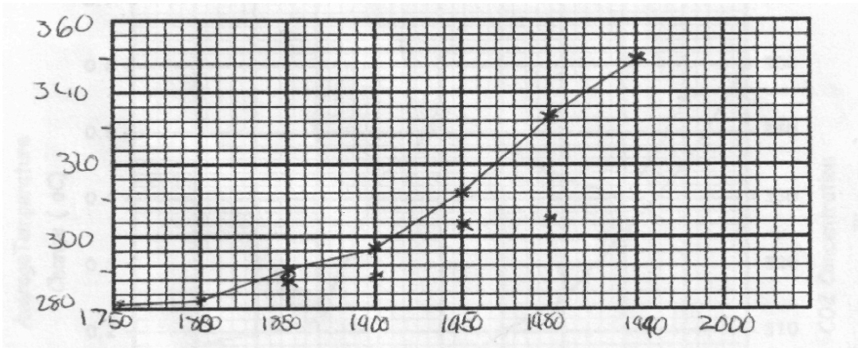
From Table 7.1 we can see that for Task 1, 17.2% of the first round S2 cohort could not attain any marks for the line graph in Task 1. This was due in large part to the pupils' inability to scale either the x-or y-axis of the graph, apply appropriate labels with units to the x-or y-axis, or plot the points on the line graph. On occasion, some pupils even attempted to draw a bar chart rather than a line graph, whereas only 14.3% of the round 2 S2 cohort could not pick up a mark for task 1, for the same reasons. Figure 7.9 illustrates three examples of pupil response which gathered no marks for task 1. However, 31.7% of the first round and 17.1% of the second round S2 cohorts managed to attain all 3 marks for task 1 with 37.1% of the second round and 20% of the first round S2 cohort attaining only 1 mark for task 1. What is clear from this task is that a significant and sizable minority of S2 pupils from the first round cohort struggle to scale and draw a relatively simple line graph. However, 51.4% of the second round S2 cohort was unable to scale and draw the line graph (Figure 7.9 and 7.10 give an indication of the types of difficulties faced by the pupils).

Figure 7.9: *Examples of Pupils' responses to Task 1 on the Analysing-Greenhouse-Gas-Data Worksheet for the First Round that attained 0 marks.*

A



B



C

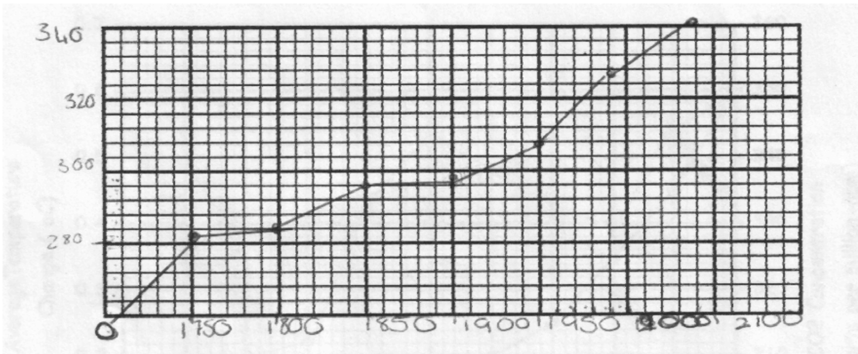
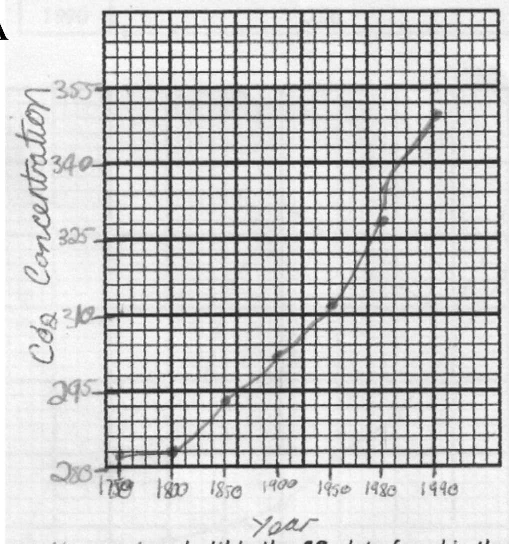


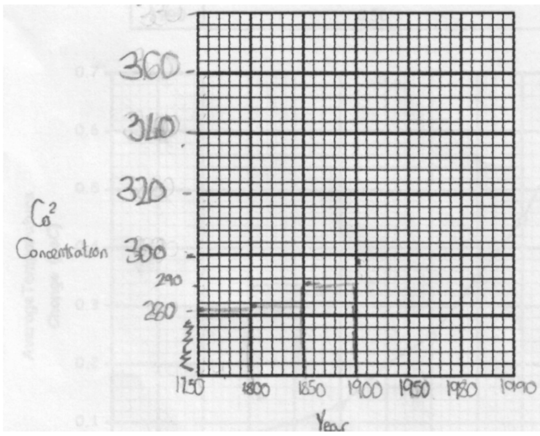
Figure 7.9 shows examples of pupil graphs where there are no axes labels with units. In addition, in Figure 7.9A the x-axis scale is wrong and the pupil has had obvious difficulty scaling the y-axis. The pupil has also attempted to draw a bar chart instead of a line graph. In Figure 7.9B the x-axis is wrong and by default the plot is wrong even after a second attempt. Figure 7.9C shows the pupil adding a data point not in the table by joining the line to zero.

Figure 7.10: *Examples of Pupils' responses to Task 1 on the Analysing-Greenhouse-Gas-Data Worksheet for the Second Round that attained 0 marks.*

A



B



C

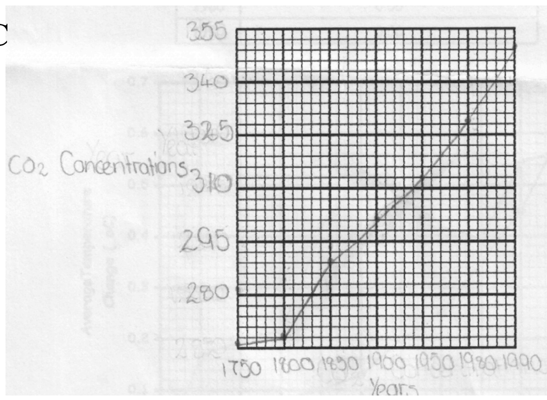


Figure 7.10 Shows three examples from the second round where pupils scored nothing for task one. All three graphs have missing labels with no units and the x-axis scaled incorrectly. Fig 7.10A and C shows an incorrectly plotted lines and Fig. 7.10B shows the pupils attempt to draw a histogram.

Figures 7.11 and 1.12 show that the some pupils from both the first and second round were able to draw the graph from task 1 correctly.

Figure 7.11 *Examples of Pupils' responses to Task 1 on the Analysing-Greenhouse-Gas-Data Worksheet for the First Round that attained 3 marks.*

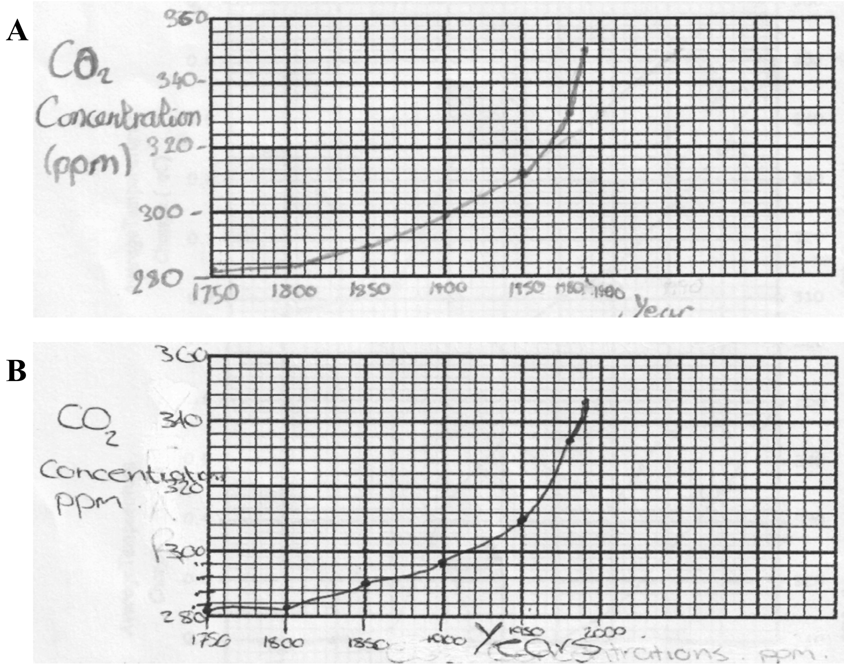


Figure 7.11A and B shows two examples of pupils' responses which score 3 marks in that the labels with units are present, both x- and y-axes are scaled correctly and both graphs are plotted correctly.

Figure 7.12: *Examples of Pupils' responses to Task 1 on the Analysing-Greenhouse-Gas-Data Worksheet for the Second Round that attained 3 marks.*

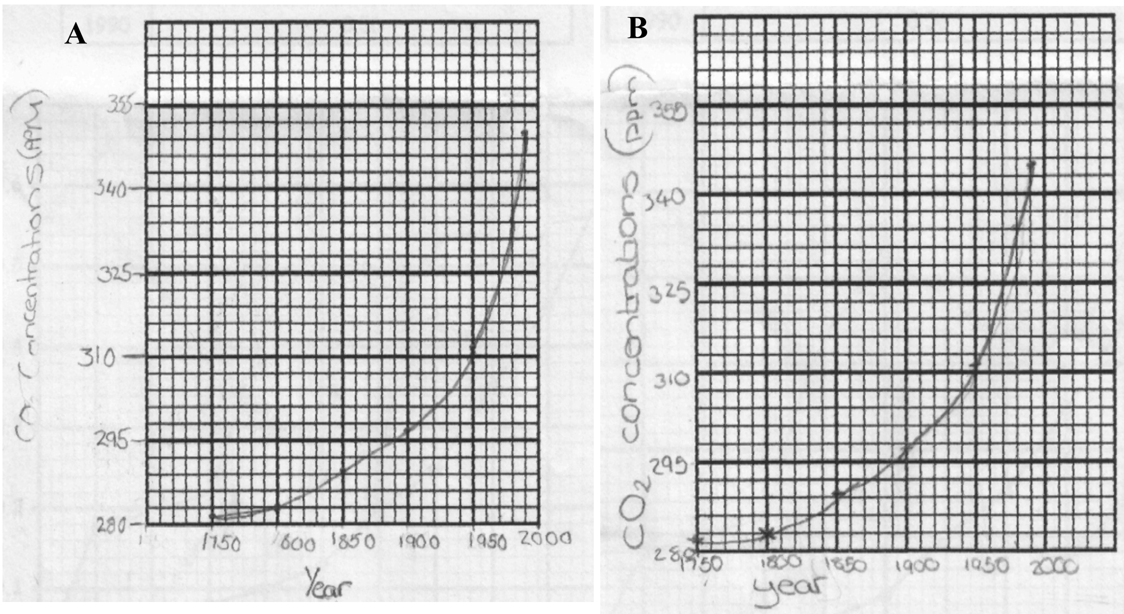
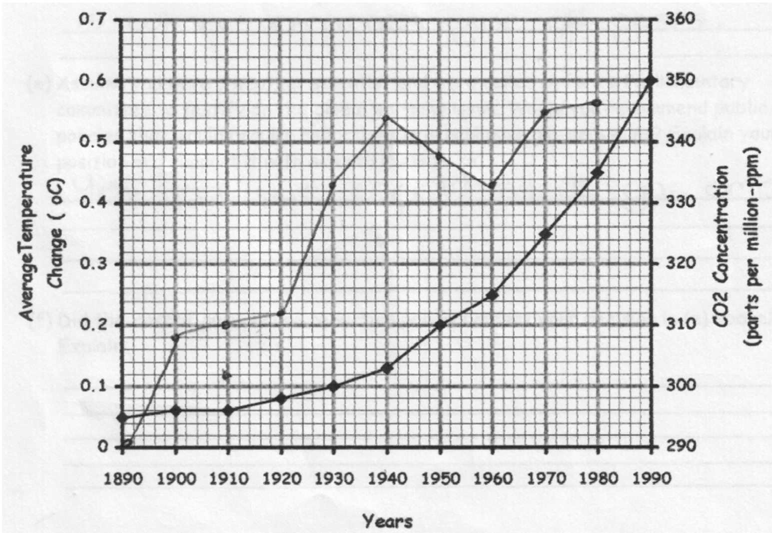


Figure 7.12A and B shows two examples of pupils' responses which score 3 marks from the second round of the action research in that the labels with units are present, both x- and y-axes are scaled correctly and both graphs are plotted correctly.

Interestingly, only 46.1% of the first round S2 cohort could describe the trend shown by the graph in task 1 (Q1a), whereas 78.6% of the second round S2 cohort could. However, when asked in (Q1b) '*During which 50 year period was the trend most pronounced?*', 70.4% of the first round S2 cohort and 71.4% of the second round S2 cohort answered the question correctly. When the pupil responses to task 2 are examined there is a significant difference in ability to attain the mark available. From the first round S2 cohort, 74.4% of the pupils could draw the additional line on to the graph. However, only 51.4% of the second round pupils could complete the task. Figure 7.13 shows two examples of pupils' responses to task 2.

Figure 7.13 *Example of pupil response which attained no marks and 1 mark.*

A



B

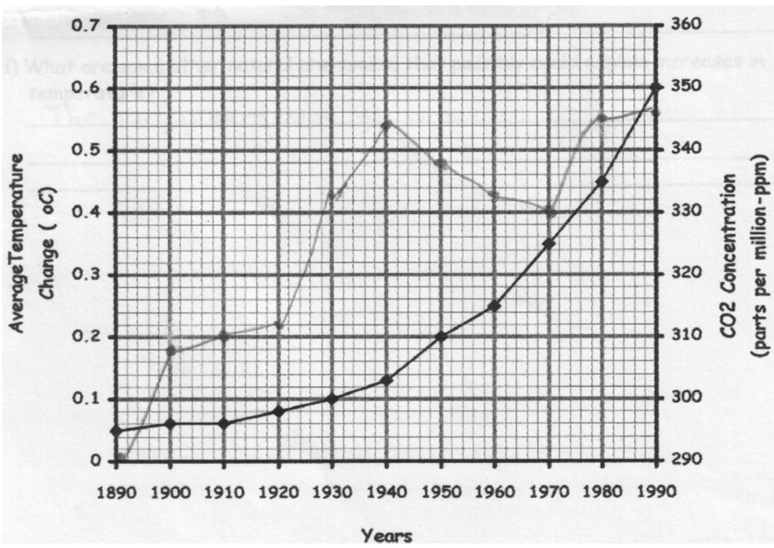


Figure 7.13A shows a graph where the pupil attained no mark as the line was incorrectly plotted. Figure 7.13B shows a graph where the pupil correctly plotted the points and joined up the points with a line.

One possible explanation for the difference in response between the two rounds of the action research to this task is that, in the second round, one class (20 pupils) were told by their teacher to miss out task 2 as she felt it was too difficult for them. This has possibly skewed the results for this task but it does not fully explain the difference.

The required responses to Q2a (*During what time period was the observed temperature increase the greatest?*) and b (*What time period shows the greatest increase in CO_2 concentrations?*) were changed in the second round from a written response to a tick box choice matrix as the teachers felt that this would make these two questions more accessible to the less-able pupils in the S2 cohort. However, when one looks at the difference between the two rounds, 85% of the first round S2 cohort compared to 48.6% of the second round S2 cohort managed to attain the marks for Q2a, with 85.6% of the first round S2 cohort and 52.9% of the second round S2 cohort being able to pick up the mark for Q2b. This result shows that the teachers' perception of what is difficult for the pupils does not match with reality, as more pupils could answer the question in the first round compared to the second round.

The pupils' responses to Q2c show that 42.8% of the first round S2 cohort and 32.9% of the second round S2 cohort could recognise that the data as presented did not support the conclusion that increasing CO_2 gas emissions are responsible for the 0.5ºC increase in observed temperature during the past 110 years. However, only 9.4% of the first round S2 cohort and 12.9% of the second round cohort could give a correct explanation as to why they did not think that the data supports the conclusion. Worryingly, 47% of the first round S2 cohort and 54.3% of the second round S2 cohort thought that the data did support the conclusion. This suggests that the pupils failed to grasp the fact that the data presented to them were in conflict with the conclusion.

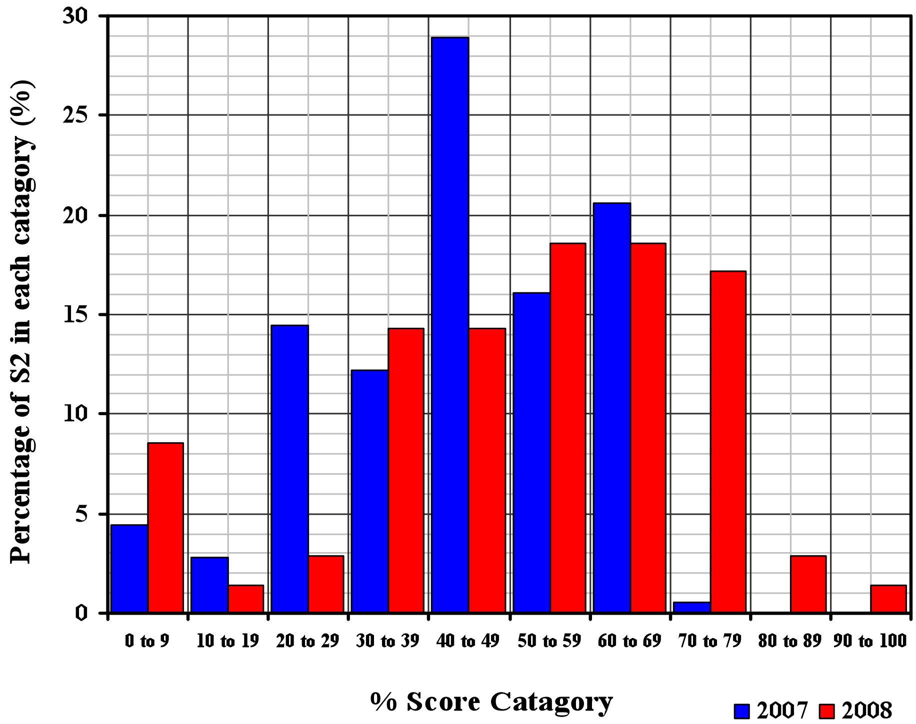
A major concern was that 73.3% of the first round S2 cohort could not answer Q2d (*What are some other natural phenomena that possibly could explain increases in temperature?*). The most obvious answer to this question is increased solar activity.

However, 42.9% of the second round S2 cohort could answer this question correctly. Questions 2e and 2f were dropped from the second round version of the worksheet as only 8.9% of the first round S2 cohort could achieve 1 of the 2 marks available for Q2e and none of the S2 pupils could answer Q2f. When you take into consideration the difference between the worksheet in terms of the questions and correct the scores for this, the comparison of the distribution of pupils in each % score category between the first and second round of the action research changes as shown in Figure 7.14A and B

Figure 7.14A shows the distribution of scores for the analysing-greenhouse-gas-data worksheet for the first (2007) and second round (2008) of the action research. There is a considerable difference in the distribution of scores between the two rounds of research. For example the majority of the first round S2 cohort struggled to get a score above 50% compared to the second round cohort where the majority of the second round S2 cohort attained a score ≥ 50%. However, when the first round S2 cohort scores are corrected to remove the scores for questions 2 (e) and (f), thereby making the two worksheets total marks equal and recalculating the percentage scores, the distribution changes. Figure 7.14B shows the change in distribution of scores for the analysing greenhouse gas data worksheet between the first and second round cohorts. Figure 7.14B shows that in fact the first round S2 cohort fared better than the second round cohort, since 38% of the first round cohort scored ≥ 70% compared to only 22% of the second round cohort attaining ≥ 70%.

Figure 7.14 *Comparison of pupil distribution scores for the analysing-greenhouse-gas-data worksheet between the first and second round of the action research.*

A



B

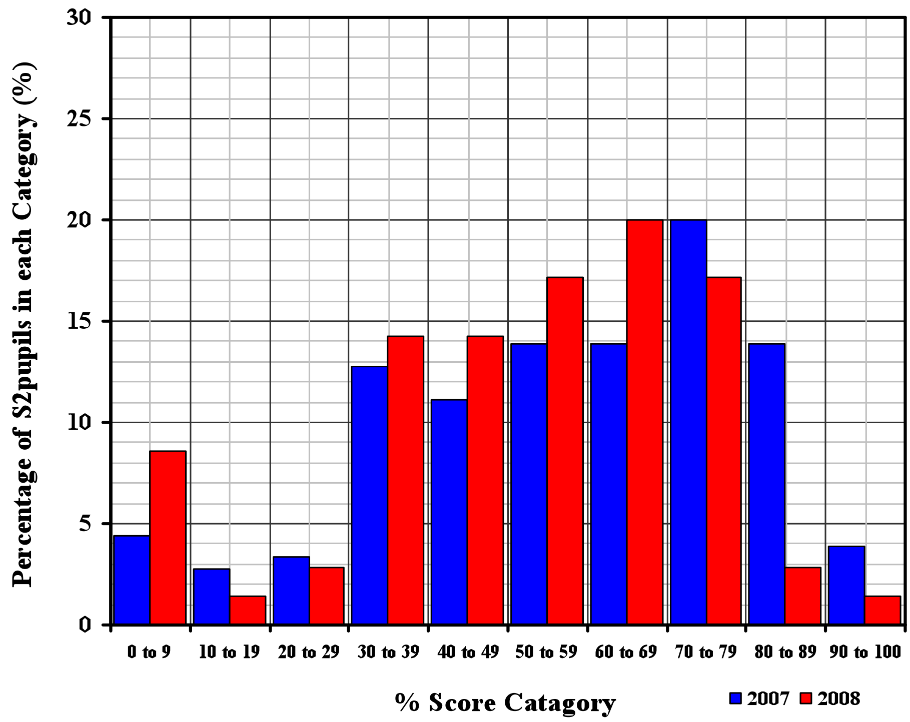


Figure 7.14A shows the distribution of marks for the analysing-greenhouse-gas-data worksheet. Figure 7.14B shows the corrected distribution for the analysing-greenhouse-gas-data worksheet.

7.2.5 Decision-grid from lesson three of the First Round of Action Research.

In the first round of action research, lesson three involved the pupils discussing a proposed Carbon Emissions Bill and two counter proposals. The substance of the choices before the cooperative groups was as follows;

1. A Labour proposed Carbon Emissions Bill would set a carbon charge at £100 per ton, phased in over a period of 10 years, with some of the tax revenues being used for environmental research and environment clean-up operations. To lessen the overall financial burden of the carbon tax, The Carbon Emissions Bill would call for some reductions in social security and income taxes.

2. A Conservative counter proposal suggested that the carbon emissions tax would hurt economic growth and employment. It further suggested that the overall effect of the tax, despite some social security and income tax reductions, would be to reduce people's real incomes. Claiming that this would be especially hard on the poor, it suggested that the Carbon Emissions Bill was too expensive and would force the whole economy away from fossil fuels and, until more is known about greenhouse warming, the best policy option is to do nothing at this time.

3. A Liberal Democrat proposal criticised the economic costs of The Carbon Emissions Bill and proposed a "Global Warming Insurance Policy" Bill, which calls for a £10 per ton carbon tax. The tax revenues would fund significant increases in research funding for the areas of Global warming and greenhouse gas studies as well as for climate change and energy efficiency research.

The cooperative groups were shown how to fill in a decision-grid (shown in Figure 7.15) as a way to help them evaluate the likely impact of each of the proposed policy positions. This was done by explaining to the groups that the heading in each column of the decision grid corresponds to potential outcomes of each policy and that if they saw advantages to the each policy under each of the column headings they could add a **(+),** more than one plus sign indicated that they saw this as strongly positive and likewise if they saw a disadvantage then they could add a **(-),** and again more than one would indicates a strong negative.

Figure 7.15 *An example of a Pupil Decision Grid*

Carbon Tax Scenario Worksheet. Global Warming Lesson 3

Food for Thought

- In this case study the MP's are dealing with an issue that is receiving much attention—Global warming. The issue is whether to impose a "carbon tax" on fossil fuels, such as coal, oil, and natural gas.
- Analyse the arguments put forward by each MP in this case study and use the Decision Worksheet and the Decision Grid to help determine whether such a tax would be a good idea. Be prepared to defend your decision!

Decision Grid

Alternatives	*Reduces CO_2*	*Cost*	*Fairness*	*Economic Growth*	*Promote Energy Efficiency*
The Carbon Emissions Bill	+	−	−	−	+
Do nothing at this time	−	−	−	+	−
Greenhouse Warming Insurance Policy	+	+	+	−	+

1. If you were an MP Which option would you vote for?

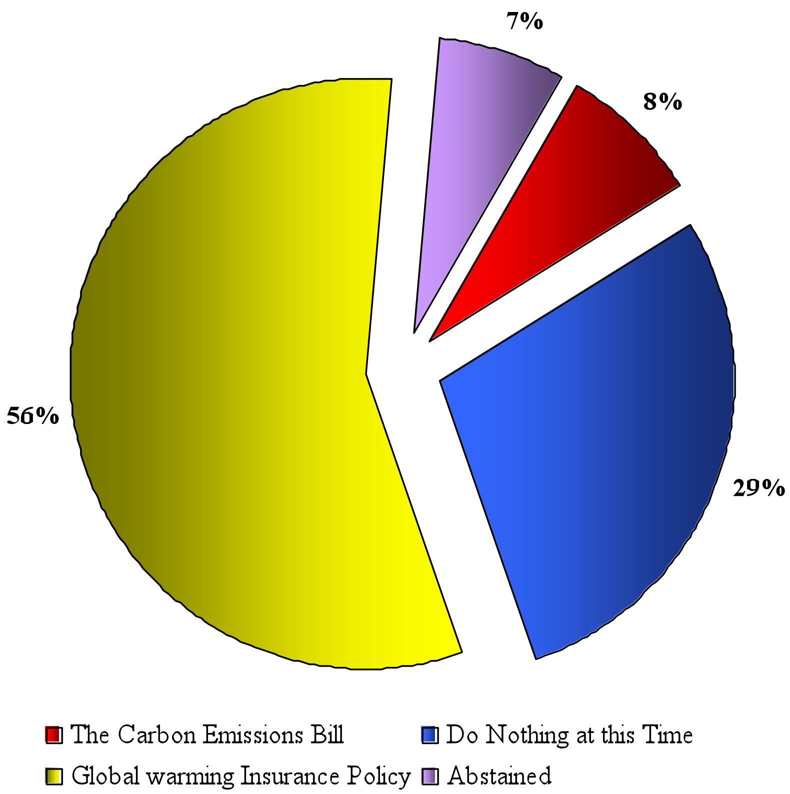
the 'Greenhouse Warming Insurance Policy'

2. Which Policy do you prefer? Explain why you prefer this choice?

'Greenhouse Warming Insurance Policy' because it will help reduce CO2, it will cost us, but it won't cost too much, it is very fair and it will help to promote energy efficiency.

The pupils were then asked to decide which of the three proposals they would choose and why. Afterwards, the pupils went on to have a mock debate once they had the opportunity to ask the teacher some questions that they had about each of the MP statements. At the end of the debate they were asked to vote for which proposal they supported in a secret ballot. The results of this vote are shown in Figure 7.16. It shows that the Liberal Democrat counter proposal was the most popular with 56% of the vote; the Conservative proposal of doing nothing for the moment came second with 29% of the vote; and the Labour proposal came third with only 8% of the vote. Only 7% of the year group abstained from the vote.

Figure 7.16 *Proportion of votes cast in the first round of action research House of Commons debate on a proposed Carbon Emissions Tax.*



Looking closer at the reasons for choosing the Liberal Democrat proposal, most pupils who chose it commented that they did so as it may reduce CO_2 emissions, is less costly than the Carbon Emissions Bill, and it was fair as the money raised would be used to fund more research and help promote energy-efficient behaviours. Those pupils how chose the Conservative proposal, to do nothing for the moment, commented that they did not think that they should pay a tax on carbon when the scientists were not sure if CO_2 caused increased global warming. They did not see why they should pay more money when there are other things that could be causing it such as increased solar activity. They felt that it was unfair to tax people in this way especially if the cost would affect the poor more than the rich. All of the pupils who chose to vote for the Carbon Emissions Bill commented that this tax would radically reduce CO_2 emissions and that this would help to reduce global warming.

What this data suggest is that this S2 cohort was able to come to a democratic decision by weighing up differing and often competing factors such as fairness, cost, economic growth, the promotion of energy efficiency, and reduction of carbon emissions. However, the main factor that influenced their choice was a sense of social justice. This was exhibited in a number of comments in answer to question 2 on the carbon tax Scenario Worksheet. For example, the effect of levying a carbon tax of £100 per ton of carbon emitted was considered by the pupils to be unfair as the poor use the same amount of energy as the rich and they are less able to pay. A number of pupils also commented that the Carbon Emissions Bill would hurt the economy, which could in turn lead to jobs being cut, which would be unfair.

Those pupils who chose to vote for the 'Do nothing at the moment' proposal also commented on the fairness of a carbon tax by suggesting that as the science was unclear as to what was causing the increase in global warming that it was unfair to pay a tax for a waste product that may be found not to be causing the increased global warming. They also suggested that the increase in global warming could be caused by an increase in the solar activity, with one pupil cynically commenting that

> *They will be taxing us for that next.* **S2 pupil from the first round**

It could be argued that the reason why the majority of this S2 cohort voted for the Liberal Democrat proposal was that it was most acceptable in terms of fairness; as it was a relatively low cost proposal as well as being transparent; since the funds raised would be used for further research into the causes of global warning; would be used to fund research in renewable sources of energy and the promotion of energy efficiency; and as such represented a compromise between the two extreme positions. The sense of social justice felt by this pupil group provides a useful first step in preparing the pupils to participate in the democratic process. Social justice or the sense of fairness plays a pivotal role in the thought processes of citizens when deciding how best to come to an informed opinion on an issue such as a carbon tax.

7.3 End-of-topic test for the first and second round of action research.

The end-of-topic test for the first round of action research was constructed to test the pupils' knowledge and understanding of the climate change and global warming topic but also aimed to assess the pupils' ability to write a piece of extended writing on the climate change and global warming issue (See Appendix I). The test contained five questions which tested the pupils' knowledge and understanding and an essay question which assessed the pupils' ability to communicate their understanding of the issue in a written form. This test had a total mark of 27, 7 marks assessing knowledge and understanding and 20 marks for the essay. The distribution of marks from the first round end-of-topic test is shown in Figure 7.17.

Figure 7.17: *Distribution of Marks from the First Round End-of-Topic Test.*

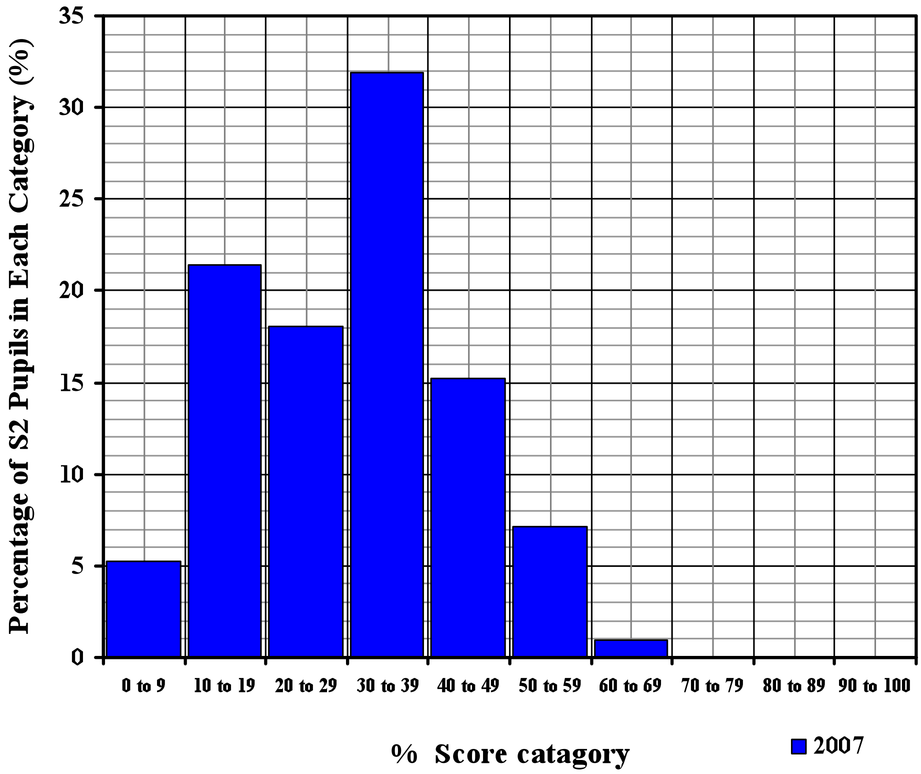


Figure 7.17 shows that the distribution of marks was approximately normally distributed with the largest peak representing 31.9% of the first round S2 cohort in

the 30-39% category. The mean ± standard deviation score for the first round end of topic test was 30% ± 13%, with a maximum score of 63% and a minimum score of 3.7% and a median score of 30%.

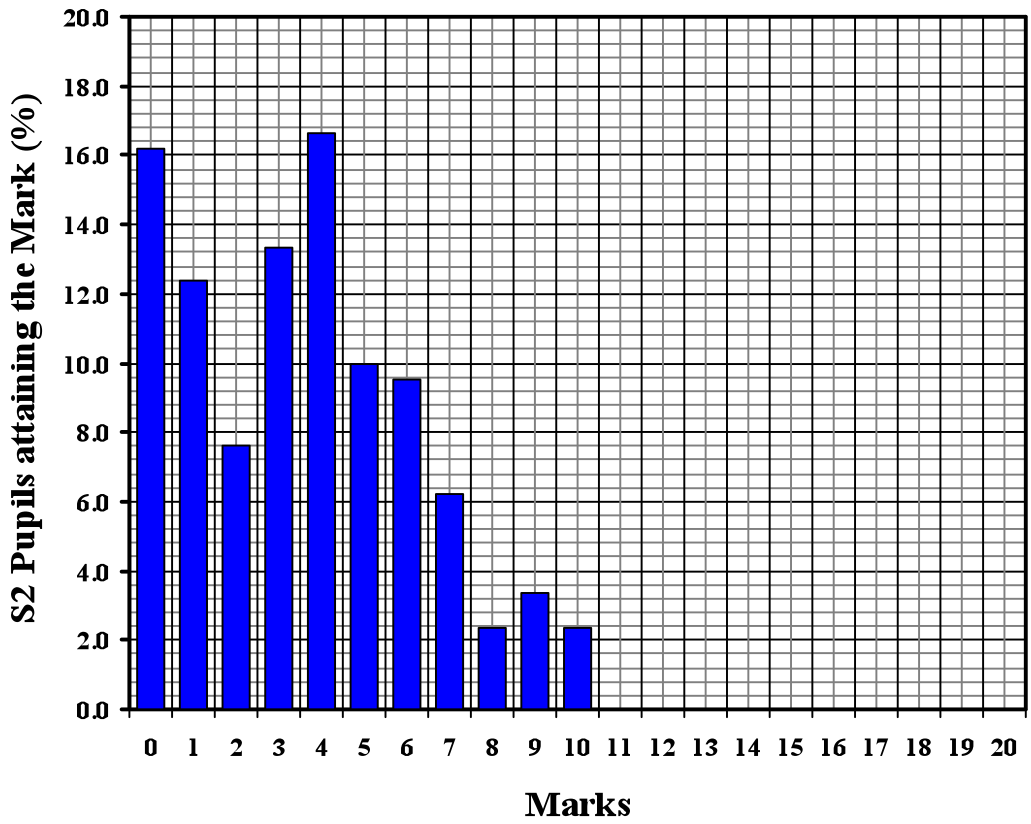
Detailed analysis of the individual test items reveals some interesting statistics. Question 1(a) asked the pupils to interpret a graph and describe how the temperature of the Earth has changed over the last 100 years for one mark. 87.6% of the first round S2 cohort attained the mark with 12.4% of the S2 cohort not able to do so. Question 1(b) asked the pupils to describe two things that can happen as a result of this temperature change. 52.4% attained the two marks available with 27.6% attaining one mark and 12.4% being unable to attain any marks. Question 1(c) asked the pupils to give the scientific name for this temperature change with 83.8% being able to attain the mark but worryingly 16.2% were unable to do so. Question 1d (i) asked the pupils to name two greenhouse gases that cause the temperature change. Only 30.5% of the S2 cohort could attain both marks, with 61% attaining one mark and 8.6% being unable to attain any marks. Question 1d (ii) asked the pupils; Where do these gases come from? Worryingly, only 16.7% of the S2 cohort could attain the mark available, with 83.3% of them being unable to answer the question correctly.

Question 2 asked the pupils to imagine that they were an investigative reporter for *The Herald*. The editor wants them to write an article about greenhouse gases and global warming and the possible impact that this issue will have on the environment and on society. In this question they were given four bullet points to help guide them:

- What are greenhouse gases and what is the greenhouse effect?
- What is the impact of greenhouse gases on global warming?
- What is the effect of global warming on the environment and society?
- What measures could be introduced to reduce the effect of global warming?

This question was designed to allow them to write about what they had learned from the series of lessons on climate change and global warming. Lesson one of the series related to what global warming was and how greenhouse gases affect global warming in theory. Lesson two tackled the issue of cause and effect and how increased CO_2 levels do not fully explain the increases in temperature and lesson three dealt with decision-making about carbon tax. Therefore, each pupil should have been able to write at least a few sentences under each of the bullet points. However, only 2.4% of this S2 cohort was able to attain half marks (10/20) in this task but 16.2% of the first round S2 cohort either did not attempt the essay or, if they did, they did not answer the question at all. Figure 7.18 shows the marks distribution for the essay question in the round one test.

Figure 7.18: *Mark distribution for Question 2 essay question from Round One End-of-Topic Test (2007).*



The mark distribution for this essay question shows that the S2 cohort struggled with this writing task. Worryingly, only 33.8% of the first round S2 cohort could attain five marks or more, with 66.2% attaining less than five marks. Upon further scrutiny, of those who attained zero marks, 10% of the 16.2% did not attempt to write anything, with the remainder writing either very little or a lot of what can be best described as 'waffle' which did not answer the question posed. Figure 7.19 shows an example of one such piece of pupil writing.

Figure 7.19: *Example of a pupil's response to Question 2 to of the First Round End-of-Topic Test that did not answer the question posed scoring 0 marks.*

2. Imagine you are an investigative reporter for The Glasgow Herald. Your editor wants you to write an article about Greenhouse gases and global warming and the possible impact that this issue will have on the environment and on society.

You must write this article using the following questions as a guide

- What are greenhouse gases and what is the greenhouse effect?
- What is the impact of greenhouse gases on global warming?
- What is the effect of global warming on the environment and society?
- What measure could be introduced to reduce the effect of global warming?

Professor Bilko was in his home in Germany when the telephone rang.
"Hello, Professor Bilko is that you?" the man on the other end asked.
"Ja, who is that?" Bilko asked.
But the man ignored him. "I would like you to get yourself on the next plane to America. We have a crisis on our hands and we heard you were the best of the best!" the man told him.
"What crisis?" Bilko asked bewildered.
"Just get yourself to the JFK Airport and sharp - I repeat, we have a crisis on our hands!"
Bilko had not a clue about what the man was talking about but he sounded high up in the military so Bilko thought that he would take the trip to the USA.
"Okay, I'll go!" he said in his German accent.
But the man had put the phone down.
So without any hesitation Bilko packed his clothes and belongings and rushed himself to the airport.
The year was 2075 and not many things had changed. It's not like the normal 2075 that many of you think it was. There were no flying cars or any robots because they all needed extra fuel but there was a shortage and only if you were rich did you have a car as they were very expensive.
Professor Bilko's plane had just touched down in New York.
As soon as he stepped off onto American soil he was rushed away by the army to a secret bunker.
"Okay," a man in an army uniform said, "we need you here Mr Bilko because we heard that you were the best of the best on the subject of global warming! Are you?"
"Ja, I am - why?" Bilko asked, confused.
"Do you not know that in exactly 24 hours the world will

Figure 7.19: *Continued.*

explode because of global warming?" the man asked.
"No, I expected it to be destroyed by the year 3050 but this is a shock!" Bilko answered gobsmacked.
"So now you know - what do you think we should do?"
"Well, the Earth is getting warmer because of the sun so if we move the world away then the world will be cooler and not explode!" Bilko announced.
"My God it's so crazy it's wonderful!" the man exclaimed.
Professor Bilko worked on the machine that would move the world further away from the sun for 18 hours straight then was finished.
"Will it work?" the man asked.
"yes, it should! If I press this button!" the professor told him. He pushed the red button he was holding and the world jerked. The temperature then got cooler and cooler!
"yes, it is working!" the man exclaimed.
But the earth wasn't stopping.
"It's not stopping - I can't get it to stop!" Bilko shouted.
The temperature dropped rapidly then everything froze. Everything on the Earth froze because the earth was too far away from the sun. The world then froze and bumped into the moon and shattered. Then Professor Bilko woke up in his German home.
"Oh, what a dream I had!" he told himself.
The year was 1990 and everything that happened to the world was just a dream.
"At least if that does happen, I will not be around to witness it!"

Admittedly this is an extreme case. However, there were at least another 8 examples which could have illustrated the point. These findings were discussed with the Principal teacher of English and Two Deputy Head Teachers who were former Principal Teachers of English within XHS and they suggested that for the first round essay that:

> *In English we would not expect second year pupils to complete a task like that under exam conditions. This type of task would be given as a piece of course work which would count towards their Standard Grade portfolio.*
>
> **PT English, XHS**

This suggests that this test item placed an unfair demand on the pupils and as such should not have been included in the test. However, the Principal teacher of Chemistry/ S1/2 Science suggested that in her opinion:

> *This type of task should not be beyond this year group. We took part in the Scottish Survey of Achievement in Science in 2007 and we were asked to provide evidence of a piece of extended writing in science, which was marked by the science teacher and cross-marked by an English teacher. What we found was that the science teacher graded the essays on average, one grade level less, sometimes two grades less, than the English teacher who cross-marked them. They were giving a level E to an essay when we gave it a level C. When I asked the English department about this, they said that they did not mark the essay on the correctness of the content, rather they looked at overall structure, spelling, grammar and sentence structure. They said that we may be expecting too much from the pupils, which is daft. If they can't write down their views together with the relevant facts in an accurate and coherent manner, why bother with development of scientific literacy because they won't be able to show their understanding. In science, procedural English is essential.* **PT Chemistry, XHS**

This quote from the PT Chemistry illustrates the gap in expectation between Science teachers and English teachers. The PT Chemistry of XHS alluded to the Scottish Survey of Achievement (SSA) 2007 which focused on Science. The reported finding of the SSA 2007 states:

> As the focus of the SSA 2007 was Science, teachers were asked to submit a functional piece of writing for a given sub-sample of pupils which had been generated through a Science context. The writing could be an extended, complete piece, assessed using the 5-14 national criteria, or a short, continuous piece assessed using a 'best-fit' approach (Scottish Executive Education Department, 2008).

The best-fit approach was developed for assessing writing in the Assessment of Achievement Programme 2003 to address difficulties in applying extended writing criteria to short pieces of writing. The best-fit descriptors at each 5-14 level are allied to the corresponding level of the 5-14 national writing criteria. The guidance for selecting writing document issued to participating schools suggests that there should be no difference in the quality of the writing expected. By using a holistic rather than an analytical approach, the assessor should be able to assign a level which best ‘fits’ a short piece of writing. It may well be that a piece of writing reflects standards contained at a number of levels, but using professional judgement, the teacher decides which level is the best-fit. Teachers opting to use the best-fit approach were advised that pupils should be given ample opportunity to discuss a topic before beginning writing and should be reminded of the criteria which would be used to assess their writing.

The marking criteria for assessing the extended writing part of the SSA 2007 states:

> Read the piece of writing, ideally more than once.
>
> - Do the language and structure meet the conventions of the genre?
> - Does the writing address the purpose of the task?
>
> Once you are satisfied that the writer has addressed the task set, using professional judgement, mentally award the writing a level. Read the description for the appropriate level and decide if the piece of writing fits the description. Emphasis must be placed on the criteria highlighted in **bold**. Because you are using a best-fit approach, the piece of writing might not meet the criteria fully. This is acceptable. If the writing appears to sit equally well at two levels, look for the relative strengths and weaknesses within the writing and decide if the strengths outweigh the weaknesses or vice versa. If in your professional judgement a piece of writing is insufficient to meet the requirements for Level A, record it as an ‘N’.
>
> Level A
> **The writing conveys one or two details which are linked and mostly relevant. Common linking words are used to organise ideas (e.g. and, then).** A capital letter and a full stop are used to mark at least one sentence. Commonly used words are spelt accurately.
>
> Level B
> **The writing conveys a main idea with sufficient information to make the message clear. The information is mostly organised logically.** Common linking words are used to organise ideas into sentences (e.g. and, then, but, so, that) and punctuation is beginning to support what has been written. An increased range of commonly used words is spelt accurately.
>
> Level C
> **The writing conveys a clear sense of ideas that are organised logically in the main without significant omission or repetition.** There is a simple

> conclusion, where appropriate. The punctuation mainly supports what has been written. Less commonly used words are spelt with increasing confidence and accuracy.
>
> Level D
> **Ideas are described in detail and are logically and clearly organised throughout. The writing includes relevant and consistent supporting detail.** There is a simple but effective conclusion, where appropriate. There is some variety in sentence structure and most sentences are punctuated accurately. Most of the words needed for the task are accurately spelt.
>
> Level E (or above)
> **The writing begins to convey discernment. Ideas are logically and clearly organised throughout and are well-linked and supported with appropriate detail.** There is a well developed, effective conclusion. There is appropriate variety in sentence structure and sentences are accurately constructed, linked and punctuated. Spelling is accurate in the main (Scottish Executive Education Department, 2008).

It is clear from the marking criteria for levels D and E that pupils at that level should be able to write their ideas in a detailed and logical manner which should include relevant and consistent supporting detail. The problem faced by science teachers is that they are primarily interested in the accuracy and correctness of the detail rather than the structure, whereas English teachers are primarily interested in the structure and not the accuracy and correctness of the detail.

In the case of XHS, the S2 cohorts in both the first and second rounds of the action research had at least six class periods of discussion on climate change and global warming prior to sitting the end of topic tests, so one would think that the pupils would be well prepared to do a piece of extended writing or a science literacy test on climate change and global warming. However, these results suggest that they were not. It could be argued that since this type of work is not normal practice in science classrooms, the pupils were ill-prepared, since essay writing is not the norm. While it is true to say that essay writing is not the norm in S1 and S2 Science, essay writing is not new to S2 pupils and it could be argued that they should be able to at least attempt the essay.

The first round S2 cohort's inability to complete this essay question under exam conditions was surprising especially considering the level of guidance given. However, upon reflection, one must consider the pupils' experience of such writing tasks across the curriculum, for example in English. It could be argued that they would never be expected to tackle a writing task such as this under exam conditions at this stage in their education. In Standard Grade English, this type of task would be internally assessed and as a result would only be submitted and graded after extensive drafting by the pupil under their teacher's direction. Perhaps therefore it should not be such a surprise that the vast majority of the first round S2 cohort could not achieve success in this task.

Overall, it is interesting to compare the first round of action research end of topic test results with the S2 cohort's average Science percentage scores. Figure 7.20 shows a scatter plot of these results.

Figure 7.20 *First Round of action research (2007) S2 cohort's end-of-topic test scores versus their S2 Science percentage score.*

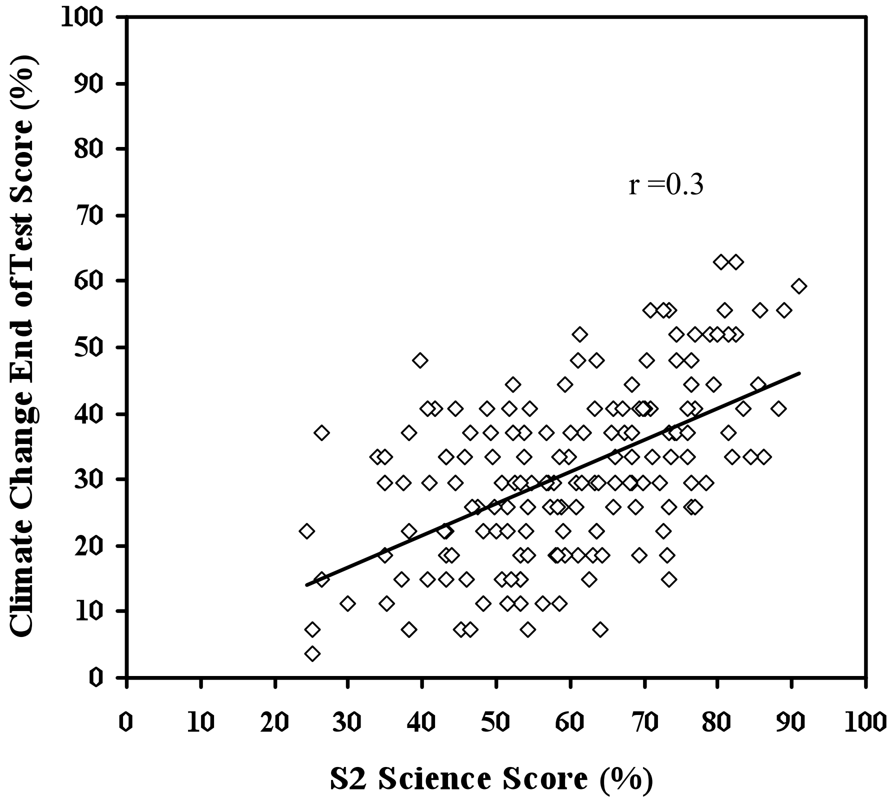


Figure 7.20 shows that there is a positive correlation between the first round of action research S2 cohort's climate change end-of-topic test and their S2 percentage score (Pearson's correlation of r=0.3, which is statistically significant, p<0.01 at 95%

confidence level). However, the data are skewed due to the poor showing in the essay question.

In the second round of action research, the end-of-topic test was significantly changed. Instead of assessing the pupils' writing under exam conditions, the pupils' ability to read for understanding and answer questions on the climate change and global warming topic was assessed differently (See Appendix J). This assessment was a modified version of the global warming science literacy test used in the Scottish Survey of Achievement 2007. The test contained ten questions which assessed pupils' ability to read a passage and summarise it using a cloze summary technique. It also assessed the pupils' knowledge and understanding of the topic as well as their ability to read and interpret data. The total number of marks available was 27, 10 marks for the cloze summary, 11 marks for knowledge and understanding on the topic and 6 marks for problem-solving using data. The distribution of marks from the second round end of topic test is shown in Figure 7.21.

Figure 7.21: *Distribution of Marks from the Second Round climate change end-of-topic test.*

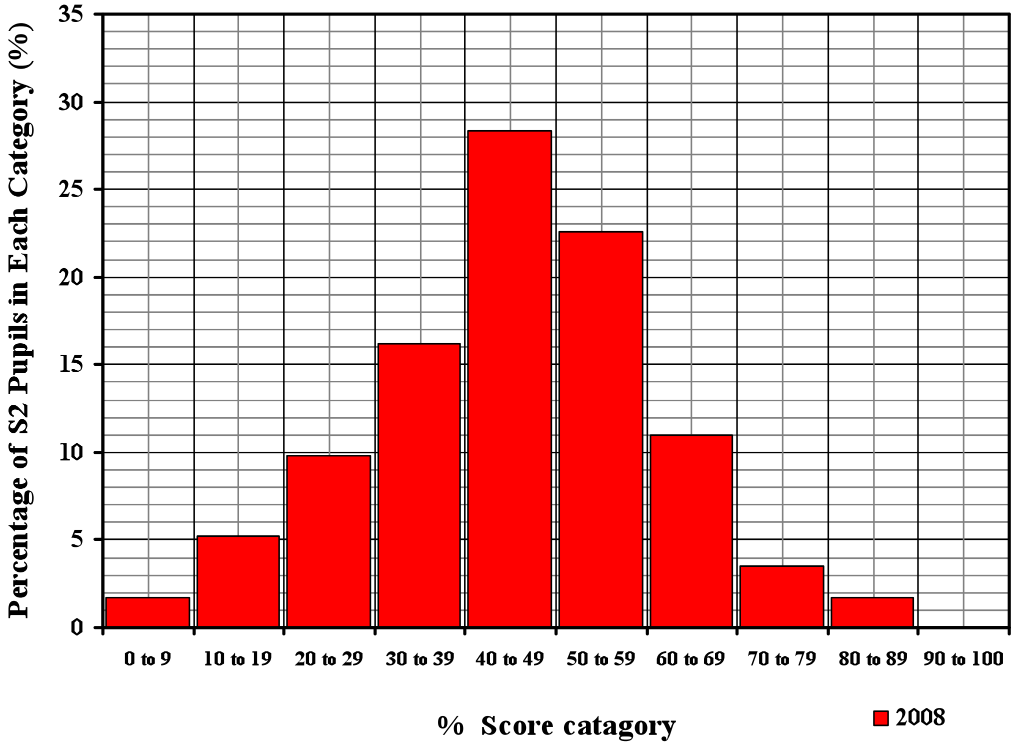
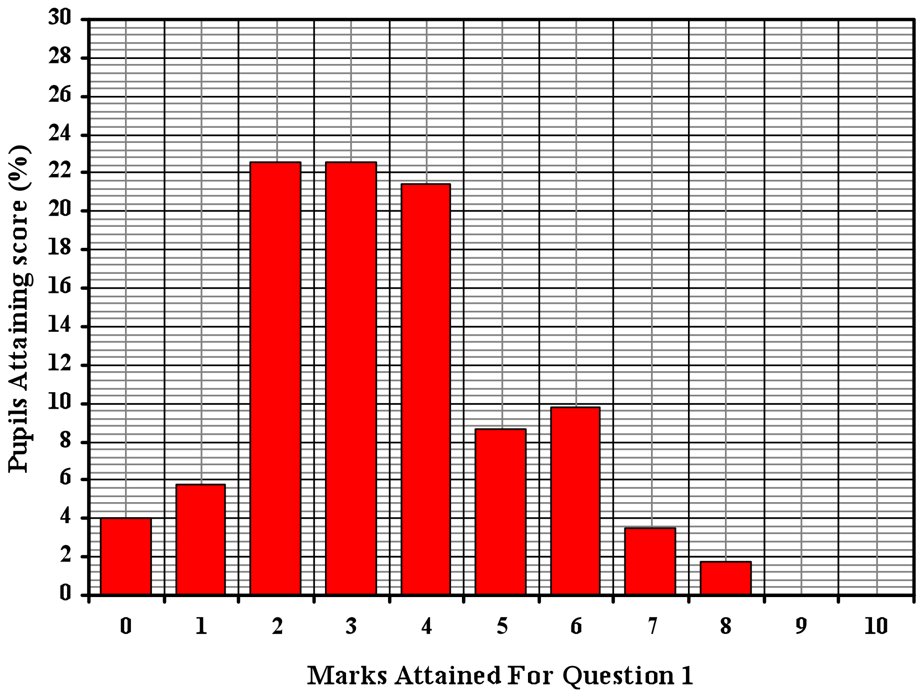


Figure 7.21 shows that the distribution of marks was normal with a peak representing 28.3% of the second round S2 cohort in the 40-49% category. The mean ± standard deviation score for the second round end of topic test was 45.0% ± 16.3%, with a maximum score of 81.5%, a minimum score of 3.7% and a median score of 48.1%.

Detailed analysis of the individual test items yields some interesting results. Question 1 required pupils to read an extract from a report written by the BBC Broadcasting Meteorologist, Helen Willetts, on the issue of global warming and fill in the blanks in a cloze summary of the text. This task assessed the pupils' ability to read for understanding and summarise the text without losing the meaning of the original. The number of marks available for this item was 10 marks, one mark for each blank space. On the whole, this question was poorly attempted by the second round S2 cohort as the mean ± standard deviation score for it was 3.4 ± 1.8 marks. When one looks closely at the distribution of pupils' scores for this question (See Figure 7.22), 73.6% of the second round S2 cohort scored <5 marks for question 1, whereas only 23.7% of the second round S2 cohort attained ≥ 5 marks. None of the S2 cohort scored 9 or 10 marks. The majority (66.4%) of the S2 cohort scored between 2 and 4 marks.

Figure 7.22. *Distribution of Mark for Question 1 of the Second Round climate change end-of-topic test.*



These data show that this S2 cohort struggled to answer this question which suggests that the majority of S2 pupils do not have the ability to read and summarise text without loss of meaning. The data, in conjunction with the findings from question 2 in the first round end-of-topic test, cast a shadow over the S2 pupils' literacy skills.

Even taking into account the fact that this assessment was designed to test the S2 pupils up to 5-14 level F, it was interesting to note that a significant majority of the second round S2 cohort could not attain ≥ 5 marks for question 1. Figure 5.1 and Table 5.1 from Chapter 5 show that 44% and 48.6% of S2 pupils at XHS attained the 5-14 levels E and F in writing and reading respectively. In addition to this, the school context in terms of Standard Grade English should indicate that these S2 pupils are better equipped to cope with literacy items, as both the first and second round S2 pupil cohorts have completed one year of their two year Standard Grade English course by the end of S2. Further, both tests were administered towards the end of S2, therefore these pupils should be ideally suited to attain the marks available.

The data lead one to question: W*hy are these S2 pupils finding writing and reading tasks difficult? Is there an underlining problem with the 5-14 and Standard Grade English courses?* In the judgement of this researcher, the problem may lie in the difference in expectations of science teachers compared to those of English teachers. In addition to this, in terms of 5-14 English reading and writing assessments, the pupils are only ever tested once if they are successful at either level E or F so the reliability of these 5-14 test results is questionable. The data presented here would suggest that they are rather unreliable.

For question 2, 92% of the S2 cohort could identify from the text the correct answer. However, for question 3 only 29% of the S2 cohort could identify from the text why the industrial revolution caused a large increase in the amount of atmospheric carbon dioxide. In question 4, pupils were asked to *give one naturally occurring way that* CO_2 *can get into the atmosphere?* Surprisingly 86% of the S2 cohort could not identify the answer from the text. Question 5 asked the pupils to *give one non-naturally occurring way that* CO_2 *can get into the atmosphere?* Only 27.2% of the S2 cohort could identify the correct answer from the text.

In question 6, the pupils were asked to *explain why CO_2 emissions since the Industrial Revolution are blamed for the increase in global warming, rather than the emission before this*? Only 2.3% of the S2 cohort could correctly answer this question. Question 7 involved the pupils looking at a map and using information from the text to *give two reasons why global warming might cause the sea level to rise.* Only 18.5% of the S2 cohort could give two reasons with 41% being able to give one, but 40.5% of the S2 cohort could not give any reasons.

One could argue that questions 1 to 7 were not assessing science at all but English close reading skill, a skill that is thought to be transferable, which accounts for 63% of the total available marks. What is clear from these data is that the second round S2 cohorts close reading skills were poor in this test.

Question 8 assessed pupils' ability to arrange lettered statements on a diagram to show the effect of increased greenhouse gases in the atmosphere. This question was generally well done in that 44.5% of the S2 cohort could attain all 4 of the marks available with 29.5% being ably to attain 3 marks and 6.9% being able to attain 1 mark with 8.1% being unable to attain any marks.

Question 9(a) asked pupils to draw a conclusion from the data presented in a graph. 61.9% of the S2 cohort could correctly draw the conclusion from the graph. Question 9(b) required the pupil to *using the graph estimate approximately in which year the mass of carbon in the atmosphere reached 6 billion tonnes.* Interestingly only 45.1% of the S2 cohort could attain the available mark. Most worryingly, 67.6% of this S2 cohort could not answer question 9(c) correctly (*estimate the mass of carbon in the atmosphere in 1980*?) when all that was required was for them to simply read the answer off the graph. Question 9(d) asked the pupils: *In the 100 years between 1860 and 1960 the mass of carbon emissions increased approximately 2.5 times. How many years did it take for emissions to become twice that of 1960?* Only 30.1% of the S2 cohort could answer this question correctly.

Question 10 required the pupils to complete a pie-chart using data from a table of results. The total marks available for this item was 2 marks. To get both marks the pupil had to correctly draw in the slices of the pie-chart and correctly label the sections. For this question 68.8% of the S2 cohort could attain 2 marks, with 7.5% attaining 1 mark and 23.7% attaining no marks.

Figure 7.23: *Second Round of action research (2008) S2 cohorts' climate change end-of-topic test scores versus their S2 Science percentage score.*

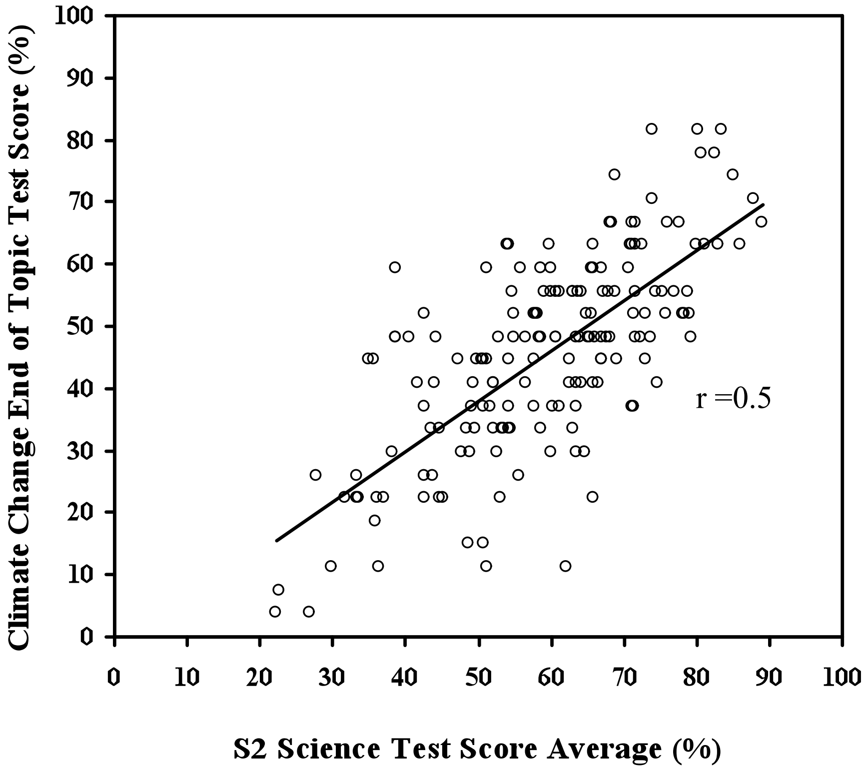


Figure 7.23 shows that there is a positive correlation between the second round of action research S2 cohort's climate change end-of-topic test and their S2 percentage score (Pearson's correlation of r=0.5). The data show that the second round S2 cohort's climate change end-of-topic test has a stronger correlation with their S2 Science test score average when compared to the first round (Pearson's correlation of 0.5 for the second round v 0.29 for the first round). This is despite the difficulties that the second round S2 cohort had with the first question in the test. One aspect of the second round test data which is not obvious from Figure 7.23 is that 41 pupils (19.5%) could attain an S2 science percentage score greater than the cut-off score for entry to a Standard Grade Biology, Chemistry or Physics class but could not score ≥ 50% in the climate change end-of-topic scientific literacy test. This constitutes potentially two whole classes of pupils unable to grasp basic close reading skills. It could be argued that if they were to have completed three or four such assessments,

they would possibly have learned how to complete such assessments more successfully. However close reading made up 63% of the total marks available in the end-of-topic test and this is a transferable skill used across the curriculum and as such is practised regularly, particularly in English, History, Modern Studies and Geography. One might argue that the end-of-topic tests for both the first and second round of the action research give a cross-sectional snapshot of how the S2 pupils are developing at that point in time and that they may get there in the end, given more time to develop in terms of maturity and practice. This leads one to ask how these S2 cohorts faired in their Standard Grade English examination the following year. Figure 7.24 and 7.25 shows the distribution of grades for the first and second round respectively.

Figure 7.24 *First round S2 Cohorts Standard Grade English Grade Distribution from the 2008 Exam diet.*

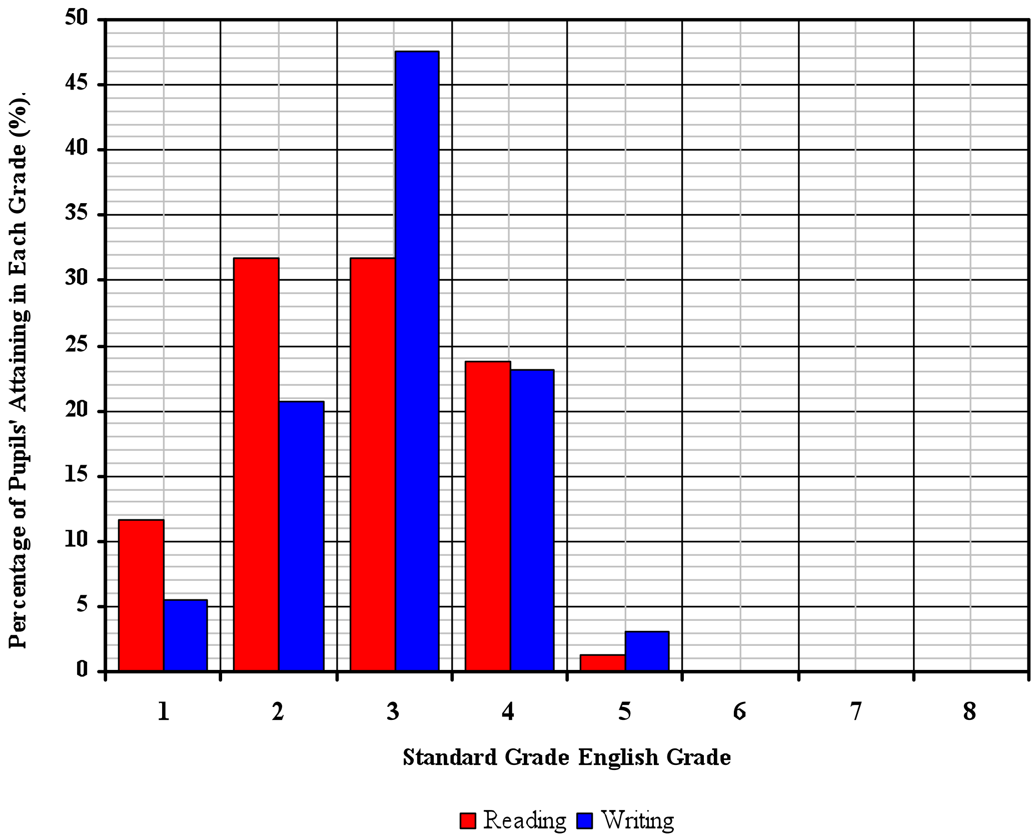
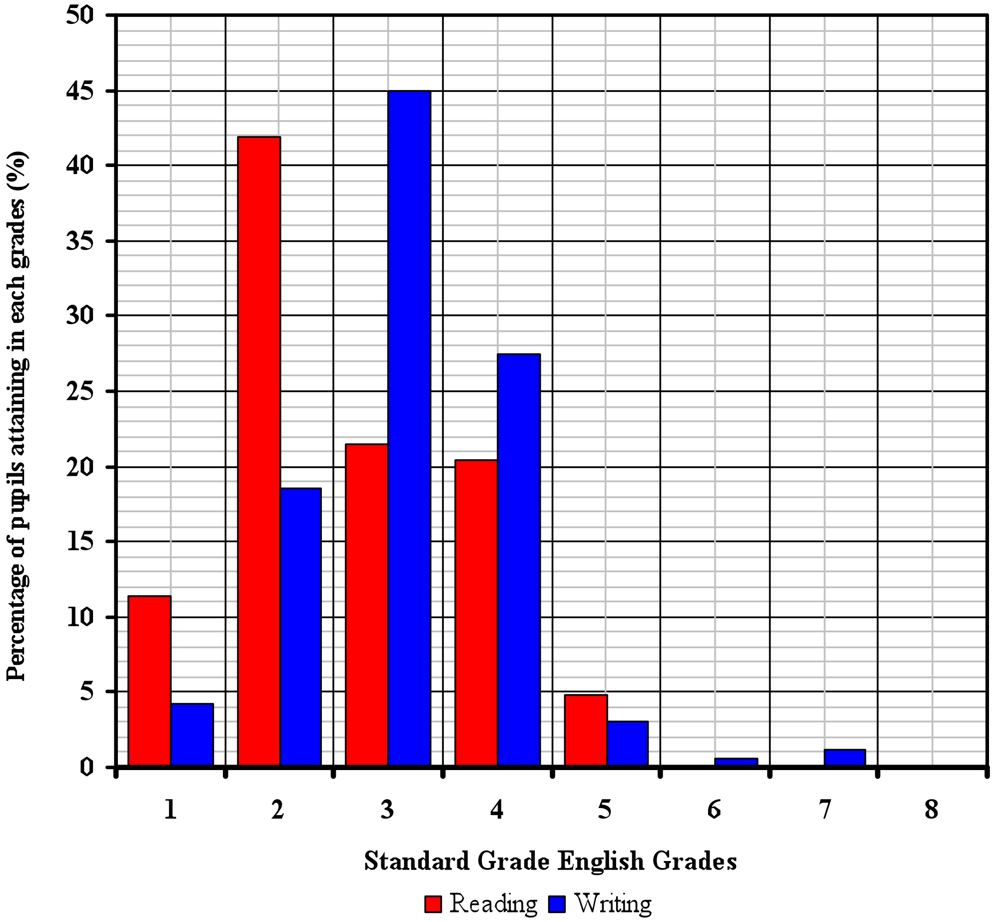


Figure 7.25 *Second round S2 Cohorts Standard Grade English Grade Distribution from the 2009 Exam diet.*



Detailed analysis of the data presented in Figures 7.24 and 7.25 indicates that for the first round S2 cohort, 43.3% attained a Credit grade for Reading with only 26.2% of pupils able to attain a Credit pass for Writing. In addition, 55.5% of the first round pupils attained a General grade for Reading with 70.8% attaining a General grade for Writing. This suggests that the first round S2 cohort were far better at Reading than Writing. This trend continues with the second round cohort where 53.3% of pupils attained a Credit grade for Reading with 41.9% attaining a General grade and 22.8% of pupil gaining a Credit grade for Writing with 72.4% gaining a General grade. These data suggest that these two S2 cohorts are better at Reading than Writing and that the second round cohort had 10% more pupils attaining a Credit grade for Reading than in the first round. Furthermore, these data could be used to suggest that the pupils eventually make up the ground in terms of literacy by the end of Standard Grade. The problem remains with Writing. This is somewhat surprising as the

Writing grade is largely influenced by internal assessment of portfolio work, where the pupils' work goes through the draft, submitted-for-feedback, redraft and then submitted-again learning cycle.

The literacy problem highlighted by the first round end-of-topic test data in terms of Writing seems to only improve marginally. However, the problem of Reading for understanding, highlighted by the second round end-of-topic test data seems to have improved dramatically in terms of the Standard Grade English Reading grade. In the opinion of this researcher, these suggests that in terms of Reading the pupils do get there by the end of Standard Grade but in terms of Writing the problem still remains for most pupils.

7. 4 Summary

A number of issues raised in chapter six were described in detail in this chapter. The ozone misconception shown in KWL grids and graffiti boards over the course of the action research indicated that the pupils struggled to differentiate between the greenhouse effect and the hole in the ozone layer. Several of the pupil poster presentations also illustrated the point that some pupils only have a tentative understanding of the greenhouse effect.

In terms of analysing data, the S2 pupils showed that they have considerable difficulty scaling, labelling and plotting a simple line graph. In addition, the S2 pupils found interpreting the data difficult. This suggests that there is considerable work to be done to ameliorate these issues as the ability to analyse and interpret data is a key element of scientific literacy.

In terms of decision-making, the S2 pupils use a sense of social justice when deciding which option they would chose from three MP proposals on a Carbon Emissions Bill. The pupils' strong sense of social justice was apparent from three perspectives: one looked at the fairness of the proposed bill on the poor; another looked at the fairness of heavily taxing people on the premise that increased Carbon dioxide emissions cause the increase in global warming when the science suggests that it is not the sole or most important driver. The final perspective centred on the unfairness of doing nothing as the consequences affect future generations rather than our own. These perspectives pivoted around the pupils' view on global warming.

The end-of-topic tests from the first and second rounds of action research paint a picture of poor literacy skills in each S2 cohort. Despite the majority of both S2 cohorts being at 5-14 levels E and F for both English reading and writing, both S2 cohorts performed poorly in essay writing and close reading assessments. These findings indicate that the baseline for the development of scientific literacy is low and the first task for the development of scientific literacy ought to begin with using science to underpin Literacy and Numeracy across the curriculum.

Chapter 8. Discussion of the Action Research Findings.

The aim of this research was first to clarify the concept of ‘scientific literacy’ and set it within a framework which science teachers can access by identifying its characteristic components and outlining how these characteristics might be developed in secondary science education. Second, it was to determine pupils’ views on science, particularly in relation to teaching through the discussion of climate change and global warming and to evaluate how pupils’ attitudes to science impact on their engagement with the issues. Third, to outline a working model of cooperative learning which science teachers can use when managing discussion of controversial socio-scientific issues. Fourth, to identify areas of difficulty with the delivery of teaching towards the topical science strand of *CfE*, highlighting potential issues which might arise from the development of materials to be used in discussion within the topical science strand of the new science curriculum.

This chapter discusses the findings from the action research, in the context of the research questions posed, the literature in general and the context of *CfE* in particular. This chapter also offers comment on the implementation of discussion in science teaching practice, with particular reference to the implementation of cooperative learning and teaching through discussion of controversial socio-scientific issues intended to promote scientific literacy.

8.1 Research question 1.

What is ‘scientific literacy’ and what are the characteristic elements which define it as a concept which can be developed within secondary school science education?

The development of pupils as scientifically literate citizens is seen internationally as a major aim of science education. Indeed the term ‘scientific literacy’ has been used to describe an aim of science education and to act as an educational slogan under whose banner educational reformers flock. In this regard, the current educational reforms in Scotland under the auspices of *CfE* do not differ from other reform movements across Europe and North America. Closer examination of the literature from an historical perspective, suggests that agreement as to the definition of the term is elusive. However, two influential organisations, the American Association for the Advancement of Science (AAAS) and the European Union's Organisation for Economic Co-operation and Development (OECD) have suggested that scientific literacy is a multi-faceted construct which includes individuals being aware of the scientific knowledge required to answer questions with a science dimension; to acquire new knowledge; to explain scientific phenomena; and to be able to draw evidence-based conclusions. They further suggest that scientific literacy also requires an appreciation of the key feature of science as a form of human knowledge and enquiry; an awareness of how science and technology shape the material, intellectual and cultural environment; and includes a willingness on the part of the citizen to engage with science-related issues in a reflective manner (OECD, 2006; Rutherford et al., 1990). While these descriptions are helpful in so far as they provide a skeletal framework from which teachers can build, they do not offer many practical clues as to how they are to develop such awareness and appreciation of science.

What the characteristic elements of scientific literacy are in relation to the development of scientifically literate citizens is complex and varies depending on the particular philosophical position one takes when arguing one's case. In Chapter two, this researcher, building on work done by Kemp (2000), closely analysed twenty-four papers from which thirteen characteristic elements emerge as important elements of scientific literacy. These elements being: (1) Intellectual Independence; (2) Science Communication; (3) Science and Society; (4) Conceptual Knowledge; (5) Science in everyday life; (6) Science Appreciation; (7) Ethics of Science; (8) Science and Technology; (9) Nature of Science; (10) History of Science; (11) Science in the Humanities; (12) Science Skills; and (13) Science and Mathematics.

The relative importance of each element across these papers varied. For example, when ranked in order of whether an element is mentioned (see Table 2.2) all of the surveyed papers viewed conceptual knowledge as important, with 88% of the papers mentioning science and society, and 77% mentioning science and technology and science in everyday life as important. Somewhat surprisingly, only 63% mentioned intellectual independence as important, with the ethics of science being mentioned by only 42% of the papers. One may be forgiven for thinking that the basics, such as literacy and numeracy, are not seen as important since few of the surveyed papers make specific mention of either of these elements. Literacy and numeracy are essential elements of general education and as such it is this researcher's opinion that both of these elements are generally taken for granted by these authors. Hence they do not mention them specifically.

In terms of developing pupils' scientific literacy, a number of these papers suggest that scientific literacy as a conceptual construct can be broken down into different levels. For example, Bybee (1997) suggests that scientific literacy can be broken into four developmental levels; (1) *nominal*; (2) *functional*; (3) *conceptual and procedural*; and (4) *multidimensiona*l scientific literacy, with each of these levels providing a developmental progression which takes into account pupils' stages of cognitive development, motivation, interest and attitude. In teaching terms, any construct which accounts for these often-difficult outcomes is helpful as most Scottish science teachers would recognise that there is a high degree of variation in pupil ability, motivation, interest and attitude towards learning science in any given S1 or S2 Science class.

The question of how best to develop scientific literacy depends on which level of scientific literacy the majority of pupils would be expected to reach by the end of their compulsory science education. Using the research presented in chapter two, it is possible to argue that the development of scientific literacy can be met through a combination of more traditional pedagogy which deals with the acquisition of content knowledge and practice in the process of science through carefully constructed practical (experimental) work, since content knowledge was identified as a feature in all of the papers analysed; and the use of newer pedagogies, for example, cooperative learning or problem-based learning which may be used to promote more open forms of discussion (with the discussion of controversial socio-scientific issues being suggested as particularly useful for the development of scientific literacy, since such discussions help pupils to appreciate the nature of science (Abd-El-Khalick F & Lederman N.G, 2000), the limitations of science (Kolsto et al., 2006), uncertainty and risk (Colucci-Gray, Camino, Barbiero, & Gray, 2006) as well as the multiple perspectives from which the advances made by contemporary science can be viewed).

A number of science educators (Bryce et al., 2004; Jenkins, 1990; Kolsto et al., 2006; Levinson, 2006a; Levinson, 2006b; Levinson, 2003; Levinson et al., 2001; Millar et al., 1998; Sadler, 2004b; Sadler, 2004a; Sadler et al., 2007; Sadler et al., 2004; Sadler et al., 2005b; Sadler et al., 2005a; Zeidler et al., 2003) have argued for the inclusion of socio-scientific discussion in modern science curricula since they provide teachers with a way to develop pupils appreciation for the role that science plays in contemporary society. In addition, some suggest that these discussions also allow pupils to practise the social and communicative skills required for participation in the democratic process (Kolsto, 2001; Sadler et al., 2007).

The question as to which characteristic elements of scientific literacy could be developed directly by science teachers is not addressed specifically by the literature. However, the literature does imply that there are basic skills which can be nurtured and developed by the science teacher e.g. the acquisition of content knowledge and understanding; an appreciation of data handling and analysis techniques; an awareness of multiple interpretations of data; an understanding of key concepts such as reliability, validity, accuracy and precision in relation to experimental design; the ability to communicate in an oral and written form one's thoughts and opinions on scientific issues; and through a combination of all of these, the ability to make evidence-based decisions in a thoughtful and considered manner.

How science teachers deliver lessons which aid the development of these elements and at which stage of education each element should be taught, are as yet unanswered by the literature. It is important to recognise that cognitive psychology suggests that most of the elements of scientific literacy require a sophisticated level of cognitive development to have occurred before teachers can introduce some of these elements to pupils. It is this researcher's view that a prerequisite for the development of scientific literacy must be that a pupil should have more than just a basic grasp of literacy and numeracy, since accessing the materials and knowledge requires the pupil to read a lot of information from many sources; evaluate that information for bias; interpret the validity of the information; and make decisions about questions posed by that information. It can be argued that these are high order cognitive skills especially when coupled with numerical and graphical analysis of data. That is not to imply that science cannot be used to develop literacy and numeracy, rather the development of scientific literacy as defined by the acquisition of these elements of scientific literacy should only occur when the basic literacy and numeracy skills of the pupil are sufficient for them to grasp the concepts that they would be exposed to during such lessons in a *meaningful* manner.

If one accepts this proposition, then Science teachers need to design learning experiences which foster the development of literacy and numeracy skills which are linked to the elements of scientific literacy. Teaching these elements of general education in science will provide pupils with a meaningful context through which they might see the relevance of such skills to their everyday lives and help them to appreciate the relevance of the science knowledge that are taught. This in turn would allow Science teachers to construct more meaningful and eventually, more complex, discussions through which pupils can develop their scientific understanding and their communication, listening and social skills.

It is this researcher's contention that the acquisition of scientific literacy ought to be seen as a developmental process which encompasses different levels depending on the cognitive ability of the pupils and is highly dependent on a strong foundation of literacy and numeracy. In terms of how the development of pupils' scientific literacy fits into the structure of the education system as a whole, one must look towards how the new Science curriculum fits into the post-*CfE* curricular structure. Table 8.1 outlines how the progression in level of scientific literacy would marry up with the age and stage levels of the *CfE* structure.

Table 8.1 *How the levels of scientific literacy fit into the Scottish Education System.*

Scientific Literacy Level	*CfE* Level	Stage of Education	Age Range
Nominal	Early	Nursery	3-5
		Primary P1	4-5
	First	P2	5-6
		P3	6-7
		P4	7-8
	Second	P5	8-9
		P6	9-10
		P7	10-11
	Third	Secondary S1	11-12
Functional		S2	12-13
	Fourth	S3	13-14
	Senior	S4	14-16
		S5	15-17
		S6	17-18
Conceptual/ Procedural		College/ University	18+

How one defines nominal, functional and conceptual/procedural scientific literacy is open to debate. However, one could suggest that from a Piagetian perspective nominal scientific literacy might begin with the acquisition of vocabulary and basic literacy and numeracy skills, with progression through the nominal stage being linked to pupils' development through the pre-operational; concrete and formal operational stages of cognitive development. Thus at a basic level, nominal scientific literacy is about the acquisition of a basic scientific vocabulary i.e. words and meanings; numeracy skills related to simple data manipulation and interpretation; literacy skill related to the reading and understanding of simple science-related texts and a basic understanding of science as a way of questioning and testing ideas about the natural world. Nominal scientific literacy would provide a staged progression from the more concrete towards the abstract, with primary school science providing a means through which basic scientific vocabulary might be assimilated and where the simple reasoning skills of science could be introduced. Within nominal scientific literacy, the development of basic thinking skills derived from simple observations and practical problem-solving within the science context would provide an outlet for the development of pupils as *effective contributors* and *confident individuals* due in part to their growing confidence in their own ability to think for themselves and, in the main, to their conceptual understanding of how they can contribute to their own and others' learning.

One could further argue that pupil development through the nominal scientific literacy level would allow secondary science teachers the opportunity to manage the transition from primary to secondary science in a more flexible and sensitive manner by building on the pupil's prior experience rather than knowledge, as an assumption that topic content has been covered in primary school (from prior experience of 5-14 science) often leads to gaps in the content knowledge of the pupil due to a lack of topic coverage in primary. In addition, moving nominal scientific literacy away from a topic-basis, to a reasoning skills-basis would allow primary and secondary Science teachers the opportunity to assess the pupil's ability in a more holistic manner, based on what they 'can do' rather than on what they 'cannot'.

At the interface between nominal and functional scientific literacy, the more able pupils could be given cognitively more difficult tasks with lesser able pupils being given differentiated materials based on similar content but with simpler outcomes (providing differentiation).

Functional scientific literacy has been viewed by different commentators in different ways. For example, Ryder (2001) has characterised functional scientific literacy as a person's ability to *understand* the subject matter; the process of collecting and evaluating data; how data is interpreted; how modelling is used in science; the place of uncertainty in science; and how science is communicated in the public domain. On the other hand, Bybee (1997) suggests that functional scientific literacy "entails a person being able to *demonstrate* a functional level of literacy, respond adequately and appropriately to vocabulary… they can read and write passages with simple scientific vocabulary… They may also associate vocabulary with larger conceptual schemes… but have a token understanding of these associations" (p.84-85). The emphasis of *understanding* and the ability to *demonstrate,* which these two commentators place on functional scientific literacy is important as they imply that functional scientific literacy is an active stage, requiring the individual pupil to take action and by implication responsibility for their own learning.

One might argue that the distinction between nominal and functional scientific literacy is that in the nominal stage, the pupils acquires the basic skills required to *understand* the subject matter, whereas in the functional stage, the pupils uses and further develops those skills to *demonstrate* their understanding of the scientific knowledge, but more importantly how the science perspective interacts with, and at times influences, other perspectives such as the moral, ethical, economic, environmental and political. It is this researcher's view that discussion of controversial socio-scientific issues provides the stimulus for development within the functional scientific literacy stage. An ancillary effect of such discussion is that pupils would be able to model decision-making processes and perhaps appreciate the difficulties experienced when decisions have to be taken in the absence of adequate evidence thereby practising participation in the democratic process. While it is perfectly reasonable to suggest that useful socio-scientific discussion is possible in the nominal stage, one might suggest that the complexity of such discussion would be tempered by the cognitive ability of the pupils and as such would be rudimentary by comparison to comparable discussions in the functional stage.

Zeidler and Keefer (2003) suggest that through discussion of socio-scientific issues, functional scientific literacy becomes both *process* and *product* through social interactions and discourse. During such discussion there is a correspondence between trans-active discussions (the extent to which one's thinking influences that of others) and the dissonance that one may experience when evidence is confronted that does not immediately fit into one's prior experiences. They claim that trans-active discussions evolve from naïve perspectives of egocentric thinking to mutually shaped understanding of social and physical phenomena (Zeidler et al., 2003). Thus, engagement in discussion of socio-scientific issues provides a stimulus for the development of pupils' thinking as many pupils may approach such discussion from different perspectives and with a less than 'open mind'. They also suggest that the choices made by pupils are often formed early in the decision-making process and, as with scientific misconceptions, become quickly fixed and resistant to change when new evidence is presented.

One may argue that when pupils engage in socio-scientific discussion, they are displaying varying degrees of scientific literacy and by engaging, they are cultivating a positive scepticism in relation to the ontological status of scientific knowledge as well as developing an appreciation of the cultural factors that guide the decision-making process so that they realise that their decisions do not occur in isolation (Zeidler & Lewis, 2003).

When structuring lessons designed to aid this developmental process, science teachers are helping pupils to recognise that these decisions involve consequences at both the personal and societal level. In addition, they must provide pupils with intellectual challenge, encouraging them to question both their own opinions and those of others, in the light of new evidence and alternative views. Disequilibrium plays a pivotal role in the functional stage, between the knowledge, perspective and the opinions currently held by the pupils and the new knowledge being presented whereby they may, if sufficiently persuaded by the evidence, *assimilate* the new data into their schema or *accommodate* them. If the evidence is sufficiently persuasive, it may even force the pupils to construct a new schema and dismantle the old. It is through the process of intellectual challenge and disequilibrium that the pupils' reasoning skills are developed but it is through the social interaction between the teacher and the pupil, as well as between the pupil and their peers, that this process thrives. It is the act of discussion of controversial socio-scientific issues which differentiates functional scientific literacy from nominal.

As pupils progress through the functional stage of scientific literacy towards the conceptual/procedural stage, the complexity of the discussion that pupils are capable of holding increases, one might argue, as the areas of reasonable agreement between the different perspectives which impinge on the issue decreases. If this is the case, then movement from functional to conceptual/procedural scientific literacy may only ever be possible for those with maturity, open-mindedness and a willingness to listen to perspectives and opinions which may directly be in conflict with their own.

It is for this reason that the interface between functional scientific literacy and the conceptual/procedural stage is more semi-permeable, than a true boundary since some individuals may possess the attributes of maturity, open-mindedness and a willingness to listen to views on one issue but not another. For example, one may be working at the conceptual procedural stage of scientific literacy when discussing the issue of climate change and global warming, but be less than willing to listen, let alone engage, in an open manner to views and arguments about the use of embryonic stem cells, or the debate between evolution and creation.

It is this researcher's view that the best level of scientific literacy that one might expect to develop by the end of compulsory science education is functional scientific literacy. One might speculate that it would be reasonable to expect the majority of 16 year old pupils to reach the functional scientific literacy stage with a few (possibly the top 5%) reaching the conceptual/procedural level with a larger minority possibly (10 to 15%) only reaching the boundary of nominal to functional scientific literacy.

It is this researcher's considered opinion that scientific literacy for all is a laudable goal which as Shamos (1995) suggests, may be impossible to achieve.

8.2 Research question 2.

What conceptual models of discussion do Science teachers hold and do they differ from those held by Humanities teachers?

The data presented in Chapter 4 provide an insight into teachers' thinking about classroom discussion. As a field of research, teachers' conceptual models of discussion and factors that may influence their use of it has received relatively little attention, particularly in Scotland. The theoretical models presented in this thesis help to fill this gap. What the data show is that Scottish teachers hold complex conceptual models of discussion. This complexity may partly explain why they use the term discussion as an umbrella term to describe most interactions between teacher and pupil (Bridges, 1979; Cazden, 1988; Dillon, 1994; Dillon, 1984). These data show that teachers put considerable thought into how they interact with their pupils. They also indicate that teachers differentiate between different models of discussion, with each model having different characteristics elements and purposes depending on the teachers' objectives for the lesson being taught.

The five conceptual models of discussion outlined in Chapter 4 were generated from a sample of teachers drawn from subject disciplines ranging across the curriculum (Biology, Chemistry, Physics, English, History, Geography and Religious and Moral Education) but experienced and newly qualified science teacher views were a particular focus of this study (as science teachers do not use discussion regularly within their practice). Recent research suggests that science teachers feel uncomfortable discussing matters such as controversial socio-scientific issues (Bryce et al., 2004; Gray et al., 2006), and when they do use discussion in their lessons, it has been shown to be teacher-dominated, of poor quality and limited in duration (Osborne et al., 2002).

It is encouraging to note that this group of teachers did not see recitation or more specifically *Initiation, Response and Feedback* discourse as discussion. This is in contrast to the findings of Larson (2000), who found that American Social Science teachers saw recitation as a viable type of discussion. The recitative-style of classroom discourse has been described as the pedagogical opposite of discussion, in terms of it purposes and intended outcomes (Bridges, 1987; Bridges, 1979; Dillon, 1990; Dillon, 1994; Dillon, 1984; Henning, 2008).

How teachers choose which model to use depends on the context, aims and learning objectives of the lesson. How these interact is important, as they form a developmental pathway which becomes increasingly complex in terms of the teaching skills required to manage them and the confidence required by both the teacher and the pupils in fulfilling their respective roles. The classroom norms of each teacher impact on the classroom culture experienced by pupils. Therefore, if the teachers' normal classroom practise is autocratic and closed in terms of the dominant discourse, shifting from that norm towards a less autocratic, more open discourse could be difficult.

Osborne *et al* (2002) suggests that the normal daily practice of the science teacher does not provide many opportunities for the kind of interpretive and open discussion that the English teacher or History teacher might encourage. This suggests that English and History teachers, because of the nature of their subject, use discussion more and may possibly be better at it. Furthermore, Levinson (2001) has suggested that controversial issues in science might best be taught by Humanities teachers.

To date, no studies have been conducted which answer the question of whether Science teachers hold a poor conceptual understanding of discussion when compared to those held by their Humanities colleagues. What these data show is that science teachers hold equally complex conceptual models of discussion when compared to their Humanities colleagues. However, there are differences in emphasis between experienced Science teachers, newly qualified Science teachers and experienced Humanities teachers as to the purpose of it. When compared to experienced Science teachers, fewer newly qualified Science teachers mention that discussion is useful for the development of social skills, confidence, communication skills, exposure to multiple perspectives and the assessment of knowledge. However, more newly qualified Science teachers mention that discussion helps to develop thinking skills.

When compared to experienced Humanities teachers, experienced Science teachers mention discussion for the development of social skills, confidence and communication skills more frequently. However, all of the humanities teachers mentioned that discussion is used for the development of thinking skills with more saying that it helps expose pupils to multiple perspectives useful to the formation of personal opinions than did experienced Science teachers.

These differences suggest that Science teachers' emphasis when using discussion is centred on the development of social skills, communication skills and listening skills (*discussion as an outcome*). To achieve this they would tend to use the conceptual levels; discussion as teacher mediated discourse; and for the practice of democratic citizenship, whereas Humanities teachers' emphasis is centred on the development of reasoning skills, exposure of pupils to multiple perspectives for the development of personal opinion. They operate at the conceptual level of discussion: as open-ended inquiry and for the development of reasoning skills (*discussion as a method of instruction*). In general, this group of teachers see discussion as both a learning outcome to be practised and as a teaching method for transfer of curricular content knowledge. However, Science teachers tend to see discussion more as an outcome to be practised whereas Humanities teachers see discussion more as a teaching method for transfer of curricular content knowledge.

Science teachers interviewed in this study claim that they would be comfortable discussing controversial socio-scientific issues which, on the face of it, seems to contradict recent research findings (Bryce & Gray, 2004; Gray & Bryce, 2006; Levinson et al., 2001) that Science teachers are uncomfortable leading such discussions. However, the reported comfort level of the Science teachers in this study was conditional, with the main conditions being the level of knowledge and understanding of the teacher (as well as the personal interest of the teacher) in relation to the issue being discussed. This indicates that these Science teachers are far less comfortable than they report. A number of Science teachers also commented that there were issues that they would not discuss for personal reasons, with one teacher suggesting that he would avoid discussions that put him outside his 'comfort zone'.

It could be argued that Science teachers are used to dominating the classroom discourse through their input and control of the content knowledge being transferred during lessons. A number of Science teachers reported that they would prepare extensively so that they knew the relevant facts required for discussion of socio-scientific issues prior to delivery of these lessons. This could be viewed that, for these Science teachers, it is important that they know more about an issue or topic than the pupil. One might further argue that the status of the Science teacher as an authoritative and knowledgeable figure within the classroom discourse shapes the Science teacher's feeling of comfort. It is this loss of comfort and, by extension, control of the classroom discourse which one may speculate leads to Science teachers' neglect of discussion within their practice. One may further speculate that this loss of comfort and control of the classroom discourse might potentially make them fearful of a loss in control of class discipline.

However, Humanities teachers are less fearful of a loss of control of the classroom discourse. The data from Chapter 4 indicates that Humanities teachers are happy to allow pupils to take control of the discourse. Relinquishing control of the discourse does not imply a loss of control of the class discipline. Humanities teachers see a clear distinction between who dominates the classroom discourse and who is in control of the class. It could be argued that the main difference between Humanities teachers' views on the use of different models of discussion and those of Science teachers is confidence. Science teachers lack confidence in using discussion, as it requires them to give control of the discourse over to pupils and it is fear of a consequential loss of control of discipline which holds them back.

This train of thought requires one to consider the role played by the teacher in discussion. Humanities teachers believe that their leadership of the discussion is critical to the success of that discussion. It should be noted that this does not imply that Humanities teachers wish to control all of the interactions within the discussion. Their leadership of a discussion is dependent on the conceptual model or level of discussion they wish to adhere to. ExHT6 exemplifies this suggestion as he likes to drift in and out of the discussion in his class, taking part in the discussion or encouraging others by moderating it. This type of interaction between the teacher and the pupils clearly shows that ExHT6 is in control of the discipline and conduct of the lesson but not the discourse.

The difference in emphasis on discussion between Science and Humanities teachers suggests that for Science teachers to utilise the full range of discussion models available to them, they need to shift their emphasis towards the position held by Humanities teachers, if the promotion of discussion in science, required under *CfE,* is to be fruitful in terms of pupil development towards scientific literacy and, more particularly towards some achievement of the four capacities.

Science teachers' emphasis on discussion as an outcome belies the fact that many Science teachers define work done by pupils in terms of a piece of concrete work (usually written) on a page in a jotter. Discussion, in general, produces little in the way of written evidence that it has occurred. Therefore, it is difficult for some Science teachers to judge the success of such discussion in terms of knowledge acquisition. In other words, Science teachers may see the learning process in science as a reproductive act (teacher tells pupil, pupil repeats back to teacher in a written form) rather than a generative process (teacher poses a question, pupils give multiple responses based on their understanding at that point in time). Science knowledge is tentative in nature and open to modification over time when new evidence emerges from experimental research, thus science knowledge is not fixed but is emergent (or generated) over time.

Scientific knowledge is often portrayed by school Science as fixed and therefore not open to question or revision. Some Science teachers might even see the scientific knowledge that they teach as a body of facts to be assimilated over time for the purposes of passing an end-stage exam. This leads pupils to gain knowledge without understanding rather than a deep conceptual understanding of how the knowledge fits into a given context.

Discussion works best when a pupil's conceptual understanding of a topic is challenged either by the teacher or by his/her peers. This challenge leads to a cognitive conflict (disequilibrium) which may result in the pupil's thinking being either modified, in the light of views expressed during the discussion, confirmed or even completely overturned. Meta-cognition by pupils exposes their thinking to scrutiny in the light of their personal experience within the discussion and allows them to improve and develop their own thinking so that in future they become better at evaluating their own and others' arguments.

Humanities teachers use discussion in this way, seeking to challenge pupils' thinking, perceptions and attitudes at a deeper level, since they are dealing with opinions and perspectives rather than objective facts. This in many respects forces Humanities teachers to adopt a less autocratic style in the absence of an absolute answer to many of the questions that they pose.

If Science teachers are to use discussion more in their practice, and are to develop approaches useful for the discussion of controversial socio-scientific issues in particular, as part of their effort towards the development of scientific literacy, a paradigm shift is required in the way that they view the nature of science, the aims of science education and their role within the delivery of the curriculum. This would require them to view scientific knowledge in a far less rigid manner than at present; to change their lesson delivery to include approaches which foster more genuine forms of open inquiry; to view science education as a vehicle for the promotion of scientific literacy rather than as a preparatory road to specialism for the few, and to end the present culture of teaching only that which is to be externally examined.

8.3 Research question 3.

How useful is cooperative learning as a pedagogical approach for the teaching of discussion within the science classroom setting?

The data outlined in Chapter 6 indicate that Science teachers are generally open to using discussion within their teaching. However, the use of cooperative learning as an approach to teaching through discussion, in the opinion of these Science teachers, was only useful up to a point.

As an approach to the development of discussion, cooperative learning was useful in managing the shift in science classroom discourse from a closed, recitative form to a more open, pupil-centred discussion. In particular, the cooperative learning approach allowed pupils to: (1) take control of the discussion as evidenced by the observed shift in typical exchanges seen during the lesson series; (2) become well engaged with the discussion (as commented by the science teachers); (3) air their views and; (4) take on board multiple perspectives. However, some of the science teachers felt that the cooperative learning approach was less successful when dealing with data analysis and interpretation, feeling that this type of lesson content required them to scaffold tasks more than the cooperative learning approach allowed.

In general, the science teachers felt that cooperative learning was particularly useful when pupils were required to research areas of interest in the discussion and present the information found in a PowerPoint presentation to their peers. All of the science teachers commented that the cooperative learning approach had made their classes more aware of the need for proper behaviour when engaging with the discussion. The continued emphasis on social skills was attributed by the science teachers to improved on-task behaviour. However, the experience of one science teacher when using cooperative learning during the discussion was negative, in that the class behaviour, although better than normal, was not acceptable within the context of the discussion. During pupil-group interviews, a number of pupils from two of this teacher's classes corroborated the observer's view that these lessons were less successful than hoped for in terms of behaviour and lesson delivery when compared to other lessons observed in the series. The pupils from both classes claimed that the teacher's lack of control over particular individuals within the class was a problem throughout the year, but they felt that the behaviour of the class for the climate change and global warming topic was better than normal, and that the 'usual suspects' were the ones who caused all the problems.

This finding sounds a note of caution when implementing cooperative learning as it introduces a distracting variable into the lesson where the teacher's attention is more focused on answering group questions, thereby shifting the teacher's focus away from monitoring off-task behaviour, thus providing greater opportunity for misbehaviour. While this problem might be reduced through sufficient practice, it may not be completely eradicated. Cooperative learning's underpinning in the social constructivist field does not factor in deliberate subversion of the lesson by pupils who are determined to evade work altogether, as was the case with the class illustrated earlier. The pupils' cooperation with the teaching approach itself is often taken for granted, whereas in reality, pupil cooperation is often variable and dependent on the personality of both pupils and the teacher in charge of the lesson. Any perceived weakness in the teacher's control of the class by pupils usually results in increased indiscipline and disruption to the learning and teaching. This is what happened to the teacher in the earlier illustration.

This finding was not just confined to low level disruption, it also extended to the pupils' interpretation of what individual tasks involved. For example in a number of lessons, pupils deviated from their assigned task since their teachers spent more time with other groups dispelling a misconception that arose during the groups discussion rather than being able to guide them through the task. The need to unravel the misconception left little opportunity for the teacher to monitor groups progress during task completion. This resulted in some of the group poster presentations being deficient in terms of the task set (see Chapter 7)

Looking more specifically at the misconception which appeared during discussions in all three rounds of action research, which was that ozone layer depletion was linked to global warming and climate change, one is left to wonder how this misconception arose in the minds of the pupils in the first place.

The pupils claimed that they had picked this up from television and newspaper reports as well as from primary school. Recent research into prospective Primary teachers conceptual understanding of climate change, the greenhouse effect and ozone depletion reveals that they do hold an inadequate conceptual understanding of these areas of science (Papadimitriou, 2004). More specifically, Papadimitriou (2004) found that 40.6% of study participants did not give any description of the mechanism through which the greenhouse effect takes place, with 26.7% making a clear connection between the hole in the ozone layer and the rise in the Earth's temperature. This study corroborates an earlier study by Francis *et al* (1993) who identified this confusion, suggesting that these misconceptions may have their origins in the fusion of ideas in the minds of the students in a single construct in which the issues themselves conflate (Francis, Boyes, Qualter, & Stanisstreet, 1993).

These studies show that this area of science is conceptually confusing for pupils and pre-service primary teachers alike. The data presented in this thesis also shows that this misconception exists within S2 pupils' thinking prior to these discussion lessons. However, it was shown to still exist in the minds of some pupils even after the topic as evidenced by the KWL grid data and end-of-topic test data. This is further evidence of the insidious nature of misconceptions and the difficulties faced by Science teachers when confronted by such misconceptions.

Some of the Science teachers were worried about the possible perpetuation of misconceptions when using cooperative learning since they found it difficult to combat them as they arose during the lessons. One teacher chose to stop all of the groups and return to a more traditional approach (chalk and talk) to endeavour to resolve the misconception problem before pressing on with the cooperative learning approach.

The issue of preparation time was raised by the science teachers as a negative factor. Most of them felt that the lesson preparation time for the cooperative learning lessons was greater when compared to their typical lesson preparation. They further suggested that in an already crowded curriculum, this problem would lead to them not considering using cooperative learning as the time taken to deliver the curriculum was too short for such an approach to be 'cost effective'.

This suggests that the proposed 'de-cluttering' of the curriculum by *CfE* would be welcomed and perhaps would encourage Science teachers to adopt approaches such as cooperative learning. The time take to deliver the curriculum should become less pressurised in terms of time.

In terms of how effective the cooperative learning approach was for teaching through the discussion of controversial socio-scientific issues, the data presented in Chapters 6 and 7 indicate that cooperative learning is effective in terms of shifting the emphasis of the discourse from a closed to a more open form. It is also effective in terms of promoting greater pupil engagement in the discussion process and is effective in terms of building pupils' social, communication and listening skills. Thus cooperative learning was effective at meeting both the social objectives and the citizenship outcomes of the discussion lesson series over the three rounds of research. However, the data showed that, in terms of acquired knowledge and understanding, as evidenced by end-of topic testing, the cooperative learning model was less successful.

9.4 Research question 4.

What are the pupils' attitudes towards Science & Technology and School Science and how do they impact on engagement in discussion of socio-scientific issues?

In the light of the publication of new science outcomes from *CfE* it is important to take on board pupils' views of what they would like to learn, which and how many topics they would like to learn, and the depth to which these should be taught, if we are to avoid putting pupils off studying Science. In addition, their views on science and technology and its impact on society, together with their understanding of the nature of science, are also important if we are to actively engage our pupils in discussion about controversial socioscientific issues emanating from contemporary science. Knowledge of these views also gives teachers a baseline from which they can gauge pupils' developing attitudes towards science and technology in general and school science in particular, over time.

With this in mind, the underlying purpose of the pupil questionnaire was to discover what the S2 pupils' views were on a range of issues and to determine how the S2 pupils compared to the national data. Since this research study was carried out in one school, it was important to determine whether these S2 pupils differed in terms of their attitude and views on science. The data from the S2 questionnaire correlated significantly (r=0.83 for sections ADI, see Figure 5.3) with that of the ROSE Scotland data, suggesting that the XHS S2 pupils do not differ significantly from those in the Scottish ROSE study sample. This is encouraging since the latter showed that there was no regional variation in pupils' views on the environment, science and society and school science. The present results show that XHS S2 pupils constitute a valid pupil population which is comparable to other Scottish pupils of that age group.

In addition, the findings of the S2 questionnaire show that the pattern of responses to the statements in each section of the questionnaire correlated both with the Scottish ROSE data and are broadly in line with similar data from England and the Irish Republic (Farmer, Finlayson, Kibble, & Roach, 2006; Jenkins & Nelson, 2005; Matthews, 2007). However, when discussing pupils' interest in any particular topic, it is important to place a caveat. One must keep in mind that an expression of interest in science does not distinguish between interests in any one scientific discipline or between aspects within the same discipline. This can be illustrated by the fact that when asked *"What I want to learn about"*, the most popular topic overall was "How it feels to be weightless in space" (Overall mean 3.32 ± 1.00) which was also the top male topic (mean 3.48 ± 0.88) but was only the third highest topic for S2 Females (mean 2.98 ± 1.06). On the face of it this is not unusual. Physics in XHS is relatively unpopular when compared to Biology (Figure 5.5 and table 5.8). This point is further strengthened by the fact that, although Biology in XHS is by far the most popular of the scientific disciplines, seven of the ten least popular topics were biological in context.

Furthermore, one must concede that an indication by a pupil of a wish to learn a topic does not equate to a willingness to make an intellectual effort, nor does it guarantee the commitment required to learn and understand that topic. Jenkins (2005) suggests that it cannot be assumed that, in expressing a preference for a topic, pupils are making an informed choice. He suggests that a lack of enthusiasm for a topic might indicate a lack of perception on the pupil's part as to the fundamental importance of that topic to scientific understanding, which could indicate that such a perception is probably coloured by the pupil's introduction to the topic during their school science education.

If curriculum relevance is to have any meaning, and if the new science curriculum from *CfE* is to succeed, the views of the pupils themselves cannot be ignored. In education, relevance has all too often been viewed and defined from an adult's, rather than pupil's, perspective (Rudduck & Flutter, 2000). These caveats notwithstanding, these data suggest that a lot of pupils have already made up their minds whether or not they wish to pursue a career in science by the age of 14 which is before they embark on their chosen courses of study (in Scotland the time that most S2 pupils pick their S3 courses). This suggests that there is a need to move the science curriculum away from science for specialist education toward a more generalist/humanist content, since the majority of pupils do not wish to pursue a career in science. This is further strengthened by the data from sections E, statement E16 and F, statement 13b which indicate that 40% of S2 males and 90.4% of S2 females would not like to get a job in technology and that 68.2% of S2 males and 72.4% of S2 females do not think science is a good career path.

If this is the case, then the data imply that better quality science teaching to younger pupils is of paramount importance if a greater appreciation and interest in science is to be achieved. This also has implications for the teaching of science in the primary school, since the Scottish ROSE survey shows, and the XHS S2 data backs the view, that most school pupils did not find primary science interesting (Scottish ROSE mean 2.00, XHS mean 2.02 ± 1.03) and did not see their primary science experience as adequate preparation for future study in secondary school science (Scottish ROSE mean 1.79, XHS mean 1.73 ± 0.97).

When discussing pupils' responses to their science education (see Tables 5.5 and 5.6) it is important to distinguish between pupil *interest* and *motivation*. Statements L03 and L05 focus on the use of practical work as a factor which makes pupils want to study science and if the practical content of the science course was increased that would increase the pupils enjoyment. It can be claimed that carrying out practical work increases pupil motivation. Practical work can increase the immediate degree of interest shown by pupils but it is important to recognise that *motivation* can be described as a personal response which evokes a strong sense of direction to one's present and future activity, which is not the same as an *interest* which tends to represent a short-lived, temporary response to a particular experience. Science teachers know that all but the most negative of pupils become more interested in practical work, even by the most mundane practical tasks, than by a theory-ladened, book-based lesson. However, the normal sequence of events in a science lesson which involves a practical task is preceded and/or followed by an intellectually demanding period in which the results of the practical are explained by the teacher. Although practical work is of immediate interest to the pupil, it can be a relatively minor part of the overall experience of science class.

It could be argued that practical work in science only has the appearance of making science more 'concrete'. However, in reality, the explanations of the results gained through practical work always go beyond the evidence immediately available. Most science teachers would agree that a considerable amount of intellectual ability is required to understand the wide range of abstract concepts, used even at Standard Grade General Level. For many pupils, the level of interest aroused by a practical is tempered by the level of theory which impinges on the practical work, thus *interest* is often not converted into *motivation*.

When one looks closely at section C in the XHS S2 pupils' questionnaire which deals with responses to 'my opinion on Science and Technology', it is clear that the XHS S2 pupils strongly view science and technology as important for society (overall mean 3.11 ± 0.93, 78.4% agreeing, S2 male mean 3.30, with 84.9% S2 female mean 2.92 with 71.8% agreeing) but that the S2 females agree less strongly than the S2 males. This trend continues over most of the statements in this section: over the sixteen statements, the female responses to thirteen of these were more negative than the males. The three which showed a greater percentage of females agreeing than males were actually negative statements towards science. This trend is also seen in the Scottish ROSE data. However, it is encouraging to note that the XHS S2 data show that, in terms of the pupils' understanding of the nature of science, they can see where science has limitations. On the one hand, 83.7% of S2 males and 85.9% of S2 females agreed that science and technology will find cures to diseases such as HIV/AIDS and cancer but, on the other hand only 41.9% of S2 males and 25.9% of S2 female agreed that science and technology can solve nearly all problems. Further, 42.9% of S2 males and 25.3% of S2 females agreed that science and technology is helping the poor.

Looking at the context of this study, it was important to know what the S2 pupils' views on environmental issues were, since they were engaging in discussions involving climate change and global warming. Section B of the pupil questionnaire asked the S2 pupils about the extent of their agreement with a series of 18 statements (see Table 5.2) on 'me and the environmental challenges'. From these data overall, the XHS S2 pupils see threats to the environment as their business (73.7% agreeing) and that environmental problems make the future of the world look bleak (56.8% agreeing); but that they see it as their responsibility to make a contribution to protect the environment (66.5% agreeing), but 60% of the S2 pupils overall said they were not willing to sacrifice many goods for the protection of the environment. This indicates that as a group the S2 pupils see environmental issues as important and worthy of our protection but that they are not prepared to give up their lifestyle in order to achieve this. This finding is in agreement with the Scottish, English and Irish Republic ROSE data. Interestingly, young people don't think that environmental issues are exaggerated but they do think that people worry too much about environmental problems, yet overall they are optimistic about the future.

These data contain a number of contradictions in that it is difficult, from an adult perspective, to see how on the one hand environmental issues are important, and that everyone should be doing more to protect the environment by modifying their behaviour, but on the other that you would not give up goods to protect the environment. This seems illogical, but it is important to realise that young teenagers are, in the main, self-centred and thus fail to see that a modification of their behaviour towards being more environmentally responsible takes personal sacrifice. This lack of linkage is supported by statement B16 and B12 where statement B12 '*I think each of us can make a significant contribution to environmental protection*', overall S2 mean 2.77, male 2.80 with female 2.97) contradicts statement B6 '*I can personally influence what happens with the environment*', overall S2 mean 2.20, male 2.34 with females 2.06). However, if we see this from the pupils' perspective this could be interpreted as them saying that they can influence their local environment but that on the global scale they cannot see how their actions can influence the global environment.

Another, more worrying sign for medical science, is the pupils' lack of ability to see flaws in their own logic which can be seen in their response to statements B15 and 16 where the statement '*animals should have the same right to life as people*' resulted in 67.5% of S2 agreeing (55.3% male and 73.8% female) and that '*it's right to use animals in medical experiments if this can save human lives*' where overall 58.3% of the S2 pupils disagreed (with 44.7% of males disagreeing and 55.3% agreeing and 72.3% of females disagreeing and 27.7% agreeing). When one asks the question *do animals have the same right to life as humans?* a logical extension to this positive response would be the question *is killing animals for food murder*? Or, *if you eat meat are you committing murder?* This researcher would argue no, killing animals for food is not murder, but a vegan vegetarian may argue the opposite.

There are many influences on public opinion and particularly on children's opinions. Arguably this questionnaire was not sensitive enough to probe pupils on the issues of animal rights and human intervention as these tend to be highly emotive and require a complex series of probing questions in an interview situation to tease out the perspectives.

How the pupils' attitude towards science affects their engagement in discussion of controversial socio-scientific issues is pivotal to the success of such discussions. If their interest, attitude and motivation to learn science is poor then it could be argued that willingness to engage with the issue will be compromised.

In order to answer to this question, section J in the pupil questionnaire probed pupils' views on the issue of climate change and global warming; on the materials used; on their engagement within the lessons; and the cooperative learning approach used in the discussion. The data presented in Chapter 6 shows that overall the S2 pupils viewed their engagement with the issue of climate change and global warming in positive terms. For example, although overall only 40.5% of the S2 pupils were interested in the climate change and global warming topic prior to the lesson series, 65.5% of the S2 pupils felt that everyone in their group took part in the lessons, with 50.3% of the S2 pupils indicating that they enjoyed the discussion topic and 59.7% of the S2 pupils indicating that they were not bored by the discussion. However, differences appeared along gender lines, with 43.1% of S2 males and 37.7% of S2 females indicating that the issue interested them prior to the lesson series. In addition, 53.5% of S2 males and only 47% of S2 females indicated that they enjoyed the discussion with 38.4% of S2 males and 42.4% of S2 females indicated that they found the discussion boring. Interestingly, 41.2% of the S2 females found the discussion hard compared to only 23.3% of S2 males. This finding was corroborated by classroom observations for each lesson across the year groups involved over the three rounds of research. The observed classes were well-engaged and visibly enjoyed the experience. However, there was a noticeable minority of pupils in the first round of action research who questioned the discussion in terms of the lesson content, stating that for the analysing-greenhouse-gas-data worksheet they felt that the lesson was more like a Maths lesson and the House of Commons debate was more like a Modern Studies lesson.

These data, while not surprising, suggest that despite the fact that some pupils may hold a poor attitude towards science (45.9% of S2 female with 24.4% of S2 males being classified as anti-science (see Chapter 5, Table 5.7), or may be poorly motivated to engage in science, they do engage in discussions of a socio-scientific nature.

It is clear from the data presented in Chapters 5 and 6 that there is a gender split in terms of pupils liking for and engagement with science. This information should have been factored into the thinking when the new science curriculum, experiences and outcomes for *CfE* were designed. However, in the view of this researcher, the developers have failed to take many of these views on board. For example, while the number of experiences and outcomes relating to the discussion of controversial socio-scientific issue has increased and the number of learning outcomes relating to content has decreased (when compared with the 5-14 Environmental Science guidelines), the content of the new curriculum has hardly been updated. It could be argued that the experiences and outcomes for the new curriculum contain content which differs little from the days of Curriculum Paper 7 in 1969.

If science teachers are to encourage science appreciation, as part of scientific literacy, they require a curriculum which is modern in terms of content and outlook. The data presented here and from international research (Farmer et al., 2006; Jenkins, 2006; Jenkins et al., 2005; Matthews, 2007; Ogawa et al., 2004) suggest that secondary school science education is a turn off at present for the majority of secondary pupils. If Scottish Science teachers are to slow, never mind halt or reverse, this trend of falling interest in school Science, a curriculum which is effectively a watered down version of topics derived from Standard Grades Biology, Chemistry and Physic is likely to be ineffective. In terms of female engagement in science, the new curriculum experiences and outcome do little to encourage girls to engage in the study of science, since six of the topics which the Scottish ROSE study suggest are girls least favourite sit centrally within the new curriculum.

In terms of open discussion, it was worrying to find in the investigation that only 45% of S2 pupils questioned believed that they were given a chance to express their own opinions during the climate change and global warming lesson series. This finding may have arisen due to group composition in the lesson series, as a number of pupils in the pupil-group interviews suggested that they did not like being put into groups with people that they would not chose to associate with normally. They may have held back from expressing themselves during the discussion for personal reasons such as to protect their social status within the groups or class, or they may not have wished to provoke a reaction from people whom they did not know or possibly trust. This view is supported by observations made during the discussion series by the researcher. A few groups in a number of observed lessons appeared to lack cohesion, possibly through unfamiliarity with this style of teaching. However, a number of pupils within these groups were vocal in their dislike for this style of teaching and the people within their group. This observation was most prevalent during the first round of action research but was much less prevalent during the second and third rounds.

8.5 Research question 5.

What issues arise from teaching the Topical Science strand of the new science curriculum in terms of the development of teaching materials, time to deliver, teacher CPD and management of resources?

A number of issues arose from the teaching of the climate change and global warming discussion over the three rounds of action research. These issues can be broken down into three categories; (1) Development of teaching materials; (2) Issues with delivery and; (3) Pupils' difficulties.

8.5.1 Development of teaching materials.

The development of teaching materials over the three rounds took up a considerable amount of time. For example, the development of the video-clip embedded PowerPoint in the third round took up more development time than the development of the teaching materials for the entire first round. The one lesson to emerge from this experience was that science departments need to begin their development of teaching materials modestly and then over time add to them in terms of detail and complexity.

In terms of the complexity of the materials, care was taken to ensure that the information in all the worksheets was differentiated in such a way that the language was suitable for the age range of pupils being taught. However, some of the teachers still felt that the language level of some of the teaching materials was too high. It is this researcher's view that teachers need to remember that differentiation of language carries the danger of decreasing the challenge to pupil understanding, resulting in a failure to accumulate a more sophisticated vocabulary, which in turn leads to difficulties when pupils move on to more difficult materials later in their education.

When designing teaching materials, the learning objectives of the lesson were used to guide the construction of worksheets. For example, the analysing-greenhouse-gas-data worksheet was constructed to fulfil learning objective linked to the analysis and interpretation of data. This lesson also required the pupils to use transferable skills from numeracy across the curriculum outcomes, such as graph drawing. The aim of this worksheet was to help develop pupils' ability to analyse and interpret data (a key element of scientific literacy). However, the teachers commented that this worksheet was difficult for the pupils in terms of drawing the graphs and answering the questions posed but, when these worksheets were analysed for the year group, the main issue was not that they found the worksheet difficult but that they lacked some key skills, such as the ability to scale the graph and plot the points. What this suggests is that the success of the teaching materials can only be assessed when taking into account the contexts of the analysis of year group as a whole, rather than the opinion of the individual teacher who sees the success or failure of the worksheet from their own perspective. The latter can be biased and depend on localised variables which may impact on the pupils' ability to engage with the material as presented.

Sourcing of suitable information has been made relatively easy with the advent of the internet. However, the finding of information at a suitable level for 13-14 year olds was more difficult in terms of complexity of information, language level and difficulty level of the subject matter. This also led to an increase in development time as evaluation of websites suitability took time particularly in the second and third round preparation and planning.

8.5.2 Issues with delivery.

There were a number of practical issues which arose during the use of discussion during all three rounds. Website access and availability was a particular problem in the second and third round as most of the teachers reported that the pupils were unable to access some of the recommended websites. This occurred either as a result of a poor connectivity to the wireless network or because the school firewall blocked access to some sites. Furthermore, this problem was potentially compounded when some teachers expected the pupils to use only the particular websites that were recommended rather than (as it was expected) allowing the pupils to freely search the internet themselves as part of the learning objective for researching and evaluating information available from multiple sources.

The time to deliver the lesson series in the first round of the action research was exceeded by 83.1%, in the second round by 35.1%, but in the third round the lesson series over-ran by only 9.2%. This was despite the fact that the content of each planned period increased after each round of the research. This result was encouraging as all the teachers commented that they felt increasingly more comfortable with the cooperative learning approach and with discussion in particular.

Looking more specifically at the cooperative learning approach, the teachers felt that the use of cooperative learning was not suitable for teaching data analysis and interpretation. They felt that this aspect was a critical skill required for the development of scientific literacy, but more specifically, was pivotal to the pupils' understanding of some of the arguments put forward in the discussion of climate change and global warming. The teachers felt that this required more scaffolding and detailed explanation than the cooperative learning approach allowed.

Some of the science teachers felt that the topic itself was a problem, citing that the arguments put forward in the discussion were too subtle for the majority of pupils to grasp and that the data, as presented to the pupils, conflicted with the prevailing view that increased atmospheric CO_2 concentrations were causing the increase in global warming. They accepted the argument that the science is contentious and that agreement as to the validity of the evidence which supports the CO_2 hypothesis is looking increasingly weak but, they correctly (in the opinion of this researcher) pointed out that, in terms of the SQA examinations, the pupils would be expected to answer a question on global warming by saying that increased CO_2 levels in the air are causing increased global warming. Therefore, if they taught the pupils in S2 that the CO_2 hypothesis is in doubt, but in S4 that it is not, then they run the risk of confusing pupils and undermining their understanding of what they suggest should be an easy question in a final exam. This issue is not one that can be easily resolved and illustrates a potential problem when dealing with controversial socio-scientific issues which contain lines of argument which run contrary to the mainstream view.

This is a problem that needs to be addressed by the SQA since they are at present in the process of reviewing the curriculum in S5 and S6 to align it with the new Science curriculum which emerges from *CfE.* One thing is clear, if the new assessment system fails to assess discussion of socio-scientific issues in as holistic a manner as possible within the new Higher Grade exam, then such discussion will simply not be done and the shift in the emphasis for the Scottish Science education curriculum from specialisation to general will fail. How one examines issues which are complex remains to be debated and is beyond the scope of this thesis. However, the English AS- and A2-level course *Science in Society* and its predecessor *Science for Public Understanding* provide an insight into how such discussions might be assessed. In practice, what these course assessments measure consists of data analysis and interpretation skills, pupils' knowledge of key concepts which impact on the themes and issues discussed during the course, and the ability to synthesise new knowledge from different sources of evidence. All of these, it could be argued, test elements of scientific literacy.

It is clear from this action research, that introducing discussion into science teachers' practice requires time, patience, persuasion, open mindedness and a willingness to try. It will be particularly important to properly evaluate the development process in future research.

8.5.3 Pupils' Difficulties.

Across all three rounds of action research a number of issues emerged during the teaching through discussion of climate change and global warming. Firstly, a large proportion of pupils in rounds one and two struggled to draw the first graph in the analysing-greenhouse-gas-data worksheet. In addition, there were also a large number of pupils who found analysing the data difficult. Secondly, as a group the first round S2 pupil cohort struggled to write an essay, with the second round S2 pupil cohort struggling to read for understanding and answer questions based on their reading.

The data presented in Chapter 7 suggests that the literacy and numeracy skills of the S2 pupil cohorts involved in the first and second rounds was lacking. This finding is worrying that it indicates that the majority of the 13 and 14 year old pupils could not read for understanding and answer questions based on what they have read. Furthermore, they have considerable difficulty completing a piece of extended writing designed to convey scientific information in an accurate and logical manner. In addition, these data also indicate that the majority of these S2 pupils found scaling and plotting a simple line graph difficult and could not answer questions designed to help them interpret what the data was conveying.

Close reading skills form an important aspect of the English curriculum in Scotland, in much the same manner as graphical analysis and data interpretation is a core element of the Scottish Mathematics curriculum. This being so, one is left several awkward questions such as: *Why are these S2 pupils finding literacy and numeracy tasks so difficult? Are science teachers expecting too much from pupils'?* Or, *Are English and Mathematics teachers not demanding enough?* The answer to these questions might be difficult for teachers to hear let alone professionally discuss. However, this is a debate that must be had, if Science teachers are to understand the nature of the task they face while attempting to meet the aims of the new Science curriculum as set out by *CfE*. A better understanding of the approaches used and the difficulties faced by English and Mathematics teachers when they teach these core skills would go someway towards bridging the gap in expectations between these groups of teachers.

The prevailing culture within English is very different to that obtaining in Science. Likewise, there are cultural differences between Mathematics and Science when it comes to the teaching of graphical analysis, data analysis and interpretation. The culture within English for writing a piece of work, drafting and redrafting it after feedback from the teacher, is potentially at the heart of the literacy issues found in this research. Pupils are so used to this cycle of drafting; teacher feedback; redraft and submit; that they can no longer cope with the task without extensive scaffolding from the teacher. However, one could equally argue that the teacher's feedback on the writing task helps to develop pupils' thinking, writing style, sentence structure, spelling, grammar, argument etc…, suggesting that this cycle helps to hone the pupils' literacy skills to the point that they will require less and less feedback when faced with similar tasks in the future.

In Mathematics, graphical analysis, data handling and interpretation is done using 'ideal' data (simplified, easy whole numbers) which one could argue is relatively straight forward for pupils to handle, whereas in Science the numbers derived from experiments are 'dirty'(with decimal points and values on varying scales) or perhaps more difficult to handle. However, pupils should be used to drawing graphs using data derived from experiments. One could therefore argue that, with sufficient practice using 'real' data the pupils would become more proficient at drawing different types of graph.

When one looks more critically at these issues from the pupil perspective, one sees that their experience of close reading in English and graphical analysis, data handling and interpretation in Mathematics is dependent on the 5-14 level at which they were working towards at the time. For example, if the pupil was working at level C and towards level D in Mathematics they may never have been exposed to the kind of graphical analysis and data handling which science teachers expect them to be able to do within the Science context. If this supposition holds true, then Science teachers may be expecting more from the pupils than is fair, given their prior exposure to such skills. In this case, one could argue that the 5-14 system has been exposed as lacking in terms of cross-curricular consistency. More importantly, this research suggests that Science teachers need to work more closely with their English and Mathematics colleagues in order to reach consensus as to what is, and what is not acceptable, both in terms of their expectations and in terms of common areas of practice. This would ensure that pupils receive a comparable experience and level of expectation from these three core curricular areas.

8.6 Implications of the research.

This study provides a rich picture of how cooperative learning might be used to promote more open discussion of controversial socio-scientific issues in secondary science education. Moreover, it provides an insight into teachers' thinking about classroom discussion in general and the use of cooperative learning as a vehicle for the promotion of discussion in particular. In addition, this study provides a cross-sectional view of how Scottish 13 to 14 year olds (S2 pupils) engage with socio-scientific discussion and cope with teaching strategies designed to manage the development of different characteristic elements of scientific literacy.

As previously stated, relatively few investigations into teachers' conceptual models of discussion or factors which might affect the use of these conceptions have been reported. To date, no research of this type has been done in the United Kingdom looking specifically at secondary Science teachers' models of discussion when compared to those of Humanities teachers. The models presented in this thesis help to fill this gap. When considering the possible implications of this study, one is required to think in broad terms about its place within the research literature and more specifically, its possible locus within the context of *CfE*.

8.6.1 Implications for Science teachers.

This study provides teachers who use, or are thinking of using discussion in their teaching with a theoretical framework which might be profitably be compared to their own thinking on discussion, as part of their reflective practice. In addition, it may provide some teachers with a stimulus to engage in action research of their own where they might compare teachers' and pupils' roles, or the characteristics and purposes of their classroom discussion, so that their practice of discussion might become more efficient and possibly more frequent.

A discussion lesson is more complex in terms of planning and leading than is a recitation-style lesson. Planning a discussion lesson requires the teacher to weigh up many factors such as the cognitive ability range of pupils in the class; the learning objectives of the lesson; the age and maturity level of the pupils taking part; and the interest levels of the pupils for the issue to be discussed. Furthermore, the role of the teacher during each model of discussion is crucial to the purpose of that discussion, even when it appears to be pupil-led. The teacher has to determine what his/her role is from the beginning and must plan how they will facilitate the type of interactions they wish to stimulate. Teacher involvement in the discussion varies depending on the model of discussion being used. The teacher's presence during the interactions is important to the success of the discussion, since they exert control over its pace and the pupils' behaviour by their presence or potential participation. However, they do not necessarily control the content or direction of the discussion. This suggests that if discussion is to be promoted, planning and preparation time for teachers will increase significantly.

For Science teachers the challenge of planning and preparing discussion lessons is not particularly problematic *per se,* their main challenge is fitting discussion into an over-crowded curriculum which is tight in terms of time. The de-cluttering of the science curriculum under *CfE* should provide the space and time required for the delivery of discussion lessons in general and discussion of controversial socio-scientific issues in particular.

However, there is a need for Science teachers to re-conceptualise what the aims of Science education are and to understand that controversial socio-scientific issues require them to develop their pedagogical repertoire to include more open forms of discussion. Research in England about a decade ago showed that a large proportion of teachers across the curriculum perceive the teaching of science to be about the delivery of facts, and not about values, opinions or ethics (Levinson et al., 2001). Levinson et al found that almost half of all science teachers felt that the teaching of science should be 'value free', that it does not yield issues that have social or ethical implications. Others inferred that considering the ethical and social concerns raised by science might undermine the integrity of the subject overall. These findings clearly illustrate that there is a need for change in science teachers' thinking.

If this shift in science teachers' thinking and practice is to be achieved, it is vital that assessment practices include the assessment of socio-scientific issues in both internal and external assessment exercises otherwise there is no incentive to change the *status quo*. The worry is that discussion of socio-scientific issues will follow the path of the core skills component of the *Higher still* reforms which effectively fell by the way since it was never actually assessed. In Scotland, one must accept the premise that assessment drives practice rather than *visa versa*, thus if discussion is to be promoted, assessment of it is pivotal to successful implementation of this component of the new Science curriculum.

8.6.2 Implications for Curriculum for Excellence.

Teaching through discussion has the potential to enhance the development of the four *CfE* capacities of *confident individuals, effective contributors, responsible citizens and successful learners*. Through the process, pupils may develop the ability to interact with their peers regarding issues of common interest. Through the *practice* of discussion, pupils acquire key skills such as listening, communication and social skills, all of which are critical features of citizenship education. The use of different models of discussion may help promote different aspects of democratic citizenship such as decision-making, critical thinking, constructive criticism, debate and argumentation. The democratic system places a high value on its citizen's opinions. Pupils can be thought of as citizens-in-the-making and, as such, might learn through discussion how to engage constructively with peers of different gender, ethnic background, social status and ability, which in turn might enhance their understanding of the different perspectives from which diverse groups make up a modern, multi-cultural society. Thus discussion is a valuable pedagogy for the development of responsible citizens and effective contributors.

In terms of literacy, this research provides empirical evidence that at present, the general level of 13/14 year old pupils' literacy, in terms of their close reading and writing skills, is disappointingly poor. Furthermore, the data indicate that 13/14 year olds find drawing simple line graphs (a numeracy skill) difficult. In addition, they struggle to understand the meaning of such data in that they find it difficult to relate them their understanding of the issue being investigated.

It is clear that the new curriculum which has emerged from *CfE* has to tackle these issues systematically. Indeed, the increased emphasis on literacy and numeracy (as well as heath and wellbeing) across the curriculum places the onus onto individual subject specialists to develop teaching strategies which will meet the needs of pupils in terms of literacy and numeracy. This shifts the development of basic literacy and numeracy skills away from the English and Mathematics departments.

Science as a curricular area has much to offer pupils in terms of teaching towards literacy and numeracy across the curriculum. Through the discussion of controversial socio-scientific issues in particular, science can contribute to the development of pupils as citizens-in-the-making. However, the main issue to emerge from this research is that teachers require time to produce quality teaching materials to meet the aims of the new curriculum. In addition, they require time to pilot and refine these materials so that they are fit for purpose. Furthermore, they require time to develop suitable assessment materials which provide the necessary rigor by which pupils' attainment can be assessed. Finally, in terms of improving the learning and teaching demanded by *CfE*, teachers require more, high quality CPD if they are to enhance their own skill as part of their drive to implement the necessary changes (Gray and Bryce, 2006).

It is the considered view of this researcher that the short time frame between the decision to implement the new curriculum and its implementation (18 months from decision to full implementation nationwide), together with a serious lack of adequate CPD for teachers across the curricular spectrum, presents the first and possibly fatal hurdle to successful implementation. The data from this research indicates that the developmental pathway for teaching materials took three years to achieve an end product that was acceptable to the majority of Science teachers within the department. In addition, this study shows that it took these Science teachers time to practise and become fully conversant with the demands of both the cooperative learning method and its use for the promotion of open discussion. This suggests that the time frame as set out by the Scottish Executive may be over ambitious and should perhaps be reconsidered.

In terms of collegiality, Science teachers need to spend more time in discussion with their English and Mathematics colleagues to come to a better understanding of how literacy and numeracy skills are delivered in these areas, since this study shows that there is a lack of consistency of teacher expectation across these areas of the curriculum. If Science is to play a pivotal role in meeting both the literacy and numeracy across the curriculum experiences and outcomes of *CfE,* then Science, English and Mathematics teachers need to come together to discuss how to bridge the gap in experience and expectations being placed on the pupil by these different departments.

Pupils' prior experience of skills needs to be taken into account in the new Science curriculum in order that these skills are matched by their experience from both English and Mathematics. This places the onus of cooperation on the shoulders of Science, English and Mathematics teachers requiring them to think 'outside their own boxes', taking into account the different stresses and strains of each others curriculum before teachers begin to design curricular materials to be used in their new courses. It is only through collegiate cooperation that pupils' attainment in both literacy and numeracy will develop.

8.6.3 Implications for the development of scientific literacy.

The development of pupils' scientific literacy is set out within this research as a framework which blends traditional and more modern pedagogy. The data show that cooperative learning is useful for the promotion of open discussion and, in particular, for the discussion of controversial socio-scientific issues. In terms of teaching for the development of individual characteristic elements of scientific literacy, cooperative learning has utility. However, the teaching of data interpretation skills, a key element of scientific literacy, was felt to be better served by a more measured and teacher-dominated (traditional) approach. This study shows that, in the short term, pupils' engagement with socio-scientific discussion helps them to see the relevance of science to their lives and aids their appreciation of the role that science plays in the decision-making process as it interacts with society.

The possible impact that developing school pupils' scientific literacy has on the level of scientific literacy of the general public is impossible to assess at this point in time, but this study suggests that at least in the short term, some pupils could gain functional scientific literacy. However, long term increases in public scientific literacy might remain illusive. The question of what level of scientific literacy should be attained by most pupils by the time they finish their compulsory science education remains to be answered, but it is clear that there is a link between the attainment of a 'functional' level of literacy and numeracy and the attainment of a 'functional' scientific literacy.

From the cognitive psychology perspective it is unreasonable to expect all pupils to become highly scientifically literate (conceptual/procedural or multi-dimensional). However, it is reasonable to expect that most, if not all, pupils are capable of demonstrating a nominal level of scientific literacy with the majority of pupils able to demonstrate a level of functional scientific literacy. The question as to how one assesses secondary pupils' scientific literacy is open for discussion. However, this research suggests that the formulation of scientific literacy tests, based around literacy and numeracy skills could provide a starting point for the required assessment.

8.6.4 Implications for initial teacher education.

Training future teachers how to use discussion as a method of instruction is an important step on the road to increased use of discussion in practice, particularly within initial science teacher education. Teacher educators might examine the purpose and characteristics of the five conceptual models of discussion and discuss which model might suit different learning outcomes.

In particular, teacher educators need to model how to lead discussion explicitly, exploring and explaining each step in the process with their students, unpacking teachers' decision-making processes during discussion and instilling the purposes of different models of discussion and their role within each model. Student teachers need to be shown how to lead it, and more importantly be shown that it works with pupils, if they are to become more comfortable using discussion within their pedagogical tool kit. More specifically, student teachers need to be exposed to factors which might negatively influence discussion and practise ways of overcoming them as part of their preparation for teaching practice.

Social constructivist thinking suggests that pupils learn subject content better when they are required to organise it themselves and develop an individualised understanding of the concepts being taught through participatory planning with experienced mentors. Discussion as teacher-mediated discourse, as open-ended inquiry and as mediated transfer of knowledge to real-life contexts encourages this style of learning. However, student teachers need to be made aware of the dangers of allowing pupils to develop a conceptual understanding of subject content without teacher challenge. Teachers must challenge pupils' conceptual understanding regularly within discussion in order to expose and potentially rectify misconceptions as they arise. This requires constant vigilance on the teacher's part during discussion to monitor and challenge pupils' thinking regularly. If misconceptions arise unchallenged there is a danger that they might spread throughout the class through the normal social interactions which take place during group work. Once a misconception is seeded it is very difficult to supplant it in the pupil's mind with a better conceptual understanding.

It is therefore important that student teachers are exposed to both leading and participation in discussion during their preparation. Being a competent participant in discussion does not necessarily lead to being a competent leader of discussion (Parker and Hess, 2001).

Chapter 9. Conclusions.

In this concluding chapter the findings are related to the rationale behind the action research. In addition, the limitations of this research are considered and some future directions for further research are outlined.

9.1 Summary of Main Findings.

This study was designed to explore one Science department's efforts to implement a more open form of pedagogy for the use of discussion in response to curricular changes proposed by *CfE*. The focus of the research was the use of cooperative learning as an approach to the discussion of a controversial socio-scientific issue thus making a contribution to a range of research literature such as the development of scientific literacy; cooperative learning; the discussion of socio-scientific issues and discussion in general. However, the largest contribution that this study makes is to the growing body of research into the implementation of curricular change under the auspices of *CfE*.

The main focus of the new Science curriculum lies in the development of pupils as scientifically literate citizens, able to hold and defend opinions on social, moral, ethical, economic and environmental issues emanating from contemporary science (Scottish Executive Education Department, 2006). However, the architects of the Science curricular experiences and outcomes did not define what they meant by the term scientific literacy or whether they saw scientific literacy in terms of an incremental or staged developmental progression. This research proposes that the development of scientific literacy is linked to pupils' cognitive development and is therefore inextricably linked to pupils' development in terms of literacy and numeracy. The rationale for this argument emerges from the literature which indicates that scientific literacy is an ill-defined concept; containing up to thirteen distinct elements; it has different levels or stages of development. This suggests that all pupils begin to develop scientific literacy at the nominal stage by acquiring vocabulary and begin to understand basic science concepts. Progression through the nominal stage may be characterised by the assimilation of scientific words and meanings and a slow development of understanding of basic scientific concepts. The discussion in Chapter 8 suggests that development at the nominal stage may last, for the majority of pupils, through primary into lower secondary school, with a small minority never going beyond the nominal stage. However, some pupils could potentially be ready to move onto the functional stage between S2 and S3.

The development of functional scientific literacy requires pupils to continue to acquire the basic skills required to *understand* the subject matter, but also requires them to use and further develop those skills to *demonstrate* their understanding of the scientific knowledge. More importantly, it requires them to be able to demonstrate how the science perspective interacts with (and at times influences) other perspectives such as the moral, ethical, economic, environmental and political. This researcher suggests that the discussion of controversial socio-scientific issues provides the necessary stimulus for development within the functional scientific literacy stage. While one could argue that socio-scientific discussion is possible in the nominal stage, the complexity of it is tempered by the cognitive ability of the pupils and as such would be rudimentary by comparison to comparable discussions at the functional stage.

This suggests that as pupils progress through the functional stage of scientific literacy towards the conceptual/procedural stage, the complexity of the discussion that pupils' are capable of holding increases. Movement from functional to conceptual/procedural scientific literacy may only ever be possible for those who develop the maturity, open-mindedness and a willingness to listen to perspectives and opinions which may be in direct conflict with their own.

This research suggests that the best level of scientific literacy that science teachers might be expected to develop by the end of compulsory science education is functional scientific literacy, speculating that it would be reasonable to expect the majority of 16 year old pupils to have reached that level by the end of compulsory science education, with a few (possibly the top 5%) reaching the conceptual/procedural level; and a larger minority (possibly 10 to 15%) achieving nominal to functional scientific literacy.

In general, *CfE* calls for an increased use of discussion of socio-scientific issues in particular, since the topical science has been placed at the centre of the new science curriculum (See Chapter one Figure 1.2). Indeed the whole emphasis of Scottish Science education has been moved from science education for specialisation towards science education for the development of scientific literacy, with topical science issues forming an emergent theme, central to the curriculum. However, recent research into science teachers' use of discussion in general and the discussion of socio-scientific issue in particular, indicates that science teachers tend to shy away from them and feel generally uncomfortable handling such discussion.

The present research shows that teachers hold a complex spectrum of conceptual models of discussion which can be categorised into five distinct but inter-related models: discussion (1) *as teacher-mediated discourse*; (2) *as open-ended inquiry*; (3) *for the development of reasoning skills*; (4) *as mediated transfer of knowledge to real-life contexts*; (5) *as practice for democratic citizenship.*

In addition, the research also indicates that Science teachers hold conceptual models of discussion equally as complex to those held by their Humanities colleagues but, that the emphasis of Science teachers lay towards the development of social, communication and listening skills, whereas the emphasis of Humanities teachers lay towards using discussion for the development of thinking skills, exposure of pupils to multiple perspectives and for the development of personal opinions.

This research corroborates the research by Bryce and Gray (2004) which indicated that Science teachers were uncomfortable leading discussions of controversial socio-Scientific issues. It adds to this, by further probing Science teachers' views as to why they feel uncomfortable leading such discussion. In general, the Science teachers felt that they would only discuss such issues if they were thoroughly prepared and knew enough about the issue to answer any possible questions. This suggests that the Science teacher's position as an authoritative figure in the eyes of pupils is important to them, and suggests that their comfort level is linked to their control of the information relevant to any discussion. This view is not a position that Humanities teachers share since they suggested, when similarly probed, that the 'Science' (knowledge) perspective of an issue formed only one of many perspectives which would impinge on the discussion and as such, they were perfectly comfortable allowing pupils to control the discussion if their knowledge was 'better' or more complete.

This suggests that if science teachers are to use discussion of controversial socio-scientific issues within their teaching for the development of scientific literacy, then a shift in their current thinking, towards the position currently held by Humanities teachers is required. This would allow science teachers to adopt a more open, less autocratic and perhaps, more stimulating discourse when engaging in such discussion.

The question of how pupils' attitudes towards Science and Technology in general, and towards school science in particular, impacts on their engagement in socio-scientific discussion is a complex one. However, this research suggests that the S2 pupils saw Science and Technology as important for society and believed that Science can be of benefit to mankind, in terms of finding cures for disease but, that they did not think that Science can solve all problems. In fact only 38.5% of the S2 pupils who were questioned agreed that *we should always trust what scientists have to say*. This suggests that while S2 pupils have a healthy respect for the power of Science and Technology as a force for good in society, they are not prepared to believe all of its claims. The data presented in Chapter 5 and 6 indicates that there is a male/female divide in attitude to Science, with 45.9% of XHS females but only 24.4% of males being categorised as anti-science (see Table 5.7). However, it was encouraging to see that when asked '*if given a free choice in S3 which science would you pick*', overall only 15.2% said that they would not pick any science at all (14% male, 16.5% female). This suggests that even although 45.9% of S2 females could be described as anti-science, most of them would still pick at least one Science. In XHS that Science was invariably Biology, since it was the single biggest pupil choice either as Biology on its own (32.7%) or as part of a group with the other sciences (Physics and Chemistry).

In terms of the difference in views and opinions of the XHS S2 pupils from their peers nationally, this research suggests that the pupils surveyed in this research did not differ in terms of their views and opinions on the Environment, Science and Technology, or on what they would like to learn about in their school Science. Furthermore, their views on their Science classes and how they felt about their school science did not differ from their peers nationally as evidenced by the high degree of correlation between the S2 pupil questionnaire data and that of the Scottish ROSE study. This finding strengthens the claim that this cohort of pupils constitutes a representative group and the findings can be generalised

Looking more specifically at the teaching of the lesson series over the term of the research, it was found that the time taken to deliver the discussion lessons using cooperative learning exceeded the allocated time by 83.1% in the first round. However, this over-run had decreased to 35.7% by the second round and had further decreased to 9.2% by the third round, indicating that the teachers had become more familiar with the cooperative learning approach as well as the topic content and were better able to keep to the time allocation despite the lesson content of the series being increased over the period of the research. However, the time taken to generate the learning and teaching materials increased over the course of the research. In addition, the personal planning and preparation of individual teachers, over the course of the research varied, with teachers reporting that their planning and preparation time increased steadily over the first two rounds of action research but decreased in the third round by comparison to the first two rounds. However, this was still greater when compared to normal. This suggests that incorporating discussion using cooperative learning places an increased workload on the teacher. Therefore, an increase in the use of discussion in general and discussion of socio-scientific issue in particular, will place more pressure on teachers in an already crowded syllabus. While the *CfE* science curriculum has a reduced content load, which might offset some of the increase in the time required to deliver such lessons, a major hurdle to the successful implementation of the new science curriculum is the timeframe set by the Scottish Government. In this researcher's view, the August 2010 implementation deadline is unfeasible both in terms of course material development and in terms of the piloting and refining of materials prior to implementation.

Focusing on the discussion lesson series more closely, this research shows that the use of cooperative learning helped to facilitate the shift in classroom discourse away from an autocratic, teacher-dominated, recitation-style towards more open, democratic discourse. This shift was evident in the observation data which focused on the typical exchanges within the classrooms as well as the pace of those exchanges (see Chapter 6). The data suggest that cooperative learning provides a good working model for the practice of discussion since it helps to structure the interactions within the class and makes the management of discussion less stressful for the teacher. In terms of pupil behaviour, pupils reported that in most cases the behaviour within these lessons was better than normal but, in two classes the behaviour was problematic, due in part to the relative inexperience of the teacher concerned and, in the main, to a hard core of pupils in both classes who were determined to be disruptive. The relative success of cooperative learning in terms of behaviour, as with most pedagogical strategies, is heavily dependent on the cooperation of the pupils which in turn, is dependent on their motivation and attitude towards learning. This research suggests that cooperative learning does not adversely affect pupil behaviour; in most cases it improves it.

Looking more critically at the quality of pupils' work during the climate change and global warming discussion lessons, a number of issues arose. It was clear that across all three rounds of action research the S2 cohorts involved carried a number of misconceptions about what the greenhouse effect was and how the underlying mechanism of it contributes to global warming and climate change. The main misconception held by these pupils was that the ozone layer played a significant role in the greenhouse effect and contributed to global warming and climate change. This came to light in the first lesson of all three rounds (see Figure 7.1, 7.5 and 7.6) and the teachers reported that they found it difficult to combat in the cooperative groups as they spent more time with each group than they felt they should have trying to combat the misconception. This suggests that cooperative learning might be inefficient when combating deeply held misconceptions. This claim was bourne out in pupil's writing at the end of the topic (see Figure 7.1).

A key developmental area for scientific literacy is data handling, analysis and interpretation. In the analysing-greenhouse-gas-data worksheet a significant number of S2 pupils struggled to scale and draw line graphs. In addition, they had difficulty interpreting what the data from the graphs was showing, since only 9.4% and 12.9% of the first and second round S2 pupils respectively could correctly answer question 2 (c) in the worksheet (*Examine the date carefully. Does the data support the conclusion that increasing greenhouse emissions are responsible for the 0.5 ºC increase in observed temperature during the past 110 years? Explain your reasoning below?* See Appendix E and F for the worksheet). This suggests that, currently, S2 pupils' do not have a well developed understanding of data interpretation or a clear understanding that data can contradict, as well as support, a working hypothesis. Pupils construed this part of the lesson series as a Mathematics lesson rather than a Science lesson with some pupils commenting that "they don't do Maths".

When one focuses on end-of-topic test data for the first and second round of action research, one can see clear evidence that pupils had difficulty with writing and close reading tasks (both of which are key components of basic literacy). In the first round, pupils had difficulty writing a newspaper article. However, this difficulty was found to be partly due to differences in teacher expectation between the Science and English departments. This difference was characterised by variation in the way that Science and English teachers assess a piece of writing. Science teachers tend to focus on the accuracy of the scientific details being described whereas English teachers focus less on the accuracy of the scientific content and more on sentence and paragraph structure, grammar and use of language. In addition, the learning cycle in English for the production of a piece of extended writing differs from that in Science. In English, the pupil writes an essay, hands it into the teacher who provides feedback to the pupil; the pupil then redrafts the essay and re-submits it for feedback; and this cycle continues until the teacher is satisfied that the task is complete. However, in Science the pupil hands in the work, the teacher grades the work and moves on without any redrafting (this is particularly common in Biology).

The issues pertaining to literacy and numeracy which are highlighted by this research require Science, English and Mathematics teachers to critically assess how they teach these core skills within their curricular areas in order to establish a consistent approach, from the pupil perspective. This professional debate will undoubtedly be potentially controversial and difficult. However, for real progress to be achieved, consistency of pupil experience is critical, since greater consistency will lead to less confusion by pupils as to what teachers expect from them, thus allowing them to truly transfer the skill from one subject to another. When one looks critically at the first and second round S2 cohorts' Standard Grade English grades for Reading and Writing, there is evidence that these two cohorts attained good Reading grades with 43.3% of the first round cohort and 53.5% of the second round cohort attaining a Credit Reading grade. However, their Writing grades were poorer by comparison with 26.2% of the first round and 22.8% of the second round cohort attaining a Credit Writing grade. This suggests that these pupils managed to rise to the challenge in reading but not in writing.

Another key developmental area of pupils' scientific literacy is evidence-based decision-making. This research shows that the S2 pupils found the House of Commons debate and decision-making lessons in the series to be stimulating and different. Some pupils indicated that they saw links with Modern Studies in this lesson. The data showed that the pupils' decision-making on which one from three political proposals they preferred was based on their perspective on social justice; they used the concept of fairness to justify their position either in terms of the economic effect of a carbon tax on the poor, as well as the effect that such a tax would have on employment. Some of the pupils justified their view that there should be no tax on carbon, and that to tax carbon would be unfair since there was insufficient evidence to support the claim that carbon dioxide was responsible for the increased global temperature.

In terms of pupils' engagement with the cooperative learning approach to the discussion, observations, pupil questionnaire and pupil group interview data all suggest that pupils were fully engaged in the discussion during all three rounds of the research. Cross-tabulation analysis of the questionnaire data shows that 59.7% of S2 pupils indicated that they were not bored by the experience with 50.3% of pupils indicating that they enjoyed it. Furthermore, 59.6% of the S2 pupils responded that they were not interested in the issue of global warming and climate change prior to the start of the discussion, but that 61.5% of the S2 pupils felt that they understood more about the issue after the lessons. Interestingly, 53.6% of the S2 pupils felt that the discussion helped them to see the relevance of science to their everyday life. Worryingly, 45% of the S2 pupils felt that they could not express their own opinion during these lessons, suggesting that there is more CPD with teachers to be done in terms of opening up discussions to make them even more inclusive.

The new *CfE* science curriculum calls for the use of both traditional as well as more modern pedagogies. However, quality continuing personal development programmes aimed at helping practicing Science teachers to manage the implementation of these new pedagogical practices is almost non-existent. If Science teachers are not receiving the proper training and support in the proper use of new pedagogies, such as cooperative learning or problem-based learning, they may not be able to rise to the challenges posed by the new science curriculum and the cultural change desired by *CfE* will not happen.

9.2 Limitations of the research.

As outlined in Chapter 3, this research was carried out in one large comprehensive secondary school in the West of Scotland. As a result, the number of participating teachers was relatively small (n=18), thus there may be some issues with the generalisability of the research and the views expressed by the participating teachers. However, this researcher would argue that, since the age and range of experience of the participant teachers covered the full spectrum that one might normally expect to find in a contemporary Scottish secondary school, it could be argued that the views, perspectives and opinions expressed by this sample of teachers are *comparable* and representative of the range of view held currently by the majority of Scottish teachers working in the public sector.

The general ethos of the school is positive and forward looking with a senior management team that is general well respected and thought of as strong by teachers, pupils and parents. However, this school does have issues with challenging pupils ranging from pupils with behavioural and emotional issues to pupils with Autistic spectrum disorders. In this respect this school is no different to any modern urban Scottish secondary school and as such could be considered to be representative of any mainstream Scottish Secondary schools.

A further limitation of this study is its essentially cross-sectional nature. The data reported in this thesis provides a snap-shot in time of where these pupils were in terms of their development towards scientific literacy and as such provides a baseline illustration of their development, particularly with respect to literacy and numeracy, which this researcher would argue form key cornerstones in the development of scientific literacy. It does not provide any evidence as to the proportion of pupils who develop into functional scientific literacy nor does it claim to provide a method by which one might assess such development. However, it does speculate that most pupils should be able to achieve at least a nominal level of scientific literacy with most achieving a functional level by the end of their compulsory Science education.

This research suggests that cooperative learning is an appropriate pedagogical approach to use when teaching a number of the characteristic elements of scientific literacy using discussion. It also provides evidence that when Science teachers do use it, they become more confident and comfortable leading discussions of a socio-scientific nature. However, this thesis does not claim to show that cooperative learning is effective or efficient in terms of raising attainment as evidenced by learning gains from summative assessment data. What it does show is that, in terms of the development of positive attitudes to science, cooperative learning is an effective pedagogy for the promotion of discussion. It maintains the complexity of the issue being discussed and allows multiple perspectives to be exposed and explored. It also suggests that cooperative learning is useful for promoting increased engagement and a wider range of contributions from pupils. Therefore one might reasonably claim that its use could go some way to contributing toward the capacities of effective contributors, confident individuals, responsible citizens and successful learners.

The methodology employed in this research utilised a mixture of qualitative and quantitative approaches. The analysis of the data utilised grounded theory where there was little prior reference to the research literature at the start of the data gathering phase of the research. One might argue that this method of analysis may have allowed fruitful lines of inquiry to pass by untapped. This suggestion, while valid, does not take into account the fact that a strength of the research lay in its depiction of a rich picture of the reality of one Science department's struggle to plan and implement curricular change. In addition, the method of analysis used for both the teacher and pupil accounts of the lessons apply further limitations to the evidence since (as described in Chapter 3) the transcription of the interview audiotapes involved the loss of some data, such as non-verbal behaviour. However the constant comparative method of analysis applied in the research attempted to minimise any loss of phrasing and intonation in the interview data since the audiotapes were listened to repeatedly while the transcripts were read to aid with the coding process. The coding process itself also led to a narrowing of the interpretation of the text since the grouping of codes and their refinement into fewer, wider categories was the product of the researcher's interpretation of the text, thus one might argue that led to some further limiting of the data.

This research provides an insight into the issues surrounding the development of suitable materials, the management of lessons and the evaluation process; therefore it was important that the emergent theory was firmly grounded in the data obtained from the rounds of action research (as opposed to the data being derived from a prescriptive model which lacks the flexibility of the real-life situation). A key strength of the approach used was its high ecological (both external and internal) validity, since the research method employed endeavours to faithfully describe the views and perspectives of all the participants in an accurate manner, as well as providing a detailed account of the developmental process undergone by this group of science teachers. This account provides other Science teachers in a similar position with data against which they can compare their own situation and offers them the opportunity to transfer some of the experiences described here to their own context.

9.3 Further research

The findings of this research perhaps provide suggestions for further investigation. Discussion of contemporary controversial socio-scientific issue is set to become more widespread throughout the new *CfE,* 3-15 Science curriculum Topical Science experiences and outcomes. This leaves enormous scope for further research. First, the findings of this research could be verified by sampling a wider range of schools. Also teachers' views on the discussion of controversial socio-scientific issues in the Science classroom could be further researched in the light of *CfE* given that flexibility is encouraged and therefore variation between schools might be expected. Second, longitudinal studies could be done to assess the progress of pupils' development towards scientific literacy as they move through the educational system. Third, pedagogical action research could be done to assess how pupils' engagement with socio-scientific issues change with topic using the cooperative learning or problem-based learning approach. Fourth, observational studies could be carried out nationally to assess and monitor the implementation of the new *CfE* Science curriculum in terms of the increased use of more open-ended, student-centred forms of pedagogy. Fifth, research into how best to assess pupils' attainment in relation to scientific literacy, from both the formative and summative assessment perspective, is required to help define the transition through and between the levels of scientific literacy. Lastly, quasi-experimental studies could be carried out to assess the effectiveness of different pedagogical approaches for the development of scientific literacy compared with more traditional teaching methods, thereby providing more empirical evidence of what constitutes best practice.

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Appendix A:

Copy of LEA Approval Letter for Research Project

Our Ref:
Your Ref:
Contact: Philip McGhee
Tel: 01236 812235
Fax: 01236 812575
E Mail: mcgheep@northlan.gov.uk
Date: 03.10.2005

North Lanarkshire Council

Department of Education
Michael O'Neill, Director
Municipal Buildings
Kildonan Street
Coatbridge, ML5 3BT
www.northlan.gov.uk

Dear Stephen

Research Project: New paradigms in pedagogy: post normal science

In response to your request to carry out the above research in North Lanarkshire, I am pleased to inform you that approval has been granted at Authority level for you to approach the head/s of establishments, to ask if they are willing to participate in your project.

When you contact the head/s involved you should enclose a copy of this letter as confirmation of North Lanarkshire Council's authorisation but I would remind you that it is the head of establishment who has the final veto over whether his/her school shall participate in the research project.

When you have completed your research you should provide each school with a copy of your findings.

May I take this opportunity to wish you every success with your project. If I can be of any further assistance please do not hesitate to contact me.

Yours sincerely

Philip McGhee

Quality Improvement Officer

INVESTOR IN PEOPLE

Aiming Higher

Appendix B.

A copy of the Parental Information Sheet and Withdrawal of Consent Form

North Lanarkshire Council

Faculty of Education
Jordanhill Campus.

THE UNIVERSITY OF STRATHCLYDE IN GLASGOW

Title of Project: The use of cooperative learning for the promotion of discussion in science.

Principal Investigator: Mr S.P Day
Day Time Telephone: 01236 727956
Email: stephen.p.day@strath.ac.uk

Dear Parent/Guardian,

As you may be aware, the Scottish Executive is in the process of reviewing the secondary school curriculum as part of the 'curriculum for excellence' reform programme. Part of this reform programme is looking towards the promotion of discussion of contemporary science issue within the science curriculum. This is an area of science education that is at present, not part of the current science curriculum and is see by the Scottish Executive as an area which requires further development.

The science department of Greenfaulds High School has agreed to pilot the use of cooperative learning (a type of teaching using small group work) for the promotion of discussion of the Science, Ethics, Economics and Politics that impact on the climate change and global warming debate. The science content of this discussion would be covered as part of your son/daughters normal science curriculum. The only difference being the manner in which the teacher delivers the lesson.

The proposed research project aims to:

- Assess the usefulness of cooperative learning for the promotion of more open forms of classroom discussion.
- Identify factors which influence pupils' enjoyment when learning through discussion.
- Identify issue arising from use of cooperative learning for the teaching of science through discussion.
- Identify factors which may impact on the management of discussion based science teaching.

Part of this work will involve the teaching of a series of lesson on the issue of climate change and global warming to the second year science cohort. A small number of pupils from the second year will be invited to take part in a focus group interview which will be audio-taped, which should last up to forty minutes.

The results of this research will be shared in regular briefing with the science staff and senior management of Greenfaulds High School with a final project report being submitted to North Lanarkshire Council in early January 2010.

I would like to stress that individual pupils will not be identified in any publication or report arising from this study, unless express permission has been granted for direct quotation. All information about your son/daughter will have their name removed so that they cannot be identified from it. This project has been reviewed by the Faculty of Education Ethics Committee.

If you do not wish your son/daughter to take part in this study could you please complete the attached form and return it to you son/daughters science teacher. If you do decide to allow your child to take part in this study you are free to withdraw their participation at any time without giving a reason

Thank you for considering allowing your son/daughter to take part in this study

Mr Day.

Contact for Further information: Mr S.P Day or Dr J May, Greenfaulds High School, Athelstane Drive Cumbernauld, G67 4AQ

North Lanarkshire Council

Faculty of Education
Jordanhill Campus.

THE UNIVERSITY OF STRATHCLYDE IN GLASGOW

Withdrawal of consent

Title of Project: The use of cooperative learning for the promotion of discussion in science.

Principal Investigator: Mr S.P Day.

1. I confirm that I have read and understand the information letter for the above study and have had the opportunity to ask questions.
2. I understand that my son/daughters participation is voluntary and that I am free to withdraw them without giving any reason.

I (signature) ______________________________ do not wish my son/daughter to take part in the above study.

Date: ______________________________

Please return this form to Mr S Day

Appendix C

Teacher Backgrounds

Experienced Science Teachers

For the sake of anonymity all of the science teachers' names were omitted and each teacher was randomly given a code identifier which was known only to the investigator. The teachers' codes were randomly assigned with each code identifying the teacher with the group as follows: experienced science teacher 1 was coded as ExST1.

The average age of the experienced science teacher group was 42.5 ± 11.4 years. The ratio of males to females was 3:3, the total number of years of experience being 99 years with the average number of years of experience being 16.5 years.

ExST1 is a 31 year old female Principal Teacher of Pupil Support who teaches Biology. She has been teaching for nine years. She has a Bachelor of Education (Honours) degree in Biology and Education. She teaches S1 and S2 mixed ability Science classes as well as S3/S4 Standard Grade Biology and S3/4 access 3/Intermediate 1 Biology classes as well as S5 Intermediate 2 and Higher Human Biology classes. In addition to teaching Biology she has considerable experience of teaching S1 to S6 Personal, Social and Health Education (PSHE) classes.

ExST2 is a 38 year old female Biology teacher who has taught for eight years. She has a Bachelor of Science (Honours) degree in Immunology and a Postgraduate Certificate in Education (PGCE Secondary) in Biology with Science. She teaches S1 and S2 mixed ability Science classes as well as S3/S4 Standard Grade Biology and S3/4 access 3/Intermediate 1 Biology classes as well and S5 Intermediate 2 and Higher Human Biology classes. In addition, ExST2 also teaches S6 Advanced Higher Biology as well as S1 to S6 PSHE and has a pupil support role within the school.

ExST3 is a 50 year old male Principal Teacher of Biology who has been teaching for thirty years. ExST3 has a Bachelor of Education (Honours) degree in Biology and Education. In his time within this school he has had various responsibilities such as assistant principal teacher of guidance and acting assistant head teacher. ExST3 currently teaches S1 and S2 mixed ability Science classes. He also teaches S3/S4 Standard Grade Biology classes as well as S3/4 access 3/Intermediate 1 Biology classes. In addition ExST3 also teaches S5 Intermediate 2 Biology and S5/6 Higher Human Biology classes as well as an S5/6 Higher Psychology class.

ExST4 is a 31 year old female Biology/Chemistry teacher who has been teaching for seven years. She has a Bachelor of Science (Honours) degree in Biochemistry and a PGCE (secondary) in Biology with Science and an ATQ in Chemistry. She teaches S1 and S2 mixed ability Science classes as well as S3/S4 access 3/Intermediate 1 Biology classes. In addition, she teaches S3/S4 Standard Grade classes in both Biology and Chemistry and teaches both S5/S6 Higher Human Biology and Chemistry classes. Furthermore, she teaches S1 to S6 PSHE classes.

ExST5 is a 45 year old male Biology/Gaelic teacher who has been teaching for twenty years. He has a Doctor of Philosophy degree in Biochemistry and a Bachelor of Science degree in Biochemistry as well as a PGCE (secondary) in Biology with science and an ATQ in Computing studies. ExST5 is a native Gaelic speaker with responsibility for teaching S1 and S2 Science in Gaelic as well as S1 to S6 Gaelic classes for Mathematics in addition to Higher Gaelic. ExST5 also teaches S1 to S6 PSHE classes in English.

ExST6 is a 60 year old Principal Teacher of Physics who has been teaching for twenty-five years. He has a Bachelor of Science (Honours) degree in Physics and Mathematics and a PGCE (secondary) in Physics with Science. ExST6 teaches S1/S2 mixed ability Science classes as well as S3/S4 Standard Grade Physics classes. In addition he also teaches S5/S6 Higher Physics and Advanced Higher Physics.

ExST7 is a 43 year old female Physics teacher who has a Bachelor of Science degree in Physics and a PGCE (secondary) in Physics with Science and Mathematics. ExST7 teaches S1/S2 mixed ability Science classes as well as S3/S4 Standard Grade and Intermediate 1 Physics classes as well as S5/6 Intermediate 2 Physics. It should be noted that ExST7 did not take part in the semi-structured teacher interviews on discussion but was prepared to contribute to the teaching of the discussion of climate change and global warming using cooperative learning along with the post-lesson series semi-structured interview.

Newly Qualified Science Teacher Background

Each teacher within this group was given a code signifying the teacher with the group as follows; Newly Qualified science teacher 1 was coded as NQST1. The average age of the newly qualified science teacher group was 23.2 ± 0.4. The ratio of males to females was 2:4, the total number of years of experience being 7 years with the average number of years of experience being 1.2 years.

NQST1 is a 24 year old female Chemistry teacher who is in her second year of teaching. She has a Bachelor of Science (honours) degree in Chemistry with a Professional Graduate Diploma in Education (PGDE) in secondary education for Chemistry with Science. She teaches S1 and S2 mixed ability Science classes as well as S3/S4 access 3/Intermediate 1 Chemistry classes. In addition, she teaches S3/S4 Standard Grade Chemistry classes as well as S5 Intermediate 2 Chemistry classes. In addition, NQST1 teaches S1 to S6 PSHE classes.

NQST2 is a 23 year old female Biology probationary teacher. She has a Bachelor of Science (Honours) in Biochemistry and a PGDE (secondary) in Biology with Science. She teaches S1 and S2 mixed ability Science classes as well as S3/S4 access 3/Intermediate 1 Biology classes. In addition, she teaches S3/S4 Standard Grade Biology classes.

NQST3 is a 23 year old female Chemistry probationary teacher. She has a Bachelor of Science (honours) degree in Biochemistry with a PGDE (secondary) education for Chemistry and Biology with Science. She teaches S1 and S2 mixed ability Science classes as well as a S3/S4 access 3/Intermediate 1 Chemistry classes. In addition, she teaches a S3/S4 Standard Grade Chemistry classes and in her probationary year is teaching a S5 PSHE class.

NQST4 is a 23 year old male Physics probationary teacher. He has a Bachelor of Science in Engineering and a PGDE (secondary) in Physics and Mathematics with Science. He teaches S1 and S2 mixed ability Science classes as well as S3/S4 access

3/Intermediate 1 Physics classes. In addition, he teaches a S3/S4 a Standard Grade Physics class

NQST5 is a 23 year old female Physic probationary teacher. She has a Bachelor of Science (honours) degree in applied Physics with a PGDE (secondary) in Physics with Science. She teaches S1 and S2 mixed ability Science classes as well as a S3/S4 access 3/Intermediate 1 Physics class. In addition, she teaches a S3/S4 Standard Gade Physics class.

NQST6 is a 23 year old male Chemistry probationary teacher. He has a Bachelor of Science (honours) degree in Chemistry with a PGDE (secondary) in Chemistry with Science. He teaches S1 and S2 mixed ability Science classes as well as a S3/S4 access 3/Intermediate 1 Chemistry classes. In addition, he teaches a S3/S4 Standard Grade Chemistry class.

Experienced Humanities Teachers.

The sample of experienced humanities teachers was taken in as random a manner as possible by asking the English, RME, Geography and History departments for people to volunteer to take part in an interview. From these departments, six teachers volunteered to be interviewed. All of these teachers had taught classes from S1 to S6 at all levels from Standard Grade to Advanced Higher in their respective disciplines. Each teacher within this group was given a code signifying the teacher with the group as follows; Experienced Humanities Teacher 1 was coded as ExHT1.

The average age of the experienced humanities teacher group was 39.8 ± 15.7 years. The ratio of males to females was 5:1, the total number of years of experience being 94 years with the average number of years experience being 15.7 years.

ExHT1 is a 28 year old female Religious, Moral and Philosophy Studies teacher with six years teaching experience. She has a Master of Arts degree in Philosophy and a post-graduate diploma in Religious Studies and a PGCE (Secondary) in Religious Education.

ExHT2 is a 45 year old male Religious, Moral and Philosophy Studies teacher with thirteen years teaching experience. He has a Bachelor of Arts degree in Media Studies, a Doctor of Philosophy degree in Religion and Film in American Culture and a PGCE (secondary) in Religious Education.

ExHT3 is a 28 year old male Geography/History teacher who has been teaching for seven years. He has a Bachelor of Art (Honours) degree in Geography, a PGCE (Secondary) in Geography as well as an ATQ in History and Modern Studies. At the time of the interview he had just completed the first year of part-time study for a Master of Education degree.

ExHT4 is a 52 year old male Principal Teacher of History and Geography who has been teaching for thirty years, fifteen of which as principal teacher of History and Geography. He has a Bachelor of Arts degree in History and Education.

ExHT5 is a 57 year old male English teacher who has been teaching for thirty-two years He has a Bachelor of Arts degree in English and Philosophy, a PGCE (secondary) in English and has a Master of Education degree in Professional studies.

ExHT6 is a 30 year old male English teacher who has been teaching for seven years. He has a Bachelor of Arts (honours) degree in History and a PGCE (secondary) in English.

Appendix D.

KWL Grid from the first round of Action Research.

Name: ____________________ **Class:** ______ **Teacher:** ______

In the KWL grid below write down 5 things that you know about greenhouse gases and global warming.

In the KWL grid below write down 5 things that you need to find out more about greenhouse gases and global warming.

At the end of the topic write done 5 things that you have learnt about greenhouse gases and global warming

K: What do you know about Greenhouse gases and Global warming?	**W: What do you need to find out more about?**	**L: What have you learned about Greenhouse gases and Global warming?**

Appendix E.

Analysing greenhouse gas data worksheet from the first round of action research.

Name: ________________________ **Class:** ________________________

Analysing Greenhouse Data.

Directions:

In this activity, you will analyze and graph data on observed global temperatures and CO_2 concentrations. Then you will answer questions about this data.

Task 1: In the space below, draw a line graph of the data in Table1. Label the horizontal axis "Year" and label the vertical axis "CO_2 concentrations."

Table 1: Atmosphere Concentrations of CO_2 during the Last 230 Years

Year	CO_2 Concentration (parts per million-ppm)
1750	282
1800	283
1850	290
1900	297
1950	312
1980	335
1990	350

1 (a) Describe the pattern or trend within the CO_2 data found in the graph?

(b) During what years was the trend most pronounced?

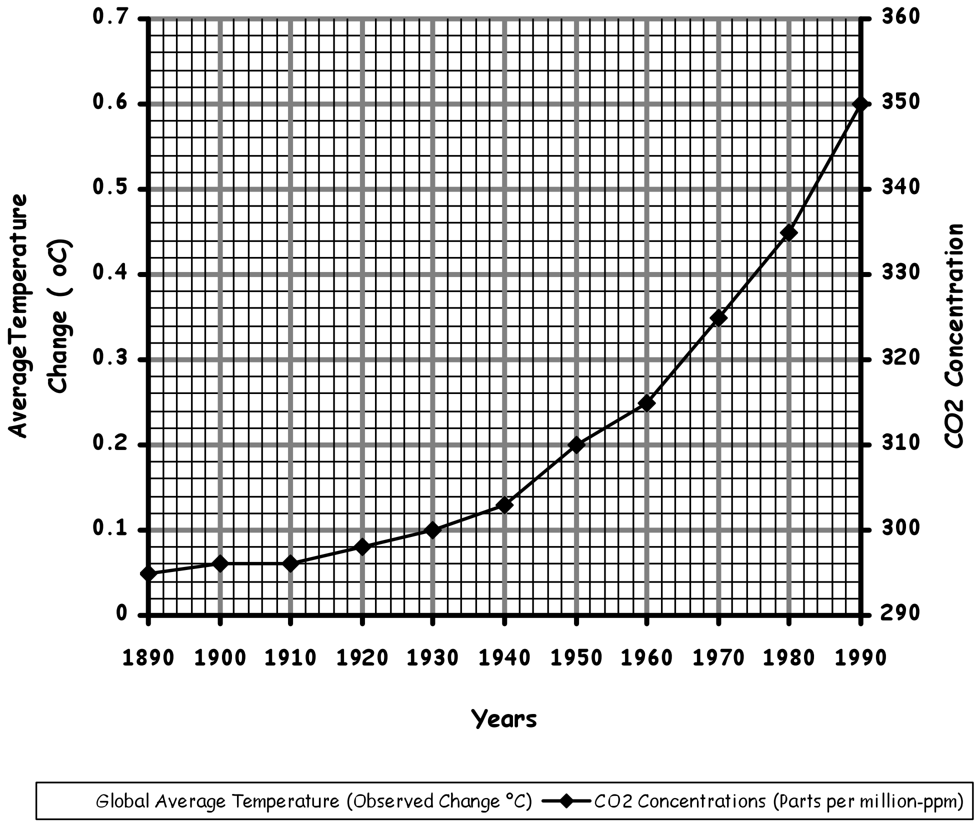
____

____

Task 2:

Table 2 gives actual average global temperature changes during the past 110 years, using 1890 as a base year. **Below** Table 2 is a graph showing CO_2 concentrations during this same time period. Graph the data in Table 2 on the graph below. Then answer the questions.

Year	Global Average Temperature (Observed Change °C)
1890	0.00
1900	0.18
1910	0.20
1920	0.22
1930	0.43
1940	0.54
1950	0.48
1960	0.43
1970	0.40
1980	0.55
1990	0.56



2 (a) During what time period was the observed temperature increase the greatest?

(b) What time period shows the greatest increase in CO_2 concentrations?

(c) Examine the date carefully. Does the data support the conclusion that increasing greenhouse emissions are responsible for the 0.5 °C increase in observed temperature during the past 110 years? Explain your reasoning below.

(d) What are some other natural phenomena that possibly could explain increases in temperature?

(e) Assume you were a weather scientist and were called before a Parliamentary committee to testify on the global warming issue. Would you recommend public policies that would require reductions in greenhouse gas emissions? Explain your position and support it with scientific evidence.

(f) Did the *cost* of greenhouse reduction policies affect your decision in (e) above? Explain.

Appendix F.

Analysing greenhouse gas data worksheet from the second round of action research.

Name: ______________________ **Class:** ______________________

Directions:

In this activity, you will analyze and graph data on observed global temperatures and CO_2 concentrations. Then you will answer questions about this data.

Task 1: In the space below, draw a line graph of the data in Table1. Label the horizontal axis "Year" and label the vertical axis "CO_2 concentrations."

Table 1: Atmosphere Concentrations of CO_2 during the Last 230 Years

Year	CO_2 Concentration (parts per million-ppm)
1750	282
1800	283
1850	290
1900	297
1950	312
1980	335
1990	350

1 (a) Describe the pattern or trend within the CO_2 data found in the graph?

____

____

(b) During which 50 year period was the trend most pronounced?

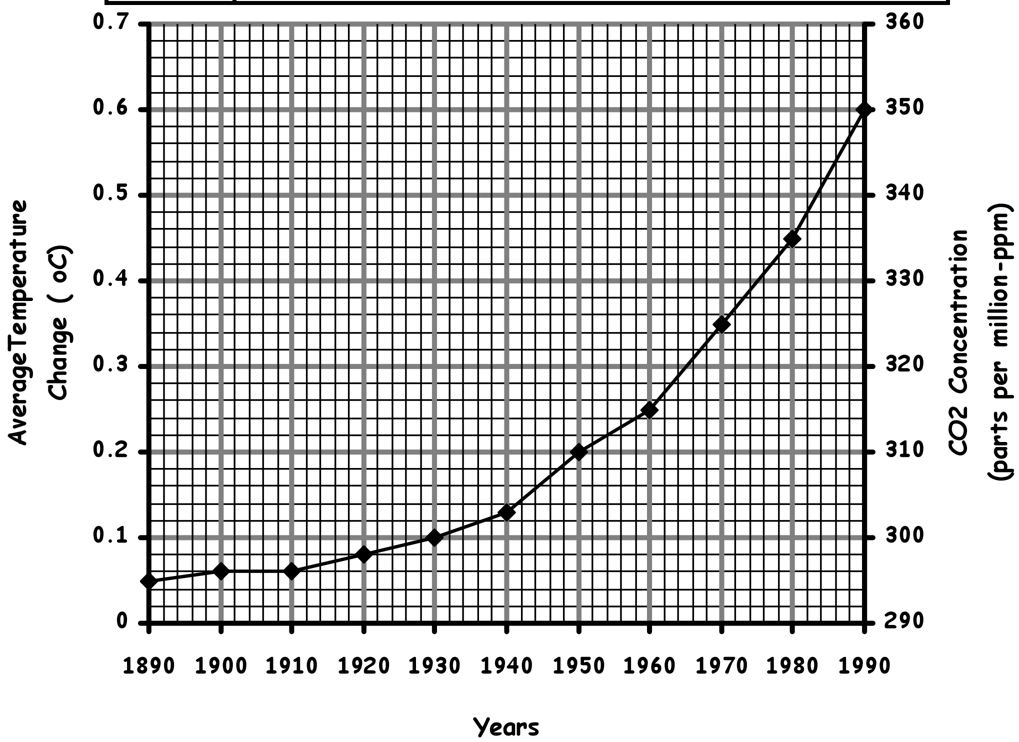
____

____

Task 2:

Table 2 gives actual average global temperature changes during the past 110 years, using 1890 as a base year. **Below** Table 2 is a graph showing CO_2 concentrations during this same time period. Graph the data in Table 2 on the graph below. Then answer the questions.

Year	Global Average Temperature (Observed Change °C)
1890	0.00
1900	0.18
1910	0.20
1920	0.22
1930	0.43
1940	0.54
1950	0.48
1960	0.43
1970	0.40
1980	0.55
1990	0.56



2 (a) During which 20 year time period was the observed temperature increase the greatest?

1890 to 1910 ☐

1910 to 1930 ☐

1930 to 1950 ☐

1950 to 1970 ☐

1970 to 1990 ☐

(b) Which 30 year time period shows the greatest increase in CO_2 concentrations?

1890 to 1920 ☐

1920 to 1950 ☐

1950 to 1980 ☐

(c) Examine the Graph 2 carefully. Does the data support the conclusion that increasing CO_2 gas emissions are responsible for the 0.5 °C increase in observed temperature during the past 110 years? Explain your answers below.

____

____

____

____

____

(d) What are some other natural phenomena that possibly could explain increases in temperature?

____

____

____

Appendix G.

Carbon Tax Scenario Worksheet

Food for Thought

- In this case study the MP's are dealing with an issue that is receiving much attention—Global warming. The issue is whether to impose a "carbon tax" on fossil fuels, such as coal, oil, and natural gas.
- Analyse the arguments put forward by each MP in this case study and use the Decision Worksheet and the Decision Grid to help determine whether such a tax would be a good idea. Be prepared to defend your decision!

Decision Grid

Alternatives	*Reduces CO_2*	*Cost*	*Fairness*	*Economic Growth*	*Promote Energy Efficiency*
The Carbon Emissions Bill					
Do nothing at this time					
Greenhouse Gas and Global Warming Insurance Policy					

1. If you were an MP Which option would you vote for?

____

____

____

2. Which Policy do you prefer? Explain why you prefer this choice?

____

____

____

____

____

Appendix H.

Pupil Questionnaire 2007

This booklet has questions about you, and about your experiences and interests related to science in school and outside school.

There are no correct or incorrect answers, only answers that are right for you. Please think carefully and give answers that reflect your own thinking.

If there is a question you do not understand or If you are in doubt, you may ask the teacher. **This is not a test!**

For most questions, you simply put a tick in the appropriate box. The purpose of this questionnaire is to find out what Secondary School Pupils think about science at school as well as in their everyday life. This information may help us to make schools science better. Your answers are **anonymous**, so please do not write your name on this questionnaire.

THANK YOU!
Your answers will be a big help.

START HERE:

I am a ☐ **girl** ☐ **boy**

I am _____ years old

A. What I want to learn about

How interested are you in learning about the following?
(Give your answer with a tick on each line. If you do not understand, ask your teacher)

		Not Intere-sted			Very Intere-sted
1	Stars, planets and the universe	☐	☐	☐	☐
2	Chemicals, their properties and how they react	☐	☐	☐	☐
3	The inside of the earth	☐	☐	☐	☐
4	How mountains, rivers and oceans develop and change	☐	☐	☐	☐
5	Clouds, rain and the weather	☐	☐	☐	☐
6	The origin and evolution of life on earth	☐	☐	☐	☐
7	How the human body is built and functions	☐	☐	☐	☐
8	Heredity, and how genes influence how we develop	☐	☐	☐	☐
9	Sex and reproduction	☐	☐	☐	☐
10	Birth control and contraception	☐	☐	☐	☐
11	How babies grow and mature	☐	☐	☐	☐
12	Cloning of animals	☐	☐	☐	☐
13	Animals in other parts of the world	☐	☐	☐	☐
14	Dinosaurs, how they lived and why they died out	☐	☐	☐	☐
15	How plants grow and reproduce	☐	☐	☐	☐
16	How people, animals, plants and the environment depend on each other	☐	☐	☐	☐
17	Atoms and molecules	☐	☐	☐	☐
18	How radioactivity affects the human body	☐	☐	☐	☐
19	Light around us that we cannot see (infrared, ultraviolet)	☐	☐	☐	☐
20	How animals use colours to hide, attract or scare	☐	☐	☐	☐
21	How different musical instruments produce different sounds	☐	☐	☐	☐
22	Black holes, supernovas and other spectacular objects in outer space	☐	☐	☐	☐
23	How meteors, comets or asteroids may cause disasters on earth	☐	☐	☐	☐
24	Earthquakes and volcanoes	☐	☐	☐	☐
25	Tornados, hurricanes and cyclones	☐	☐	☐	☐
26	Epidemics and diseases causing large losses of life	☐	☐	☐	☐
27	Brutal, dangerous and threatening animals	☐	☐	☐	☐
28	Poisonous plants in my area	☐	☐	☐	☐
29	Deadly poisons and what they do to the human body	☐	☐	☐	☐
30	How the atom bomb functions	☐	☐	☐	☐
31	Explosive chemicals	☐	☐	☐	☐
32	Biological and chemical weapons and what they do to the human body	☐	☐	☐	☐
33	The effect of strong electric shocks and lightning on the human body	☐	☐	☐	☐
34	How it feels to be weightless in space	☐	☐	☐	☐
35	How to find my way and navigate by the stars	☐	☐	☐	☐
36	How the eye can see light and colours	☐	☐	☐	☐
37	What to eat to keep healthy and fit	☐	☐	☐	☐
38	Eating disorders like anorexia or bulimia	☐	☐	☐	☐
39	The ability of lotions and creams to keep the skin young	☐	☐	☐	☐
40	How to exercise to keep the body fit and strong	☐	☐	☐	☐
41	Plastic surgery and cosmetic surgery	☐	☐	☐	☐
42	How radiation from solariums and the sun might affect the skin	☐	☐	☐	☐
43	How the ear can hear different sounds	☐	☐	☐	☐
44	Rockets, satellites and space travel	☐	☐	☐	☐
45	The use of satellites for communication and other purposes	☐	☐	☐	☐
46	How X-rays, ultrasound, etc. are used in medicine	☐	☐	☐	☐
47	How petrol and diesel engines work	☐	☐	☐	☐
48	How a nuclear power plant functions	☐	☐	☐	☐

B. Me and the environmental challenges.

To what extent do you agree with the following statements about problems with the environment (pollution of air and water, overuse of resources, global changes of the climate etc.)? (Give your answer with a tick on each line. If you do not understand, ask your teacher.)

		Disagree			Agree
1.	Threats to the environment are not my business	☐	☐	☐	☐
2.	Environmental problems make the future of the world look bleak and hopeless	☐	☐	☐	☐
3.	Environmental problems are exaggerated	☐	☐	☐	☐
4.	Science and technology can solve all environmental problems	☐	☐	☐	☐
5.	I am willing to have environmental problems solved even if this means sacrificing many goods	☐	☐	☐	☐
6.	I can personally influence what happens with the environment	☐	☐	☐	☐
7.	We can still find solutions to our environmental problems	☐	☐	☐	☐
8.	People worry too much about environmental problems	☐	☐	☐	☐
9.	Environmental problems can be solved without big changes in our way of living	☐	☐	☐	☐
10	People should care more about protection of the environment	☐	☐	☐	☐
11	It is the responsibility of the rich countries to solve the environmental problems of the world	☐	☐	☐	☐
12	I think each of us can make a significant contribution to environmental protection	☐	☐	☐	☐
13	Environmental problems should be left to the experts	☐	☐	☐	☐
14	I am optimistic about the future	☐	☐	☐	☐
15	Animals should have the same right to life as people	☐	☐	☐	☐
16	It is right to use animals in medical experiments if this can save human lives	☐	☐	☐	☐
17	Nearly all human activity is damaging for the environment	☐	☐	☐	☐
18	The natural world is sacred and should be left in peace	☐	☐	☐	☐

C. My opinions about science and technology.

To what extent do you agree with the following statements? (Give your answer with a tick on each row. If you do not understand, ask your teacher

		Disagree			Agree
1	Science and technology are important for society	☐	☐	☐	☐
2	Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc.	☐	☐	☐	☐
3	Thanks to science and technology, there will be greater opportunities for future generations	☐	☐	☐	☐
4	Science and technology make our lives healthier, easier and more comfortable	☐	☐	☐	☐
5	New technologies will make work more interesting	☐	☐	☐	☐
6	The benefits of science are greater than the harmful effects it could have	☐	☐	☐	☐
7	Science and technology will help to eradicate poverty and famine in the world	☐	☐	☐	☐
8	Science and technology can solve nearly all problems	☐	☐	☐	☐
9	Science and technology are helping the poor	☐	☐	☐	☐
10	Science and technology are the cause of the environmental problems	☐	☐	☐	☐
11	A country needs science and technology to become developed	☐	☐	☐	☐
12	Science and technology benefit mainly the developed countries	☐	☐	☐	☐
13	Scientists follow the scientific method that always leads them to correct answers	☐	☐	☐	☐
14	We should always trust what scientists have to say	☐	☐	☐	☐
15	Scientists are neutral and objective	☐	☐	☐	☐
16	Scientific theories develop and change all the time	☐	☐	☐	☐

D. What I want to learn about.

How interested are you in learning about the following?
(Give your answer with a tick on each line. If you do not understand, ask your teacher)

		Not Interested			Very Interested
1.	How crude oil is converted to other materials, like plastics and textiles	☐	☐	☐	☐
2.	Optical instruments and how they work (telescope, camera, microscope, etc.)	☐	☐	☐	☐
3.	The use of lasers for technical purposes (CD-players, bar-code readers, etc.)	☐	☐	☐	☐
4.	How cassette tapes, CDs and DVDs store and play sound and music	☐	☐	☐	☐
5.	How things like radios and televisions work	☐	☐	☐	☐
6.	How mobile phones can send and receive messages	☐	☐	☐	☐
7.	How computers work	☐	☐	☐	☐
8.	The possibility of life outside earth	☐	☐	☐	☐
9.	Astrology and horoscopes, and whether the planets can influence human beings	☐	☐	☐	☐
10	Unsolved mysteries in outer space	☐	☐	☐	☐
11	Life and death and the human soul	☐	☐	☐	☐
12	Alternative therapies (acupuncture, homeopathy, yoga, healing, etc.) and how effective they are	☐	☐	☐	☐
13	Why we dream while we are sleeping, and what the dreams may mean	☐	☐	☐	☐
14	Ghosts and witches, and whether they may exist	☐	☐	☐	☐
15	Thought transference, mind-reading, sixth sense, intuition, etc	☐	☐	☐	☐
16	Why the stars twinkle and the sky is blue	☐	☐	☐	☐
17	Why we can see the rainbow	☐	☐	☐	☐
18	Properties of gems and crystals and how these are used for beauty	☐	☐	☐	☐

E. My science classes.

To what extent do you agree with the following statements about the science that you may have had at school?
(Give your answer with a tick on each line. If you do not understand, ask your teacher.)

		Disagree			Agree
1	School science is a difficult subject	☐	☐	☐	☐
2	School science is interesting	☐	☐	☐	☐
3	School science is rather easy for me to learn	☐	☐	☐	☐
4	School science has opened my eyes to new and exciting jobs	☐	☐	☐	☐
5	I like school science better than most other subjects	☐	☐	☐	☐
6	I think everybody should learn science at school	☐	☐	☐	☐
7	The things that I learn in science at school will be helpful in my everyday life	☐	☐	☐	☐
8	I think that the science I learn at school will improve my career chances	☐	☐	☐	☐
9	School science has made me more critical and sceptical	☐	☐	☐	☐
10	School science has increased my curiosity about things we cannot yet explain	☐	☐	☐	☐
11	School science has increased my appreciation of nature	☐	☐	☐	☐
12	School science has shown me the importance of science for our way of living	☐	☐	☐	☐
13	School science has taught me how to take better care of my health	☐	☐	☐	☐
14	I would like to become a scientist	☐	☐	☐	☐
15	would like to have as much science as possible at school	☐	☐	☐	☐
16	I would like to get a job in technology	☐	☐	☐	☐

F. Statements about Science.

Please read the following statements and, within each group, **tick the one** statement that most closely represents your viewpoint only.

1a	Science is a collection of true facts.	☐
1b	Science is a procedure.	☐
1c	Science is a world view.	☐

2a	Science assumes cause and effect.	☐
2b	Science assumes nothing.	☐

3a	Science is independent of the culture.	☐
3b	Science is affected by the language and culture it is conducted in.	☐
3c	Scientific ideas are the stories that western scientists accept but have no special claim to describe reality over the stories of other cultures and people.	☐

4a	Scientific ideas are true	☐
4b	Scientific ideas are testable but can never be entirely proven:.	☐
4c	Scientific ideas are only relevant for western thinkers and only pertain to the western world view.	☐

5a	The scientific method is a loose procedure for making observations about the physical world.	☐
5b	The scientific method requires that reproducible tests be conducted.	☐

6a	Scientific thinking is logical and linear and does not involve intuition.	☐
6b	Scientific thinking is a combination of logic and intuition.	☐
6c	Scientific thinking is primarily intuitive.	☐

7a	Conclusions drawn by scientists are true.	☐
7b	Conclusions drawn by most scientists are influenced by political pressures.	☐
7c	Conclusions drawn by scientists are provisional and may be revised as more data become available.	☐
7d	Conclusions drawn by scientists may not be relevant for other people.	☐

8a	Theories can be proven.	☐
8b	Theories can only be disproven.	☐

9a	Theories are effective models for describing reality.	☐
9b	Theories are just stories.	☐
9c	Theories are based only in facts.	☐

10a	The community of scientists is open and inclusive to anyone.	☐
10b	The community of scientists requires successful completion of rigorous training to join.	☐
10c	The community of scientists is open to only specific demographic groups.	☐

11a	If I choose to, I could become a scientist.	☐
11b	If I tried to become a scientist, I might not succeed.	☐
11c	I am a scientist.	☐

12a	Scientists would be completely accepting of me if I became a scientist.	☐
12b	Scientists would mostly accept me as one of them, maybe a few would not.	☐
12c	Scientists would never fully accept me into their ranks.	☐
12d	The ranks of scientists will always be closed to me.	☐

13a	I think that science would be a good career path for me.	☐
13b	I think that science wouldn't be a good career path for me.	☐

G. How many books are in your home?

There are usually about 40 books per metre of shelving. Do not include magazines **(Please tick only one box)**

- None ☐
- 1-10 books ☐
- 11-50 books ☐
- 51-100 books ☐
- 101-250 books ☐
- 251-500 books ☐
- More than 500 books ☐

H. S3 Course Choice.

If given a **free choice** at the end of S2, which course choice would you pick from the following?

- Biology ☐
- Chemistry ☐
- Physics ☐
- Biology and Chemistry ☐
- Physics and Chemistry ☐
- Biology, Chemistry and Physics ☐
- None of the above ☐

I. What I want to learn about.

How interested are you in learning about the following?
(Give your answer with a tick on each line. If you do not understand as you teacher)

		Not Interested			Very Interested
1	Symmetries and patterns in leaves and flowers	☐	☐	☐	☐
2	How the sunset colours the sky	☐	☐	☐	☐
3	The ozone layer and how it may be affected by humans	☐	☐	☐	☐
4	The greenhouse effect and how it may be changed by humans	☐	☐	☐	☐
5	What can be done to ensure clean air and safe drinking water	☐	☐	☐	☐
6	How technology helps us to handle waste, garbage and sewage	☐	☐	☐	☐
7	How to control epidemics and diseases	☐	☐	☐	☐
8	Cancer, what we know and how we can treat it	☐	☐	☐	☐
9	Sexually transmitted diseases and how to be rotected against them	☐	☐	☐	☐
10	How to perform first-aid and use basic medical equipment	☐	☐	☐	☐
11	What we know about HIV/AIDS and how to control it	☐	☐	☐	☐
12	How alcohol and tobacco might affect the body	☐	☐	☐	☐
13	How different narcotics might affect the body	☐	☐	☐	☐
14	The possible radiation dangers of mobile phones and computers	☐	☐	☐	☐
15	How loud sound and noise may damage my hearing	☐	☐	☐	☐
16	How to protect endangered species of animals	☐	☐	☐	☐
17	How to improve the harvest in gardens and farms	☐	☐	☐	☐
19	Organic and ecological farming without use of pesticides and artificial fertilizers	☐	☐	☐	☐
20	How energy can be saved or used in a more effective way	☐	☐	☐	☐
21	New sources of energy from the sun, wind, tides, waves, etc.	☐	☐	☐	☐
22	How different sorts of food are produced, conserved and stored	☐	☐	☐	☐
23	How my body grows and matures	☐	☐	☐	☐
24	Animals in my area	☐	☐	☐	☐
25	Plants in my area	☐	☐	☐	☐
26	Detergents, soaps and how they work	☐	☐	☐	☐
27	Electricity, how it is produced and used in the home	☐	☐	☐	☐

		Not Interested			Very Interested
28	How to use and repair everyday electrical and mechanical equipment	☐	☐	☐	☐
29	The first landing on the moon and the history of space exploration	☐	☐	☐	☐
30	How electricity has affected the development of our society	☐	☐	☐	☐
31	Biological and human aspects of abortion	☐	☐	☐	☐
32	How gene technology can prevent diseases	☐	☐	☐	☐
33	Benefits and possible hazards of modern methods of farming	☐	☐	☐	☐
34	Why religion and science sometimes are in conflict	☐	☐	☐	☐
35	Risks and benefits of food additives	☐	☐	☐	☐
36	Why scientists sometimes disagree	☐	☐	☐	☐
37	Famous scientists and their lives	☐	☐	☐	☐
38	Big blunders and mistakes in research and inventions	☐	☐	☐	☐
39	How scientific ideas sometimes challenge religion, authority and tradition	☐	☐	☐	☐
40	Inventions and discoveries that have changed the world	☐	☐	☐	☐
41	Very recent inventions and discoveries in science and technology	☐	☐	☐	☐
42	Phenomena that scientists still cannot explain	☐	☐	☐	☐

J. Global Warming Discussion Lessons.

Please answer the following questions as honestly as possible. (Give your answer with a tick on each line. If you do not understand as you teacher)

		Disagree			Agree
1	I enjoyed the discussion on global warming	☐	☐	☐	☐
2	I found the discussion on global warming hard	☐	☐	☐	☐
3	The discussion on global warming gave me the chance to express my own opinions	☐	☐	☐	☐
4	Everyone in my group took part equally in the lessons	☐	☐	☐	☐
5	There was enough information provided for my group to successfully complete the tasks set in each lesson	☐	☐	☐	☐
6	The information was easy to read and the language level was suitable for my year group	☐	☐	☐	☐
7	Working in groups made the question in the worksheets easier to answer	☐	☐	☐	☐
8	The global warming issue was of interest to me before these lessons	☐	☐	☐	☐
9	The discussion has changed they way I think about global warming and climate change.	☐	☐	☐	☐
10	I found this discussion boring	☐	☐	☐	☐
11	I would like to discuss other topics such as using animal in medical research and embryonic stem cell research in my science class.	☐	☐	☐	☐
12	This discussion helped me to see how science is relevant to my life.	☐	☐	☐	☐
13	These lessons were different from my normal science lessons.	☐	☐	☐	☐
14	I like working as part of a group.	☐	☐	☐	☐
15	I feel that I understand more about greenhouse gases and global warming after these lessons	☐	☐	☐	☐
16	During the group discussion I was able to ask my teacher for help and advice	☐	☐	☐	☐

K. My future job.

How important are the following issues for your potential future occupation or job? (Give your answer with a tick on each line. If you do not understand, ask your teacher).

		Not Interested			Very Interested
1	Working with people rather than things	☐	☐	☐	☐
2	Helping other people	☐	☐	☐	☐
3	Working with animals	☐	☐	☐	☐
4	Working in the area of environmental protection	☐	☐	☐	☐
5	Working with something easy and simple	☐	☐	☐	☐
6	Building or repairing objects using my hands	☐	☐	☐	☐
7	Working with machines or tools	☐	☐	☐	☐
8	Working artistically and creatively in art	☐	☐	☐	☐
9	Using my talents and abilities	☐	☐	☐	☐
10	Making, designing or inventing something	☐	☐	☐	☐
11	Coming up with new ideas	☐	☐	☐	☐
12	Having lots of time for my friends	☐	☐	☐	☐
13	Making my own decisions	☐	☐	☐	☐
14	Working independently of other people	☐	☐	☐	☐
15	Working with something I find important and meaningful	☐	☐	☐	☐
16	Working with something that fits my attitudes and values	☐	☐	☐	☐
17	Having lots of time for my family	☐	☐	☐	☐
18	Working with something that involves a lot of travelling	☐	☐	☐	☐
19	Working at a place where something new and exciting happens frequently	☐	☐	☐	☐
20	Earning lots of money	☐	☐	☐	☐
21	Controlling other people	☐	☐	☐	☐
22	Becoming famous	☐	☐	☐	☐
23	Having lots of time for my interests, hobbies and activities	☐	☐	☐	☐
24	Becoming 'the boss' at my job	☐	☐	☐	☐
25	Developing or improving my knowledge and abilities	☐	☐	☐	☐
26	Working as part of a team with many people around me	☐	☐	☐	☐

L. How I feel about Science in School

To what extent do you agree with the following:
(Give your answer with a tick on each line. If you do not understand, ask your teacher).

		Disagree			Agree
1	In Science, I would rather learn a lot about few topics than a little about a lot of different topics.	☐	☐	☐	☐
2	Doing practical and experimental work helps me to understand science topics.	☐	☐	☐	☐
3	Doing practical and experimental work with good, modern apparatus makes me want to study science.	☐	☐	☐	☐
4	My School Science rooms are exciting places in which to work	☐	☐	☐	☐
5	If practical content of the course were increased it would give me grater enjoyment of Science.	☐	☐	☐	☐
6	I found Primary Science interesting	☐	☐	☐	☐
7	Science at Primary School prepared me well for Science classes in Secondary School	☐	☐	☐	☐
8	I find Science in Secondary School more interesting than Science in Primary School.	☐	☐	☐	☐

M. Myself as a scientist

Assume that you are grown up and work as a scientist. You are free to do research that you find important and interesting. Write some sentences about what you would like to do as a researcher and why.

I would like:

Because:

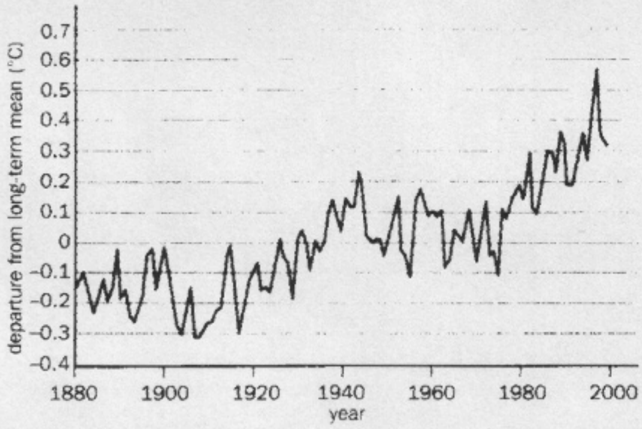
Appendix I

First Round End-of-Topic Test.

Global Warming Discussion Test

Name: ______________________ **Class:** __________ **Teacher:** __________

1. The graph shows how the temperature of the Earth has changed over the last 100 years.



(a) How has the temperature of the Earth changed over the last 100 years?

____ 1

(b) Describe two things that can happen as a result of this temperature change.

1. ____

2. ____ 2

(c) What is the scientific name for this temperature change?

____ 1

(d) (i) Name two gas that causes this temperature change.

1. ____

2. ____ 2

(ii) Where does this gas come from?

____ 1

Page 1 of 3

Global Warming Discussion Test

2. Imagine you are an investigative reporter for The Glasgow Herald. Your editor wants you to write an article about Greenhouse gases and global warming and the possible impact that this issue will have on the environment and on society.

You must write this article using the following questions as a guide

- What are greenhouse gases and what is the greenhouse effect?
- What is the impact of greenhouse gases on global warming?
- What is the effect of global warming on the environment and society?
- What measure could be introduced to reduce the effect of global warming?

20

Appendix J.

Second Round End-of-Topic Test.

Global Warming and Climate Change Test

Name: ________________ **Class:** __________ **Teacher:** _________

GLOBAL WARMING - AN OVERVIEW

BBC Broadcast Meteorologist Helen Willetts explains the issue of global warming - what the problem is and how we've contributed to it.

Like our day-to-day weather, climate change is a very complex subject. The latest thinking is that the world is warming up, but how this will affect us in the future is difficult to confirm. All scientists agree that the world is warming - the debate is centred on how much is due to human activity.

When we talk about global warming, we talk about the `greenhouse effect'. This is actually a natural and essential feature of our atmosphere without which our planet would be uninhabitable. This process works by the principle that certain atmospheric gases (or greenhouse gases) allow beneficial rays from the Sun, such as heat, to reach the Earth. At the same time, these gases prevent much of the heat reflected and radiated back off the surface of the Earth from escaping into space. The net result: more heat is received from the Sun than is lost back to space, keeping the Earth's surface some 30 to 35°C warmer than it would otherwise be.

The problem is that man is adding to and changing the levels of the gases responsible for the greenhouse effect and is therefore enhancing this warming, by preventing heat escaping back into space.

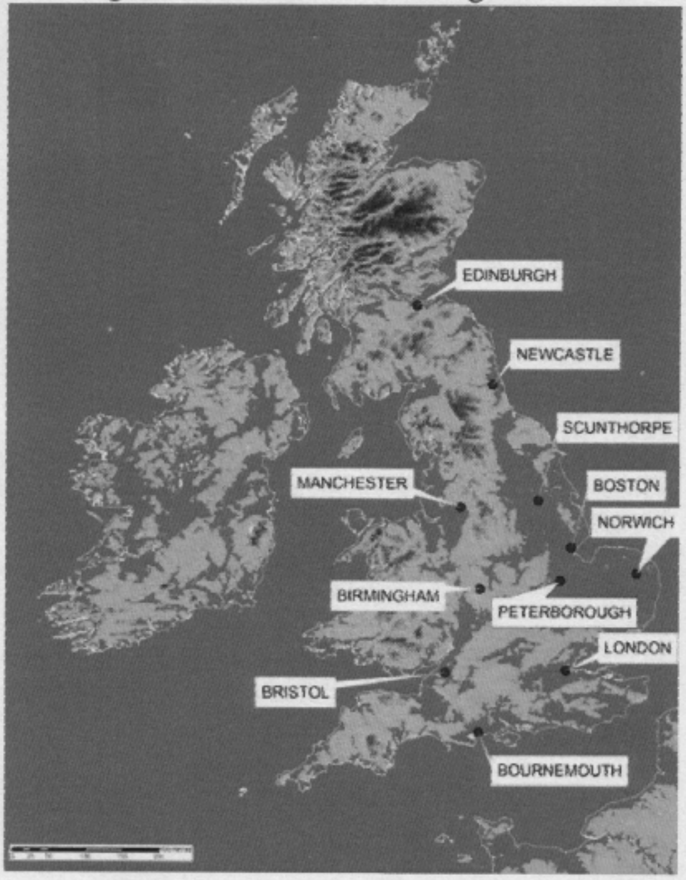
Carbon dioxide, CO_2, is the gas most significantly enhancing the greenhouse effect. Plant respiration and decomposition of organic material release more than 10 times the CO_2 released by human activities, but these releases have generally been in balance during the centuries leading up to the Industrial Revolution because of the amount of CO_2 absorbed by plants through photosynthesis. Since the Industrial Revolution the amount of CO_2 released has increased by 30%. Other greenhouse gases include methane, nitrous oxide, CFCs (manmade) and ozone. One major problem is that these gases can remain in the atmosphere for decades.

The burning of fossil fuels (oil, natural gas and coal) by heavy industry, increased transport and other human activities such as deforestation, are the primary reasons for increased emissions of these gases. Other factors slow the warming, but not to the same degree.

At the same time as greenhouse gases such as CO_2 and methane are increasing; so too are solid particles in the atmosphere from human made sulphur emission. These small sulphur particles reflect back some of the sunlight and hence act to slow down the cooling.

However whereas carbon dioxide can remain in the atmosphere for 100 years, sulphur dioxide only lasts a few days and can be easily removed by rain (creating what we call acid rain). Therefore it only temporarily masks the full effect of CO_2.

Evidence is mounting that mankind is affecting the global climate, and the current warming has exceeded natural changes.



In order to try to predict possible consequences of this warming for the future, research institutes use climate modelling to simulate the climate and oceans over many decades.

So far model simulations point to global temperature rises of approximately 3°C in the next 100 years. This doesn't sound much but it has been calculated that the difference between our temperature now and that in an ice age is only around 6-8°C.

Climate models also predict changes in rainfall and a continued rise in sea level. Sea level rises will be due to thermal expansion of the ocean along with the melting of glaciers and mountain snow and ice. The best estimate is 50cm by the year 2100, but this will vary considerably with location.

This is what could happen to the UK in future as a result of global warming - much of the country is shown to be under the water. A map of the UK after a sea level rise of 84 metres - 275 feet. This is what would be left of the UK if all the world's ice melted. Produced by the Benfield Hazard Research Centre, University of London.

Adapted from "Global Warming - an Overview" by Helen Willetts.
(www.bbc.co.uk/weather/features/global warming1)

Global Warming and Climate Change Test

1. This is a summary of the first part of the leaflet. Complete the summary by putting **one or more words in each** gap. You may use words from the leaflet or your own words.

Scientists are in no doubt that the world is ____________ but there is uncertainty about its future effects and how far we are responsible. The 'greenhouse effect' is a ____________ process. It helps the Earth ____________ more ____________ from the sun than is ____________

Unfortunately, man is ____________ the levels of gases which create the 'greenhouse effect' which is resulting in ____________ in the heat being ____________ on earth. The start of the ____________ is thought to date back to ____________ **(10)**

2. What gas is mostly responsible for global warming?

____________ **(1)**

3. Why do you think that the Industrial Revolution caused a large increase in the amount of atmospheric carbon dioxide?

____

____________ **(1)**

4. Give one naturally occurring way that carbon dioxide can get into the atmosphere.

____________ **(1)**

5. Give one non-naturally occurring way that carbon dioxide can get into the atmosphere.

____________ **(1)**

6. Why are the carbon dioxide emissions since the Industrial Revolution blamed for the increase in global warming, rather than the emissions before this?

____________ **(1)**

7. Look at the map of the UK at the end of the text. From information given in the text, give 2 reasons why global warming might cause the sea level to rise.

(i) ____________

(ii) ____________ **(2)**

8. Look at the two diagrams below.

Diagram 1 shows the natural greenhouse effect by which greenhouse gases retain enough heat to make Earth habitable.

Diagram 2 shows the effects of increased greenhouse gases in the atmosphere.

Complete Diagram 2 using the information given in the box.

Put the letter corresponding to the information in the correct box.

Diagram 1 - Natural greenhouse effect

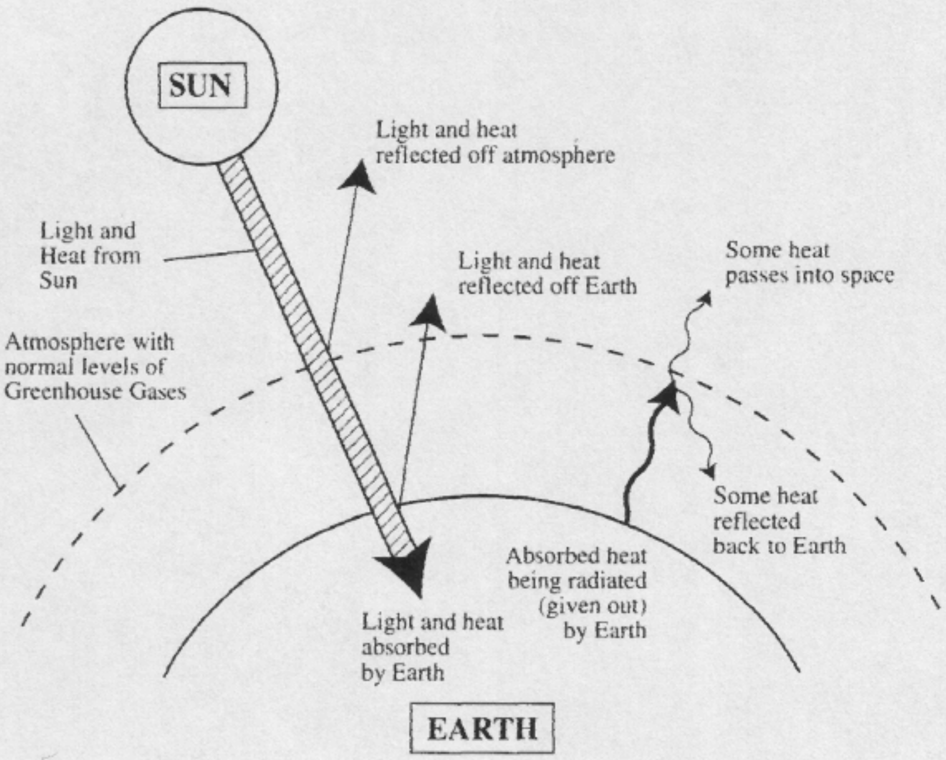
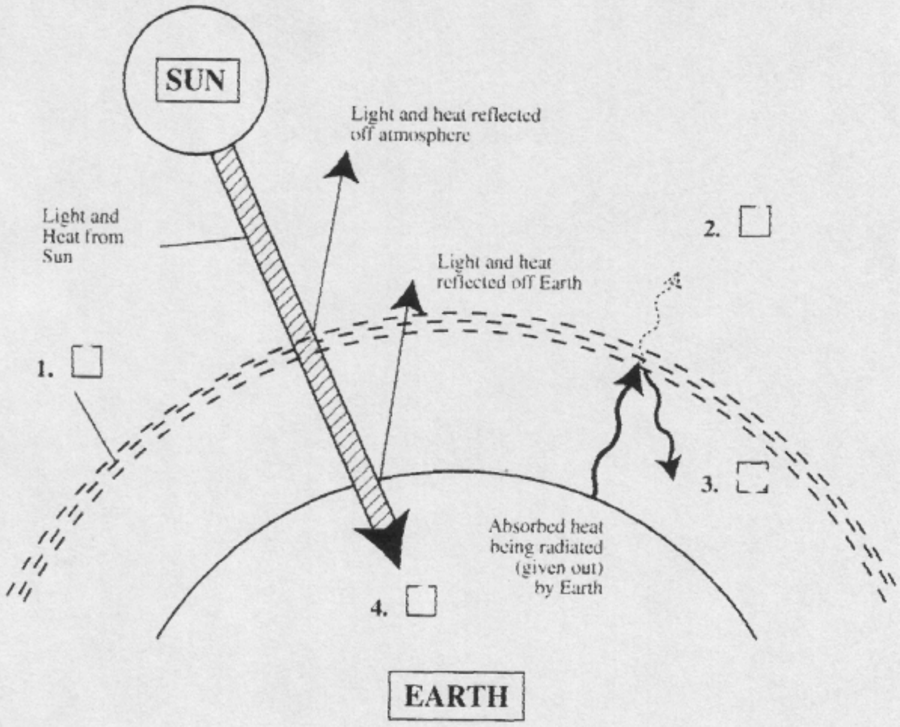


Diagram 2 – Effect of increased greenhouse gases in the atmosphere



A light and heat absorbed by the earth	**B** less heat reflected back to Earth	**C** less heat passes into space
D more heat reflected back to Earth	**E** atmosphere with increased greenhouse gases	**F** more light and heat reflected off the Earth
G atmosphere with decreased greenhouse gases		

(4)

9. This graph shows the level of carbon dioxide emissions against time.

a. What conclusion can you draw from this graph?

____ **(1)**

b. Using the graph, estimate approximately in which year the mass of carbon in the atmosphere reached 6 billion tonnes.

____

(1)

c. Estimate the mass of carbon in the atmosphere in 1980.

____ **(1)**

d. In the 100 years between 1860 and 1960 the mass of carbon emissions increased approximately 2.5 times. How many years did it take for emissions to become twice that of 1960?

About   years.

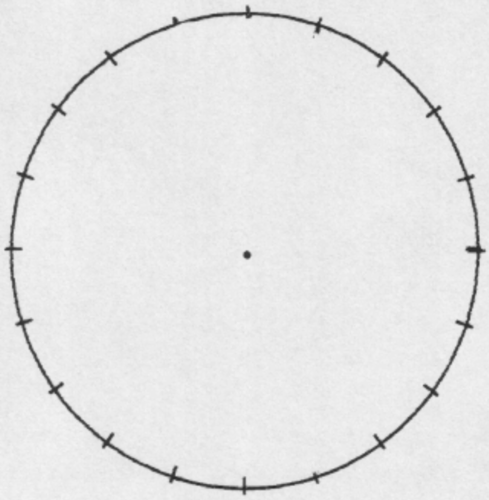
(1)

10. When radiation (like light and heat) from the sun strikes the Earth, some may be absorbed, some scattered and some reflected.

The table below shows the relative percentages of each process.

	Process	Percentage
i.	A Scattered by the atmosphere	5
ii.	B Scattered and reflected by clouds	20
iii.	C Absorbed by atmosphere and clouds	20
iv.	D Absorbed by the Earth	50
v.	E Reflected by surface of the Earth	5

Draw and label a pie chart to display this information. Use the letter to label each process on the chart.



(2)

Appendix K.
Supplementary data from the S2 pupil questionnaires.

As reported in the ROSE survey Scotland the 108 topics contained within sections A, C & E of the ROSE questionnaire had been classified by their Norwegian originators under various headings describing content and context. Many topics map to two or three such categories. The Scottish ROSE survey group indicated that there are a number of ways in which items could in principle be grouped, and as a consequence they created seven groups, each representing a particular content domain, as per Table 1

Table 1: Seven content 'domains' for the 'what I want to learn about' questions.

Content Domain	Selected Questions
Earth science	**A**(3, 4, 5, 6, 14, 24,23 25), **C**18, **E**(19, 33)
Physical science	**A**(2,17,19,21,31,36,43), **C**17, **E**(2,26,27)
Biological science	**A**(7,8,9,10,11,12,13,15,20,27,28,32,) **E**(1,16,17,18,22,23,24,25,31,32,35)
Space	**A**(1,22,34,35,44), **C**(8,10,16) , **E**29
Technology	**A**(30,45,46,47,48), **C**(1,2,3,4,5,6,7), **E**(14,20,21,28).
Human focus	**A**(16,18,26,29,33,37,38,39,40,41,42) **C**(9,11,12,13,14,15) **E**(3,4,5,6,7,8,9,10, 11,12,13,15,30)
The nature of science	**E**(34,36,37,38,39,40,41,42)

Table 2: Comparison of Whole population mean scores for Science Content Domains Covered in Sections A, D & I of the S2 pupils survey with whole population mean scores for Science Content Domains Covered in sections A, C & E from the ROSE survey Scotland

Content Domain	S2 XHS N	XHS overall Mean	S2 XHS SD	Rank Order	ROSE N	ROSE Mean	ROSE SD	Rank Order
Earth Science	171	**2.22**	*0.29*	6	2756	**2.28**	*0.56*	6
Physical Science	171	**2.24**	*0.26*	5	2756	**2.28**	*0.54*	5
Biological Science	171	**2.37**	*0.37*	3	2756	**2.38**	*0.51*	3
Space	171	**2.54**	*0.28*	1	2756	**2.51**	*0.74*	2
Technology	171	**2.33**	*0.26*	4	2756	**2.32**	*0.65*	4
Human Focus	171	**2.48**	*0.30*	2	2756	**2.55**	*0.53*	1
Nature of Science	171	**2.20**	*0.24*	7	2756	**2.21**	*0.56*	7

Table 2 shows the rank order of the content domains covered in the S2 cohort survey and the ROSE survey Scotland. These tables indicate that the S2 cohort matched the

ROSE survey rank order closely with the exception of human focus and Space which switched position in the S2 study cohort survey. This close match in terms of topic interest correlated strongly when the mean Likert score for Sections A, D & I of the S2 survey and Sections A, C & E of the ROSE survey are plotted against each other (see Figure 5.3)

Table 3*:* Comparison of Male mean Likert score for section AD&I S2cohort survey with sections ACE from the ROSE survey Scotland.

Content Domain	Male							
	XHS N	**XHS Mean**	***SD***	**Rank**	**ROSE N**	**ROSE Mean**	***ROSE SD***	**Rank**
Earth Science	86	**2.29**	*0.41*	7	1282	**2.34**	*0.54*	4
Physical Science	86	**2.32**	*0.41*	5	1282	**2.33**	*0.52*	7
Biological Science	86	**2.30**	*0.47*	6	1282	**2.34**	*0.50*	6
Space	86	**2.92**	*0.30*	1	1282	**2.64**	*0.72*	1
Technology	86	**2.60**	*0.31*	2	1282	**2.55**	*0.64*	2
Human Focus	86	**2.44**	*0.36*	3	1282	**2.45**	*0.51*	3
Nature of Science	86	**2.41**	*0.32*	4	1282	**2.34**	*0.75*	*5*

Table 4: Comparison of Female mean Likert score for section AD&I S2cohort survey with sections ACE from the ROSE survey Scotland.

Content Domain	Female							
	XHS N	**XHS Mean**	***SD***	**Rank**	**Rose N**	**Rose Mean**	***Rose SD***	**Rank**
Earth Science	85	**2.14**	*0.27*	5	1449	**2.24**	*0.56*	5
Physical Science	85	**2.15**	*0.25*	4	1449	**2.24**	*0.55*	4
Biological Science	85	**2.37**	*0.37*	3	1449	**2.42**	*0.51*	2
Space	85	**2.54**	*0.28*	1	1449	**2.40**	*0.73*	3
Technology	85	**2.06**	*0.36*	6	1449	**2.12**	*0.59*	6
Human Focus	85	**2.52**	*0.34*	2	1449	**2.65**	*0.76*	1
Nature of Science	85	**2.00**	*0.19*	7	1449	**2.09**	*0.56*	7

Detailed inspection of Tables 3 & 4 shows that the S2 study cohort males rank the content domains differently to females. For example, males ranked biological science lower than females (6th for boys, 3rd for girls) whereas males ranked technology 2nd and females ranked technology 6th. Also males ranked the nature of science 4th with females ranking it 7th. The S2 study cohort males ranked space, technology and human focus 1st, 2nd & 3rd respectively in the same order as the ROSE data. In contrast, they placed the nature of science and physical science 4^{th} & 5^{th} respectively whereas males in the ROSE survey Scotland placed them 5^{th} and 7^{th} respectively.

The S2 study cohort females ranked the content domains differently compared to the females in the ROSE survey Scotland. Space was ranked 1^{st} by S2 females whereas human focus was ranked 1^{st} by the Females in the ROSE survey Scotland. Human focus was ranked 2^{nd} by the S2 females with biological sciences ranking 3^{rd} with the S2 females and 2^{nd} in the ROSE survey Scotland. However, the top three content domains for both S2 females and the Females in the ROSE survey are Space, Human Focus and Biological Sciences although their ranks are not the same. However, S2 males ranked Biological Science 6^{th} with the ROSE survey group ranking it 3^{rd}. However Space and Human Focus were ranked in the top three content domains for both the S2 study cohort males and the ROSE group males.

Most and Least popular specific topic

As a follow on from analysing the content domains for the sections A, D & I for the S2 pupils survey and the ROSE survey Scotland it was decided that for the purposes of determining which topics were most popular within each content domain that the mean Likert score for each specific topic should be ranked to see if, even within the lowest ranked content domains, there was topics of interest to the S2 study cohort. Figure 5 shows the whole S2 study cohort top ten specific topics in comparison with the ROSE survey Scotland.

Table 5: Comparison S2 Cohorts Overall Top Ten Specific Topics with ROSE Survey Scotland

Code	Topic	XHS mean	*SD*		Code	Topic	*ROSE mean*	*SD*
A34	How it feels to be weightless in space	**3.32**	*1.00*		**C13**	Why we dream while we are sleeping, and what the dreams may mean	***3.11***	*1.02*
D13	Why we dream while we are sleeping, and what the dreams may mean	**3.19**	*1.03*		**E08**	Cancer, what we know and how we can treat it	***3.10***	*0.98*
A40	How to exercise to keep the body fit and strong	**2.89**	*1.06*		**A34**	How it feels to be weightless in space	***3.09***	*1.03*
D08	The possibility of life outside earth	**2.87**	*1.13*		**A40**	How to exercise to keep the body fit and strong	***2.99***	*0.99*
A33	The effect of strong electric shocks and lightning on the human body	**2.84**	*1.08*		**A31**	Explosive chemicals	***2.99***	*1.06*
I08	Cancer, what we know and how we can treat it	**2.84**	*1.07*		**E10**	How to perform first-aid and use basic medical equipment	***2.93***	*1.00*
I10	How to perform first-aid and use basic medical equipment	**2.84**	*1.06*		**E12**	How alcohol and tobacco might affect the body	***2.87***	*0.98*
D06	How mobile phones can send and receive messages	**2.80**	*1.04*		**A27**	Brutal, dangerous and threatening animals	***2.84***	*1.03*
A32	Biological and chemical weapons and what they do to the human body	**2.78**	*1.16*		**A33**	The effect of strong electric shocks and lightning on the human body	***2.82***	*1.00*
D14	Ghosts and witches, and whether they may exist	**2.78**	*1.19*		**A37**	What to eat to keep healthy and fit	***2.82***	*1.04*

Legend: In Table 5 Item codes from XHS beginning with A correspond to section A items in the ROSE survey. Codes beginning with D correspond to section C items in the ROSE survey and codes beginning with I corresponds to section E in the ROSE survey.

Table 6 shows that when compared to the ROSE survey data only six of the top ten topics from the ROSE survey feature in the top ten specific topics chosen by the whole S2 study cohort. It should be noted that the S2 study cohort as a group are interested in finding out whether ghosts and which exists. This kind of question highlights the way that popular pseudoscience if gaining interest within the pupils population.