The potential of earth science for the development of primary school science

DENISE JOAN BALMER

A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

of

Institute of Education, University College London

February 2019
Declaration

I, Denise Joan Balmer, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed

Date

Word Count: (excluding references and appendices) 94,788
# Contents

Contents ............................................................................................................................. 3  
Abstract ............................................................................................................................. 6  
Acknowledgements ............................................................................................................ 7  
Acronyms ........................................................................................................................... 8  
List of Tables ....................................................................................................................... 9  
List of Figures ..................................................................................................................... 11  
1 Introduction ..................................................................................................................... 13  
   1.1 My research impetus ................................................................................................. 13  
   1.2 Researcher’s background ....................................................................................... 15  
   1.3 Context of my research ......................................................................................... 17  
   1.4 Outline of research ............................................................................................... 24  
2 Review of literature pertaining to thesis ......................................................................... 26  
   2.1 Introduction ............................................................................................................. 26  
   2.2 What is science? ..................................................................................................... 27  
   2.3 Why teach science in schools – general points .................................................... 31  
   2.4 What should be in a school science primary curriculum ..................................... 37  
   2.5 When to teach science in the curriculum .............................................................. 44  
   2.6 How to teach science ............................................................................................ 45  
   2.7 How we learn science .......................................................................................... 55  
   2.8 Attitudes towards science .................................................................................... 64  
   2.8.1 Children’s attitudes towards science ................................................................. 64  
   2.9 The way forward ................................................................................................... 68  
3 Methodology ................................................................................................................... 70  
   3.1 Introduction ............................................................................................................ 70  
   3.2 Methodology behind the data collection .............................................................. 72  
   3.3 Secondary data collection .................................................................................... 77  
   3.4 Links between the data sources and the Research Questions ............................... 78  
4 Data collection and findings from trainee teacher background science experiences questionnaire ....................................................................................................................... 79  
   4.1 Introduction ............................................................................................................ 79  
   4.2 Results from the first part of the questionnaire about primary school science ........ 80  
   4.3 Results from the questions about secondary science ........................................ 82  
   4.4 Results concerning non-school science activities .............................................. 84  
   4.5 Summary and conclusions ................................................................................... 86  
5 Data collection and findings from the primary science leaders’ survey ................. 88
Appendices ........................................................................................................................................... 234
Appendix 1 Questionnaire to Trainee Teachers .............................................................................. 234
Appendix 2 Questionnaire to Primary School Teachers ................................................................. 240
Appendix 6 Earth Science Education Unit evaluation form page 1 .............................................. 242
Appendix 3 Soil story ....................................................................................................................... 244
Appendix 4 We all learnt today (WALT) sheet ............................................................................. 245
Appendix 5 Children’s comments about soil .................................................................................. 246
Appendix 7 SATRO Pupil Evaluation Form .................................................................................. 248
Appendix 8 SATRO Evaluation Form Comments from three workshops ................................. 249
Abstract

This thesis considers that teaching and learning of parts of the science curriculum in English primary schools may be successfully developed through using aspects of earth science. Earth science is identified as a subject that could enhance knowledge, understanding and enthusiasm that would be ongoing through primary school, using local examples and leading to increased interest in science at secondary level and beyond. The author, an experienced earth scientist and teacher, reviews the literature pertaining to teaching and learning, especially in primary schools and in science curriculae. A mixed methods approach was adopted for data collection. A questionnaire to trainee primary teachers revealed a lack of memorable childhood science. A second questionnaire administered with primary science leaders showed whilst most of them preferred to teach in a constructivist manner, classroom sizes and class numbers along with an overloaded curriculum lessens the feasibility of this. The analyses of these questionnaires also identified some shortfalls in primary teachers’ thinking about the nature of science. Intervention earth science lessons in two primary schools where the teachers were provided with after school CPD sessions, identified ways that earth science could increase children’s knowledge and understanding, along with enjoyment in the classroom. Classroom observations identified the motivating influence of using a well-known local resource: soil. Teacher self-efficacy also increased. Finally, an analysis of trainee teacher and children’s earth science workshops showed that, when properly taught, short, up to two hour, sessions of earth science CPD improved knowledge, understanding and confidence as well as proving motivational. It is argued that earth science examples can be used to exemplify chemistry and physics concepts through using everyday events to the benefit of understanding more about how our planet works. Over time, it is proposed, this could increase general interest in science and scientific literacy.
Acknowledgements

There are three groups of people without whom I should never have been able to complete my thesis. The first group are my two supervisors, Michael Reiss and Sue Dale Tunnicliffe. Their patience and belief in me and their support have been immeasurable in enabling me to work through my ideas. I have really appreciated all the time and advice they have given me.

The second group are those wonderful friends and colleagues; primary teachers, trainee teachers, other students and especially my student ‘buddy’ Jane. To everyone who has participated in my questionnaires, permitted me entrance to their classrooms; allowed me to work with their pupils; given me access to meetings; talked to me; answered my questions; supported me through the soul searching times; thank you! I would not have got this far without you.

And last but not least, my family, who have rallied round at various stages of this project, and never once said “why are you doing this?” To my son for rescuing me from my computer problems, and to my long suffering husband for providing coffee, meals, a shoulder and ears which have listened to countless moans about formatting.

Thank you all. I am indebted to everyone of you.
**Acronyms**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASE</td>
<td>Association for Science Education</td>
</tr>
<tr>
<td>BEd</td>
<td>Bachelor of Education degree</td>
</tr>
<tr>
<td>CLIS</td>
<td>Children Learning in Science</td>
</tr>
<tr>
<td>CPD</td>
<td>continuing professional development</td>
</tr>
<tr>
<td>DBS</td>
<td>Disclosure and Barring Service</td>
</tr>
<tr>
<td>ESEU</td>
<td>earth science education unit</td>
</tr>
<tr>
<td>ESRC</td>
<td>Economic and Social Research Council</td>
</tr>
<tr>
<td>EYFS</td>
<td>early years foundation stage</td>
</tr>
<tr>
<td>GSA</td>
<td>Geological Society of America</td>
</tr>
<tr>
<td>HMCI</td>
<td>Her Majesty’s Chief Inspector (for Schools)</td>
</tr>
<tr>
<td>IGEO</td>
<td>International Geological Education Organisation</td>
</tr>
<tr>
<td>ISS</td>
<td>International Space Station</td>
</tr>
<tr>
<td>NARST</td>
<td>National Association for Research in Science Teaching</td>
</tr>
<tr>
<td>NGSS</td>
<td>Next Generation of Science Standards</td>
</tr>
<tr>
<td>NSTA</td>
<td>National Science Teacher’s Association</td>
</tr>
<tr>
<td>PCK</td>
<td>pedagogical content knowledge</td>
</tr>
<tr>
<td>PGCE</td>
<td>post graduate certificate in education</td>
</tr>
<tr>
<td>RSC</td>
<td>Royal Society of Chemistry</td>
</tr>
<tr>
<td>SATRO</td>
<td>the name of an educational charity based in Guildford, Surrey. The initials originally stood for science and technology regional organisation</td>
</tr>
<tr>
<td>SCITT</td>
<td>school centred initial teacher training</td>
</tr>
<tr>
<td>SCK</td>
<td>subject content knowledge</td>
</tr>
<tr>
<td>SES</td>
<td>socio-economic status</td>
</tr>
<tr>
<td>SMF</td>
<td>Social Market Foundation</td>
</tr>
<tr>
<td>SPACE</td>
<td>Science Processes and Concept Exploration</td>
</tr>
<tr>
<td>SSI</td>
<td>socio-scientific issues</td>
</tr>
<tr>
<td>STEAM</td>
<td>science, technology, engineering, art and mathematics</td>
</tr>
<tr>
<td>STEM</td>
<td>science, technology, engineering and mathematics</td>
</tr>
<tr>
<td>STS</td>
<td>science, technology and society</td>
</tr>
<tr>
<td>TERC</td>
<td>Transportation Environmental Resource Council</td>
</tr>
</tbody>
</table>
List of Tables
Table 1.1 Changes in exam entries for GCSE/A level in England 2014-2018..........................19
Table 1.2 Changes in numbers gaining first degrees in UK 2013-2017.................................21
Table 3.1 The relationship between the research questions and data collection....................78
Table 4.1 Preferred subject rankings at KS3........................................................................84
Table 4.2 Most enjoyed subject rankings at GCSE level.....................................................84
Table 4.3 Preferences of important childhood activities.......................................................85
Table 4.4 Important of science activities to sample..............................................................87
Table 5.1 PSLs’ replies to Questionnaire 1, question (i)......................................................90
Table 5.2 PSLs’ replies to Questionnaire 1, question (ii).....................................................90
Table 5.3 PSLs’ replies to Questionnaire 1 question (iii)......................................................91
Table 5.4 PSLs’ replies to Questionnaire 2, question (i)......................................................92
Table 5.5 PSLs’ replies to Questionnaire 2 question (ii).....................................................93
Table 5.6 PSLs’ replies to Questionnaire 2, question (iii)....................................................93
Table 5.7 PSLs’ replies to Questionnaire 3 question (i).......................................................95
Table 5.8 PSLs’ replies to Questionnaire 3 question (ii).....................................................95
Table 5.9 PSLs’ replies to Questionnaire 3 question (iii).....................................................96
Table 5.10 Teacher beliefs about teaching and learning.....................................................97
Table 5.11 PSLs’ responses about NOS............................................................................98
Table 5.12 Combinations of the PSLs’ beliefs of teaching, learning and nature of science...100
Table 5.13 PSLs’ overall beliefs about teaching, learning science & nature of science........102
Table 6.1 SOLO assessment level changes derived from bubble diagrams of class A........113
Table 6.2 Statements from the soil bubble diagrams before intervention.............................114
Table 6.3 Statements from the soil bubble diagrams after the intervention..........................115
Table 6.4 Comparing changes before and after intervention using two taxonomies..........116
Table 6.5 Class A before/after intervention bubble diagram & WALT statements.............117
Table 6.6 Cumulative TALIA form to compare class A and class O lesson observations.....119
Table 6.7 Pedagogical strategies used in the intervention lesson.......................................121
Table 6.8 Cumulative feedback from the year 3 teaching assistants, school A.................133
Table 6.9 School A children’s statements about science & soil before intervention............136
Table 6.10 School A children's statements about soil after the soil science day……………….139
Table 6.11 Before and after statements from class R's bubble diagram……………………..146
Table 6.12 Bubble statements analysed by SOLO & Bloom taxonomies before intervention 147
Table 6.13 Bubble statements analysed by SOLO & Bloom taxonomies after intervention…147
Table 6.14 Comparison of taxonomy levels before and after intervention……………………148
Table 6.15 School B children's statements about science & soil before intervention……….151
Table 6.16 School B children's statements after the soil science day……………………….152
Table 7.1 ESEU compilation background data of primary trainee teachers, 2009-2015………..158
Table 7.2 Number of trainee teachers at workshop with degrees………………………………158
Table 7.3 Primary trainee teachers’ confidence in teaching primary science…………………159
Table 7.4 Percentage trainee teachers confident in specific sciences…………………………159
Table 7.5 Composite table of comments and themes from ESEU workshops………………162
Table 7.6 Yr3 pupils comments before & after rock workshop……………………………….170
Table 7.7 Yr5 pupils comments before and after fossil workshop…………………………….171
Table 7.8 Responses from children after attending the SATRO workshops 2013-2015……..172
Table 7.9 Composite response data from SATRO rock/soil workshop participants 2013-15.173
Table 7.10 Composite response data from SATRO fossil workshop participants 2013-15…174
Table 8.1. Pedagogical strategies used by the teacher when telling soil story………………….189
Table 8.2 Where Earth Science fits English primary science curriculum……………………197
Table 8.3 Science skills that can be developed in primary science curriculum……………….198
List of Figures

Figure 1.1 The importance of earth science (Balmer, 2007).……………………………………15
Figure 4.1 Percentage teacher trainees who enjoyed primary science……………………………82
Figure 5.1 Descriptor phrases used by Tsai (taken from Tsai, 2002).……………………………99
Figure 5.2 PSLs’ overall beliefs……………………………………………………………………100
Figure 5.3 Comparison of congruencies between Tsai & study sample………………………101
Figure 5.4 Primary science leaders’ beliefs of teaching, learning and nature of science………103
Figure 6.1 A bubble diagram for soil…………………………………………………………………109
Figure 6.2 A concept cartoon about soil (Balmer 2014)………………………………………110
Figure 6.3 Analysis of soil story transcript………………………………………………………………123
Figure 6.4 Permeability exercise ………………………………………………………………………126
Figure 6.5 Explaining about the permeability investigation………………………………………127
Figure 6.6 Examining sieve contents……………………………………………………………………129
Figure 6.7 A soil cocktail……………………………………………………………………………………130
Figure 6.8 Reflections on intervention lesson by staff………………………………………………132
Figure 6.9 Cumulative feedback by staff……………………………………………………………135
Figure 6.10 School A pupils knowledge statements before & after intervention……………140
Figure 6.11 School A pupils understanding statements before & after intervention 141
Figure 6.12 School A pupils analysis statements before & after intervention 141
Figure 6.13 The floor soil bubble diagram for class R………………………………………………146
Figure 6.14 School B pupils statements about knowledge, understanding & analysis before.152
Figure 6.15 School B pupils statements about knowledge, understanding & analysis after…..152
Figure 7.1 Trainee teachers investigating soil…………………………………………………………157
Figure 7.2 Trainee teacher confidence in teaching primary science ……………………………160
Figure 7.3 Percentage of teacher trainee no confidence in teaching primary science158 -159.
Figure 7.4 Workshop theme analysis……………………………………………………………………163
Figure 7.5 Comments on how CPD will be used……………………………………………………164
Figure 7.6 Composite rock bubble diagram from floor sheet……………………………………168
Figure 7.7 Examining rocks………………………………………………………………………………174
Figure 7.8 Percentage of themed comments about rock and soils and fossil workshops…..175
1 Introduction

1.1 My research impetus

Every generation has faced change and issues related to its environment. The need for humans to understand how to interact with their surroundings evolved over time and became instinctive: people knew the seasons of the year, the changes in daylight hours; they understood cloud patterns and much more. With improved science knowledge, scientists in the 18th century wanted to know why natural events occurred and began to investigate the earth and its processes (Wulf, 2015). Nearly all the great scientists of that era and the 19th century were competent earth scientists as well as being chemists, physicists or engineers. They understood how reliant the population was on the planet's wellbeing. However, in many respects in today's developed world, we have lost that understanding; most of us in England live in sterile urban environments – with central heating if the weather is cold, with air conditioning in offices if it is too hot; water is on tap, food in the shops – and there has been no real need to comprehend the earth and its complex interactive processes, until now. Scientific literacy or, at least, understanding basic scientific processes, has become important for preserving what we have for our future (Reiss, 2014). Earth science is as vital a subject today as it was necessary to survival in the past, and this thesis hopes to encourage increased attention to it at an early stage in life, in order that children become knowledgeable participants in their localities and possibly useful scientists in the future.

The experience of school science at primary and pre-school levels seems to have important connections with levels of interest in science in adult life (Howe et al., 2006; Wellcome Trust, 2014). If this is so, then it is imperative that we have enthusiastic and motivated teachers of science at early years and primary levels to enthuse and motivate the next generation of youngsters (Hattie, 2009) who, as well as being the next generation of the general public, will be our future scientists and engineers (Solomon, 2013) and the guardians of our planet. Research has shown that the efficacy of pre-school elementary teachers and primary teachers is vital in interesting pupils in science (Dou & Gibbs, 2013) alongside parental encouragement and other outside activities when children are young (Archer et al., 2015).

Science currently has ‘core’ status in the English primary curriculum (DfE, 2013), but because it is no longer assessed by Standard Attainment Tests (SATs) (Ofsted, 2011) it is frequently being given less teaching time in the primary curriculum (Wellcome Trust, 2014; Ofsted, 2016; Wellcome, 2017). Furthermore, most primary schools do not have a specialist science teacher (Ofsted, 2011; Royal Society of Chemistry (RSC), 2014) either. Many primary teachers lack self-efficacy in science (Kazempour, 2014), having only studied it to GCSE level (Wellcome Trust, 2013).

Children come to pre-school and primary school with experiences based on local events and happenings in early childhood, as a result of which they have derived their own theories in an attempt to explain these experiences. These early theories often embody ‘alternative conceptions’ and need to be discussed and corrected (Allen, 2010; Driver & Scanlon, 1988) before becoming too embedded in the child's mind (Pine, Messer & St. John, 2001).
By the age of nine, it seems that many youngsters have already been put off science (Collinson, 2014; Coppard, 2017). After this age it is extremely difficult to encourage them into science courses and ultimately science and engineering careers unless something really interests them and captures their imagination. We therefore owe it to our nation's future to ensure that our children have exciting, accurate and motivating science experiences when they are young so that they develop into informed adults with good views about science. What is most important is to encourage and harness early enthusiasm for science. Earth science can provide interesting and age appropriate experiences which are occurring in all local environments. This can lead to an understanding of simple scientific concepts by children; examples include local flooding and air pollution.

My lifetime career experience of working in and promoting science has led me to conclude that there are many weaknesses in our English primary science teaching. This thesis will advance and interrogate the argument that much primary science could be taught through the vehicle of earth science, which is relevant everyday science, visible, easily accessible and familiar in its basics to children and teachers alike. This might then improve enthusiasm for studying science in secondary school, where interest wanes (Osborne & Collins, 2001), and increase the numbers following science career paths, the shortage of which has become an escalating economic issue (Broughton, 2013; Perkins, 2013; PostNote, 2013).

My hypothesis is therefore, that the teaching of earth science has potential for the development of primary school science. Throughout this thesis, I am not critical of primary science teachers but aspire to help them by providing an alternative way of approaching science teaching and alleviating some of the issues with primary science currently being identified by primary teachers. Earth science can, I surmise, help primary teachers enrich their science teaching which will improve primary pupils’ investigative skills and understanding of basic science, providing a sound foundation on which to further their secondary science education.

Earth science is an all embracing applied science linking together concepts from the natural sciences (physics, chemistry and biology) with the social sciences, since many aspects relate to human activities as indicated in Figure 1.1. The figure shows that when earth science is placed at the centre of learning all other disciplines can be seen to link through it. It would therefore seem possible to begin teaching children’s primary science through earth science as everything else can follow on from this subject.
In researching my hypothesis, it is necessary to look at a number of linked issues: the importance of science in the school curriculum and the value of earth science to that curriculum globally and nationally; primary teachers' self-efficacy in science; how teachers teach and children learn; children’s feelings towards science; and how to bring together all children’s experiences and ideas to result in coherent understanding and an interest in science which will stay with them for life.

1.2 Researcher’s background

As a child, I was intrigued by the planets and stars, avidly kept a weather diary and made my own weather forecasts, tracked and recorded thunderstorm data for insurance companies, and collected rocks, minerals and fossils. My parents encouraged these hobbies, but when I suggested a career in science, they were horrified! Girls were nurses or bank clerks, not meteorologists or geologists, and anyway, what was the point of training if you were to get married and have a family? This, however, only made me more determined. Fifty years later, perhaps parents are not quite so horrified by a female offspring’s choice of a STEM\(^1\) profession, but many families in the lower socio-economic groups still perceive STEM as a job for only very able people (Parliamentary Office of Science and Technology (POSTNote), 2013). Awareness of science and the status of STEM careers in Britain still needs to be developed, through career guidance showing the potential of all sciences and mathematics (Royal Society, 2014; Morgan & Kirby, 2016).

Although my school science background did not contribute very positive memories, I was still determined to follow a career in science. At eighteen, I had the audacity to

\(^{1}\text{STEM: Science, Technology, Engineering and Mathematics}\)
apply for the Meteorological Office – a very male-dominated profession – and surprisingly was accepted. As a Meteorological Observer at Heathrow, I was one of four females in a staff of over one hundred, capably doing the same recording, observing and plotting as my male colleagues. I was determined then that science should be open to everyone. Later, as a trained earth science teacher, I discovered again that science generally, and especially earth sciences (such as geology, meteorology and astronomy) were seen as a male domain; particularly in the mining industry where old laws prevented women from working below ground. In secondary school in the late 1900s, physics and chemistry were mainly taught by men, with women teaching biology, and still today there are fewer girls taking A levels in chemistry and physics although in chemistry this has gradually improved (WISE, 2012).

As a senior teacher in a sixth form college during the 1980s/90s, I saw for myself the paucity of science knowledge acquired during their previous ten years of schooling by post-16 students. I taught these sixth formers basic science understanding in order that they do well at GCSE and A level geography and geology; to me it was important that they could understand and apply their new scientific knowledge to their everyday lives as well as the subjects being learnt. I was one of the 14-18 Geography team based at the Institute of Education in the 1970s, writing materials for the project part of the course and was for fifteen years a Senior Moderator for this Geography A-level, with some twenty schools under my tutelage in the North-West of England. I helped teachers assess their students’ work in line with the group and moderated national examination projects for fifteen years.

During this time, 1982-1995, I ran earth science CPD\(^2\) workshops for primary and secondary teachers in my local authority as well as trainee teacher courses for Manchester (Victoria) University. I used rocks, fossils and soils as topics as well as natural hazards, showing how they could be integrated in the current curriculum and be cross-curricular. These workshops were hands-on, designed to encourage science confidence in primary teachers and to upgrade knowledge and understanding for secondary teachers. Alongside these workshops, for ten years I was part of a team running a copper mine educational trust at weekends. Here we engaged with A-level students, their teachers and science advisors in the field, working with minerals found locally and teaching the chemistry and physics of earth science on site, come rain, snow or shine (Dillon, 2010). I devised three A-level field work programmes linked to this copper mine experience; these were validated as official fieldwork material for A-level examination by the JMB examining board, and used by schools as their examination coursework component. These programmes were motivating for the students but also enabled me to see, once again, their lack of understanding of basic science concepts in everyday situations. The teachers and science advisors were astonished at the ease with which work in the field could be so simply linked with classroom science, an everyday understanding of the surrounding environment and the promotion of working in a scientific profession. I also gained a distinction in my M.Ed in Educational Management and Administration, through Manchester Victoria University, with my dissertation on ‘Controlling quality in sixth form education in the 1990s’.

\(^2\) CPD: Continuing Professional Development
More recently, working as a programme developer for SATRO\textsuperscript{3} with primary schools, I further realised the need for primary teachers to be supported in delivering the science curriculum. I devised packages for primary science and encouraged STEM industries to allow their professionals to support teachers in specific lessons, in a practical, problem-solving way (SATRO, 2012). This has proved successful; teachers were grateful for the knowledge and help given by the experts, and the experts themselves discovered the importance of helping children learn some of the concepts underlying scientific principles practically. (I personally ran primary earth science workshops during this period). Children are inherently interested in fossils, rocks and minerals, and many collect these from a young age; indeed, Piaget suggested that children are naturally curious and learn from exploring their own environment (Robins, 2012). Weather is always around them as is our Moon, the planets in our Solar system and the stars, and the fascination for soil, sand and mud is of endless annoyance to parents who are constantly washing muddy clothes. All the above are topics within earth science that can be used to advantage as enquiry sessions within the primary curriculum, developing basic science skills.

Although mainly working with primary schools whilst at SATRO, I ran the Nuffield Science project for Surrey for ten years, locating four-week summer projects for first-year sixth formers. This involved working with local industries and universities to find placements as well as assessing the written projects many of which were published by the sponsors, and a number of which were exhibited at the Big Bang Festivals where their authors gained prizes. I was also the BTEC examiner for SATRO courses and was one of the first people to gain the National Moderator Award which enabled me to assess NVQ, GNVQ and BTEC awards. In both these roles I was well aware of the numbers of students taking science courses and noted how few were continuing to university to read science.

During my current experience teaching earth science workshops to teachers through the Keele University’s Earth Science Education Unit (ESEU\textsuperscript{4}) I have begun to appreciate more the dearth of understanding of earth science by many adults, and especially those issues which are presently affecting the planet – such as climate change, flooding, landslides, and sea level changes. In 2017, whilst teaching postgraduate science teacher trainees on an ESEU workshop at Oxford, I discovered that many of these students did not fully comprehend the water cycle and the concept of the water table, and spent an hour in discussion dispelling misconceptions. (I found this a worrying scenario, but the same issues were reinforced when delivering lectures on sustainability issues to first-year undergraduates at Reading University in March 2018.) These ESEU workshops deliver practical advice on teaching earth science in ways that young people can easily relate to within the limited science budgets of both primary and secondary schools, and provide much needed self confidence in this subject for many teachers.

1.3 Context of my research

My reason for researching this topic is because I passionately believe that science should be for everyone, and that earth science, in particular, is of interest and concern

\textsuperscript{3} SATRO: a small educational charity based in Surrey providing science workshops, mentoring and conferences in association with professional scientists and engineers.

\textsuperscript{4} ESEU: the Earth Science Education Unit based at Keele University, 1999-2016
The great adventurer, Alexander Humboldt, was the first person to really recognise that all earth systems work together and are reliant on each other in the early 19th century, and his writings formed the backbone to many later discoveries about earth science (Wulf, 2016). He could be called the Father of Earth Science and his writings influenced Darwin, many other eminent scientists of that period, and later Rachel Carson and James Lovelock. Earth science is topical; each of us can have a reasoned viewpoint, and earth science issues, sustainable and environmental, affect us all. As a society, we should be knowledgeable about the causes and effects of our actions with enough scientific literacy to decide what actions could and should be taken to alleviate or ameliorate some of these problems.

The general public and 16-24 year-old students still perceive science as being mainly physics, chemistry and biology as seen in the 2014 Public Attitudes to Science Survey (British Association of Science, 2014). Whilst the majority feel that understanding science is important and will provide more jobs in the future, as suggested by the 2016 Public Attitudes to Science Survey, (British Association of Science, 2016), just over half of the people surveyed did not feel informed about science issues. Most adults gained their information from television and news articles but for only a few named topics (climate change, vaccinations and renewable energy) did they state that they felt informed. Recent contentious issues include shale gas, DNA ethics, GM crops; and plastics (Thompson, 2018) have become recognised as an environmental issue but generally people trust and respect scientists to do the right thing (ESRC, 2014). News and television articles highlight major inventions but rarely discuss the background to all the minor improvements in inventions that occur. Moreover, learners do not appreciate the amount of research and work behind the scenes of any change unless they are involved (Planet Earth, 2003).

A population interested in science is an important factor for a country’s social and democratic wellbeing and its economic growth (Giles & Hayman, 2014). As such, the United Kingdom needs to ensure that its citizens are scientifically literate and, as far as possible, have effective science capital (Archer et al., 2014). It seems adults gain most scientific literacy after leaving school (Mueller & Tippins, 2011), through the media (documentaries and news items), visiting museums and science festivals and developing an interest or hobby in a specialised area, perhaps astronomy, space, their local environment or own garden. Families can develop good science capital (Archer, 2014) by discussing science with their children along with playing scientifically-orientated games and investigations and undertaking visits to farms, woodlands and museums, as well as watching many of the well-produced scientific programmes on television.

The CBI report (2018) suggests that all teaching should be encouraging thinking, questioning, creativity and team working: skills that should be very much part of a science curriculum. Government policies frequently rely on market choices and parental pressures when making educational curriculum decisions rather than looking at everyone’s entitlement to knowledge (Young, 2014). Hence, it is really vital to ensure that our primary science is fitting the need for everyday living and enthusing pupils to continue their engagement with science. A recent Wellcome Trust report (2017)
envisages a primary science experience for all of exciting relevant science with an increasing emphasis on cross-curricular science activities.

Economically, Britain’s flow of new young engineers and scientists entering the job market is not keeping pace with demand and will fall well short of the projected requirements by 2020 (SMF, 2013; Perkins, 2013) unless something is done quickly in secondary schools and universities to promote these careers to increase numbers. A report commissioned from the Royal Academy of Engineering (RAE) (Morgan & Kirby, 2016) had previously highlighted this shortfall, suggesting that the two main reasons for this deficit were the replacement requirement for those who were retiring and the expansion of new roles created by innovative businesses. The latest report from Engineering UK (Mellors-Bourne et al., 2017) still projects a shortfall of some 20,000 engineers by 2024. The RAE report (2016) points out that some 650,000 students across England, Wales and Northern Ireland achieve grades A-C at GCSE in English, mathematics and two sciences and so are eligible to progress further with STEM studies. Yet, while some 90,000 students continue with mathematics at A-level, only 30,000 continue their studies with mathematics and physics the requisites for engineering degrees. Morgan and Kirby suggest that there is a need to encourage females and minority ethnic groups into science A-levels, a point reiterated by Engineering UK (2017). Table 1.1 shows changes in examination entries for GCSE and A-level sciences over the most recent five-year period for which data are available.

Table 1.1 Changes in English examination entries from 2014 to 2018 (most data from Joint Council of Qualifications website; Geology data from 2013 to 2017 from Chris King, pers. comm.)

<table>
<thead>
<tr>
<th>Subject/level</th>
<th>Number of entries in 2014</th>
<th>Number of entries in 2018</th>
<th>% changes in entries over the five years</th>
<th>Female/male ratio in 2014</th>
<th>Female/male ratio in 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geology A</td>
<td>2221</td>
<td>1800</td>
<td>-21</td>
<td>31:69</td>
<td>34:64</td>
</tr>
<tr>
<td>Geology GCSE</td>
<td>1000</td>
<td>618</td>
<td>-30</td>
<td>27:73</td>
<td>22:78</td>
</tr>
<tr>
<td>Geography A</td>
<td>29476</td>
<td>30356</td>
<td>3</td>
<td>51:49</td>
<td>51:49</td>
</tr>
<tr>
<td>Geography GCSE</td>
<td>207857</td>
<td>242268</td>
<td>14</td>
<td>47:53</td>
<td>47:53</td>
</tr>
<tr>
<td>Biology A</td>
<td>58111</td>
<td>58179</td>
<td>0</td>
<td>59:41</td>
<td>63:37</td>
</tr>
<tr>
<td>Biology GCSE</td>
<td>131639</td>
<td>161408</td>
<td>18</td>
<td>50:50</td>
<td>50:50</td>
</tr>
<tr>
<td>Chemistry A</td>
<td>47562</td>
<td>50142</td>
<td>5</td>
<td>47:53</td>
<td>53:47</td>
</tr>
<tr>
<td>Chemistry GCSE</td>
<td>129052</td>
<td>157664</td>
<td>18</td>
<td>49:51</td>
<td>50:50</td>
</tr>
<tr>
<td>Physics A</td>
<td>33599</td>
<td>34831</td>
<td>4</td>
<td>21:79</td>
<td>22:78</td>
</tr>
<tr>
<td>Physics GCSE</td>
<td>128373</td>
<td>155994</td>
<td>18</td>
<td>49:51</td>
<td>50:50</td>
</tr>
<tr>
<td>Double Science GCSE</td>
<td>346778</td>
<td>370458</td>
<td>6</td>
<td>51:49</td>
<td>50:50</td>
</tr>
</tbody>
</table>

The background to these figures lies in the approach to science within schools and with the implementation of the EBacc (2018) in England. The National Curriculum (DfE,
2014) applies to England, Wales and Northern Ireland, with Scotland having its own curriculum and examination system. All students in England, Wales and Northern Ireland are required to study English, mathematics and science to the end of Key Stage 4 (DfE 2013) with some students studying a dual award science which gave them a background to biology, chemistry and physics, although not in as much depth as studying these sciences individually. However, a high grade on a double award science in some establishments was seen as suitable background for single science A-level study. Post Key Stage 4, students are able to choose their subjects for study. Generally, sixth forms until recently required students to study up to four AS6 subjects for one year (year 12), then concentrate on up to three subjects at A2 in year 13. Until 2017, most A-level subjects required students to study an AS level in that subject as an integral part of the examination for an A-level qualification. However, this was changed in 2016 and consequently numbers of AS students have fallen dramatically for all A-level subjects. A-level biology is still the most popular A-level science, although numbers of entries hardly increased over the 5-year period, and it is the preferred A-level science for females.

Table 1.1 shows increasing participation in chemistry and physics at both GCSE and A-level, though the increase in the number of female entries is very low at A-level. Geography remains popular at both levels. However, geology GCSE and A level examination entries have fallen dramatically since the year 2000, by more than 75%. There could be several reasons for this but one is that there are fewer teachers in schools who are able to teach geology at this level (ESTA, 2016); another is the relentless emphasis by governments since 2010 on biology, chemistry and physics. The arguments I will be exploring in this thesis as to why earth science might play a greater role in primary science do not presume or require that students will go on to study geology at GCSE or A-level.

Since 2010, English secondary schools have been assessing attainment through an English Baccalaureate (EBacc) programme. Requirements are English literature and language, mathematics, science, a foreign language and either geography or history at GCSE grade 5 (previously grade C) and above. It was suggested by the Sutton Trust (Kirby, 2013) that the baccalaureate ideal could help improve a student’s performance in English and mathematics, and research by UCL Institute of Education (2013) showed that the EBacc improves prospects for entering tertiary education and employment. As geography is one of the listed subjects it is little surprise that the numbers are increasing at GCSE. The government is pressing for 90% of students to use the EBacc subject combination by 2025.

Although entry numbers for science examinations at all levels vary slightly year on year, this can be because of changes in the population size rather than changes in student preferences. Indeed, the population of secondary children is almost bound to rise by about 10% over the next five years (Mellors-Bourne et al., 2017). Only if one subject’s entries decrease relative to the others can it be said that there is a fall in popularity of that subject.

It is difficult to ascertain numbers of science graduates in specific sciences as figures in the public domain seem only to distinguish between biological sciences and the

---

6 The AS was an intermediary examination designed to focus students on attaining half an Advanced level subject in one year, before committing to a full A-level at the end of a second year of study
physical sciences (Table 1.2). It was not possible to obtain figures for the number of primary teachers with geography degrees (David Mitchell pers.comm).

**Table 1.2 Changes in numbers gaining first degrees in UK universities from 2013 to 2017.** Extracted from HESA 2017

<table>
<thead>
<tr>
<th>Subject</th>
<th>Increase in numbers achieving first degree</th>
<th>% change</th>
<th>% in 2013</th>
<th>% in 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological sciences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>female</td>
<td>3280</td>
<td>14</td>
<td>61</td>
<td>60</td>
</tr>
<tr>
<td>male</td>
<td>1300</td>
<td>8</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Physical sciences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>female</td>
<td>617</td>
<td>9</td>
<td>41</td>
<td>47</td>
</tr>
<tr>
<td>male</td>
<td>880</td>
<td>5</td>
<td>59</td>
<td>53</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>female</td>
<td>310</td>
<td>1</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>male</td>
<td>1220</td>
<td>5</td>
<td>84</td>
<td>85</td>
</tr>
</tbody>
</table>

Note: Biological sciences refer to biochemistry, biomedicine, cell biology, microbiology, ecology, conservation, genetics. Physical sciences refer to sciences dealing with inanimate objects: physics, chemistry and astronomy. Earth sciences are not recorded by HESA but would include all the sciences that collectively seek to understand Earth and its surrounding space, including: geology, oceanography, meteorology, biogeography, soils, and hydrology.

In the 1980s the Government of the day initiated a change to funding Higher Education, introducing a ‘market forces and competition approach’ (Liston, 2011). This resulted in the Earth Sciences Review conducted by the University Grants Council in 1986 which invited comments from all university chancellors and vice principals on the future organisation of Earth Science teaching and research. Earth Science was chosen as trial subject for the physical sciences as it was a smaller subject area than chemistry and physics. As part of this review the Geological Curators Group stated that geological collections in universities were a basic requirement for teaching and researching the subject and needed safeguarding. A paper calling for strengthening university Earth Sciences was published in May 1987 but the overall outcome was that money to cover curatorial posts for geological collections was limited to five university museums, which were required to be major collection centres. The Earth Science Review was fundamentally a move to reduce government expenditure on Higher Education and Earth Science suffered by closing departments and axing jobs. Hull University was the first to close its Earth Science department. Many others were forced to close as they lost their collections (Liston, 2011). However, since 2000, earth
science, that is geology-related, or environmental science degree courses have gradually increased in number with many earth science subsidiaries being offered within chemistry and physics degrees.

A report by Marcus Brady (2017), Chief Executive of Target Jobs, suggested that the shortage of scientist and engineers was not due to a lack of graduates – as frequently reported in the media – but to these graduates not entering scientific or engineering careers. He stated that these professions were not promoting themselves as offering exciting and worthwhile opportunities or high enough salaries to entice graduates into them. The outgoing Chief Executive of the Association for Graduate Recruiters 2018, Carl Gillead, (Brady, 2017) pointed out that his members believed that one issue was the shortage of female graduates entering science professions.

The latest Tier 2 list of occupation shortages shows a dearth of ‘physical scientists'; all nine areas of shortages in the construction-related ground engineering section are geologists or geophysicists. In the civil engineering requirements section, all shortages are of a geology-related nature. Compared to the other vacancies on this shortage list of scientists and engineers, the earth science-linked posts are paid less than those in electrical engineering or people required for the nuclear dismantling industry. This would seem to substantiate Marcus Brady’s comments. However, a report on education in the Daily Mail, a popular daily paper, though possibly not the most academic of sources, of 18 August 2018 states that in the future an earth science degree will pave the way for earnings higher than other degrees.

We need therefore to improve our promotion of science and engineering careers, and the Government has taken steps to do this in secondary schools with its latest career strategy on statutory guidance (Gov.UK, 2017). However, I believe this is too late as many young people have decided on career choices much earlier (Chambers et al., 2018) and it is in the primary school that we need to invoke interest in science. Earth science is a subject of relevance to young children, starting with those at the Early Years Foundation Stage, as it encourages observing and playing with everyday materials. For primary children also, local everyday problems can be studied in a science context and these are very often earth science related – weather topics, resource availability and environmental issues, to name but a few. My thesis has as one of its aims arousing interest in using local earth science as a basis for primary science study which can then be used as a starting point for secondary physics, chemistry and biology when children already have some relevant concepts to identify with which they are familiar. Coppard (2016) argues that introducing concepts (as just described) in primary science which can then be built on at secondary level would reduce some of the problems faced after the primary-secondary transition.

It is important to ensure that our primary science is filling the need for everyday living and enthusing pupils to continue their engagement with science. Herein lies my main concern: primary teachers are frequently ill-equipped to teach specialist scientific knowledge in a way that is exciting and motivating (Wellcome Trust, 2008, 2014). STEM subjects in school, at both primary and secondary level, are seen by many youngsters and sometimes their families as well, as ‘difficult’ and ‘too theoretical’, not relating to everyday life (Giles & Hayman, 2014). This needs tackling, whilst the issues surrounding the support needed by primary teachers are another area of great concern (Murcia & Schibeci, 2010). I believe that earth science can be a vehicle to improve
primary science teaching and can encourage and engage teachers and children to explore and understand basic science concepts enthusiastically.

In England, we currently seem to have lost our way in teaching science to young children (House of Lords, 2000). There is increasing emphasis on testing mathematics and literacy reducing the wider curriculum (Ofsted, 2016, 2017). All youngsters live in an exciting world with plenty of unusual and interesting things happening everyday around them which they barely notice (Serin, 2014; Wellcome Trust, 2014). In my experience, primary schools too rarely look at these common everyday things but rather try to teach what is perceived by some as ‘real’ science – the school science of chemistry, biology and physics – subjects quite often unrelated to their pupil’s environment and experiences. Children are excited by things they can observe, feel and handle and like to notice and record changes. We should offer them this opportunity to investigate the science relevant to their environment (Tal & Dierking, 2014).

By reducing the ‘scientific’ load (as defined in the 2013 English Primary Science Curriculum) on primary teachers and also changing the primary science curriculum to something more akin to ‘real life’, perhaps we can begin to influence the direction of flow of STEM graduates and look forward to increased enthusiasm for science, technology, engineering and mathematics which will improve our standing in world markets.

The issues of primary–secondary transition are frequently highlighted (Howard, 2017) with specific reference to science and the fall-off in interest in science shown by many children as they enter secondary school (Coppard, 2017). It is suggested that this fall-off starts at about age nine or even earlier (Murphy & Beggs, 2003), and continues. Numerous ideas of bridging projects have been tried but none of these seem to capture interest for very long. I suggest that part of the problem is in trying to make the science curriculum progressive from reception (age 5) through to upper secondary (age 16) (DfE, 2014). Science is not a subject that conforms easily to a spiral curriculum as topics cannot be as readily built upon as mathematics, where one learns, uses and develops different techniques constantly as one advances to higher levels. The same point applies to languages. Science, however, is composed of numerous topics, many of which are related when one becomes an adult but which have no apparent links seen from a child’s point of view. To revisit science topics in primary school every other year, to ‘build-on’ previous learning, in a child’s eyes is repetition of the topic. To adult curriculum makers, a curriculum that builds on previous experience makes sense. But on the whole, in my experience, young children will not remember specifics to be built on, so at the start of most topics there is revision to regain ground. It is my observation that children consider they have ‘done’ this topic and are consequently frequently put-off or in their words “bored”.

I propose a more radical solution. Abandon the present primary science curriculum and replace it with one that looks at the environment through earth science, building on things children know about in their locality (from their EYFS programme), can investigate and follow through over their years in primary school. If the curriculum is properly planned, then physics and chemistry ideas can be included within this setting, but will not be hailed as ‘forces’ or ‘gravity’ or ‘reversible/irreversible changes’ (DfE, 2013) but will be seen in the light of every day events: wind, leaves falling, puddles turning to ice. These ideas can be developed in secondary school (ASE, 2018) as the
concepts are brought up and the children will have real-life experiences to relate to. Such an approach would help address several current issues: the repetition problem, since ideas are now seen from different perspectives; primary school science teaching concerns, which could be alleviated as the primary teacher will be looking at concepts from an earth science viewpoint; and the learning of scientific skills which can be taught by observation, record keeping, and analysing data, ready for further use at secondary level. The secondary school would offer new exciting science, linking the primary understanding to further concepts that demand more knowledge of the physics and chemistry backgrounds.

My reason for researching this topic is because I passionately believe that science should be for everyone, and that earth science, in particular, is of interest and concern to us all. Earth science is topical; each of us can have a reasoned viewpoint and earth science issues, sustainable and environmental, affect us all. As a society, we should be knowledgeable about the causes and effects of our actions with enough scientific literacy to decide what actions could and should be taken to alleviate or ameliorate some of these problems.

1.4 Outline of research

The thesis is organised in the following manner. A review of literature that constitutes Chapter 2 will be divided into sections where a range of research articles, reports and other literature is examined, exploring arguments for learning science and earth science in primary school. The global importance of earth science is discussed along with how the subject is viewed in curricula nationally and internationally. Pedagogies used in teaching and learning at primary level are reviewed, followed by research ideas on how children learn and their opinions about science. The chapter concludes with a summary of the ideas and problems faced by the present primary science curriculum, some reports on attempts to find solutions and the research questions to be investigated.

Chapter 3 focuses on the methodology behind the data being collected. Two kinds of data are gathered: primary and secondary. There are three sets of primary data. First, an investigation into the early background in science of trainee primary teachers is undertaken, through a questionnaire, based on research by Bulunuz and Jarrett (2010). Bulunuz and Jarrett’s research suggests that teachers’ feelings towards teaching science are influenced by their own childhood science experiences. Secondly, a survey to understand the current attitudes of primary teachers towards science is carried out through questionnaires similar to those used by Tsai (2002) who attempted to identify whether teachers hold traditional, process or constructivist views and if these views impact on their teaching. Thirdly, intervention lessons planned and taught by teachers in two primary schools after some twilight CPD sessions are described and analysed. The aim is for the teachers to understand the basic concepts of the earth science topic, soil, and how to deliver an innovative and motivating series of earth science lessons to one year group. The objective is to ascertain whether enthusiastic, informed teaching of science concepts (using earth science) can improve children’s learning, understanding and enquiry skills. Finally, secondary data are used in an analysis of the comments made on evaluation forms by primary trainee teachers about CPD workshops in earth science held from 2009-2015, and also comments made by children after participating in rock and soil and fossil workshops from 2013-2015.
Chapters 4, 5, 6, 7 focus on the methods used to gather the data and on the findings from these data, with discussion. Chapter 4 details the primary teacher trainee survey and debates the importance of high quality primary science and its influence on the future participation and interest in science shown by these teacher trainees. Few of those surveyed remembered school primary science activities making lasting memories.

In Chapter 5, the primary science leader questionnaire highlights the differences between the beliefs and practices of science teaching in the current educational climate. Ideal science teaching situations are identified and the term ‘nature of science’ is examined.

The soil intervention lessons observed and considered in Chapter 6 show differences in teaching methodologies employed in two local schools. One school took on board the innovative pedagogy suggested within short earth science CPD sessions for the teachers, with the learning results assessed through SOLO and Bloom’s taxonomies. The second school preferred to rely on its previously tried and trusted teaching methods which gave rise to little recordable learning despite the staff participating in the same CPD.

Chapter 7 examines the secondary data collected from trainee teachers participating in earth science CPD workshops and shows how simple pedagogical techniques can increase trainees’ confidence and self-efficacy in teaching earth science. Analysis of year 3 (age 8) and year 5 (age 10) children’s workshops on rocks and fossils shows that sophisticated concepts and terminology can be incorporated into learning if taught in an appropriate manner.

Finally, Chapter 8 brings together all the findings from the collected data, emphasising how earth science knowledge and skills can lead to a greater understanding of science concepts at primary school level, preparing children for more in-depth biology, physics and chemistry at secondary school. This chapter also looks at the validity of the data collected, ethical considerations and, finally, the way forward, and my journey through this thesis. The references and appendices follow these chapters.

Overall, the thesis aims to look at the potential of earth science for the development of primary science and to try to understand the reasons primary children’s innate curiosity about the world they inhabit frequently does not result in more young people furthering their science studies and entering STEM professions. Why do too many primary children say they find school science ‘boring’ (Taber, 2014) when it should be opening their eyes to more interesting aspects of life? Can primary teachers' self-efficacy (Bandura, 1977) be increased and their knowledge and understanding improved sufficiently to enhance their teaching of science by using earth science? I have spent my whole career endeavouring to enthuse people of all ages so that they appreciate that science, and earth science in particular, is exciting, interesting and worth learning, not only because it leads to an understanding of our natural world. Science is also a way of using our intellect to make sense of many new discoveries in medicine, in space and in our lives generally, by not accepting information unquestioningly but inquiring into its warrants and veracity.
2 Review of literature pertaining to thesis

2.1 Introduction

2.1.1 Organisation of literature review

The first part of the literature review examines the argument as to what science is and then discusses the debate about the nature of science. A definition and explanation of earth science follows, identifying earth science as a wide-ranging science which focuses on the many issues facing the planet of local, national and global importance.

The reasons why it is important to learn science in school are considered from a brief historical perspective, leading into the purpose behind offering science studies for everyone; here the potential advantages of a scientifically literate population are outlined as well as the economic benefits to the UK from more home-grown scientists and engineers. Having suggested why it is important to study science, what should be included in a school science curriculum is reviewed, specifically in a primary science curriculum, and the present role of earth science in this curriculum is identified. A comparison of the ways science and earth science are taught at primary level in different countries is made, in addition to investigating the status given to earth science as a subject globally. I seek to find out whether earth science is appreciated internationally by its inclusion in primary school curricula.

Literature considering when science should be introduced into the curriculum is appraised, starting with the arguments why it be included in the Early Years Foundation Stage (EYFS) curriculum, prior to primary level. The value of using earth science experiences at EYFS level and teaching earth science in primary school and its potential for improving science at this level is considered. The Big Ideas initiative and its relevance to the issues addressed in this thesis is discussed.

In a section entitled ‘How to teach science’, different educational philosophies are discussed and what is purported to be good practice in primary science teaching examined. Pedagogical practices used in teaching science are considered as well as the significance of pedagogical content knowledge (PCK) and science subject content knowledge (SCK), specifically looking at investigative practices and questioning techniques. A further section is devoted to how pupils learn science and the importance of outside agencies in developing scientific awareness. Assessment strategies are included here, alongside strategies pertaining to how children learn and what motivates children to do so. The importance of teacher learning is considered, particularly through continuing professional development.

Attitudes towards science are discussed, particularly the way the general public view science and the need for teachers to be positive in their teaching. The term ‘children’s science’ is considered and the significance of children’s early ideas and attitudes towards science at EYFS and primary level are considered, as are children’s alternative conceptions in science.

Finally, the way forward for science in the school curriculum is reviewed with a discussion of the new USA science guidelines, and the importance that the Next Generation of Science Standards places on earth science. The Geology for Society report (2015) by the Geological Society (of London) is examined and its impact in Europe reviewed. To conclude, the review brings together research on the views of researchers, teachers, children and the general public about science at the present
time, both in England and internationally. The four research questions have been
derived from the literature review and are presented at the end of the chapter.

2.1.2 Background to research about the importance of science

Most researchers and educators agree that science is a necessary and important
subject to have in a school curriculum, as it will prepare students for a more fulfilling
adult life (Reiss & White, 2014), enable the development of vital enquiry skills useful for
many modern jobs (Giles & Hayman, 2014; Pearson, 2014) and alleviate the current
shortage of scientists and engineers (Perkins, 2013; CBI, 2018). However, it is crucial
to ask a number of questions about the purpose of including studying science in a
school curriculum, not only the ‘why’ but also what should be included, at what stage or
when it should be taught, and how it should be taught. These issues need to be
examined not only from an English viewpoint but also on a global scale, so we can
understand how our economic competitors view the world. The International
Association for the Evaluation of Educational Achievement (IEA) has researched the
idea of a global science curriculum (Stacey et al., 2018), suggesting that how science
is intended to be taught provides insight into what world citizens in the future will
understand about the nature and role of scientific advances. There is some
convergence in thought as to the components of these curricula with world issues such
as human health, spread of disease, climate change and environmental impacts being
added to curricula internationally. There is a real need to identify the purpose behind
the teaching of science in schools and to distinguish between the necessity for general
scientific literacy so all can participate in informed discussion and the requirements of
those who wish to become career scientists and engineers can be met.

2.2 What is science?

2.2.1 The Nature of Science

Since 1989, science educationalists in the west have increasingly deemed the teaching
of the nature of science (NOS) to be important (Salahee & Watts, 2015). However,
whilst the term NOS is very much used these days in curricula worldwide – the 2013
English primary science curriculum states that the phrase NOS “specifies
understanding of the nature, processes and methods of science” (DfE, 2013) – there
have been many other variations on the definition (Lederman, 1999; Bartos &
Lederman, 2014; Erduran, 2014; Reiss, 2015). No consensus exists among the
scientific community for a specific definition of NOS (Abd-el-Khalick & Lederman,
2000). In her Delphi study trying to ascertain the meaning of NOS, Ratcliffe (2004)
looked at a consensus of what was thought to be NOS. Thirty experts initially identified
eighteen themes, eventually reducing these to the nine main themes which they felt
should be taught. The main themes identified in the Delphi study were: scientific
methods and critical testing; science and uncertainty; diversity of scientific thinking;
hypothesis and prediction; historical development of scientific knowledge; creativity;
science and questioning; analysis and interpretation of data; and cooperation and
collaboration of scientific knowledge. These were subsequently aggregated into five
suggests that NOS is often low in a science teacher’s list of priorities, particularly in
primary teachers’ thinking and teaching, mainly because teachers’ own background
experience of school science may have been traditional. According to Bartholomew,
Osborne and Ratcliffe, (2004) another inhibiting factor to teaching NOS could be the
lack of time allowed for teaching primary science. The 2013 English primary science
curriculum (DfE, 2013) includes NOS within its aims, stating that the curriculum aims to ensure all pupils “develop understanding of the nature, processes and methods of science …”.

Very young children from age two and before, have a natural interest in science and often have their own definite ideas about how some things work or have come about (Beeley, 2012) but are not aware that scientific views may change or that their ideas may be in conflict with accepted knowledge. At this age, they do not know the word ‘science’ (Crompton, 2013) and the EYFS curriculum does not identify science as a subject by name. By the age of ten years, though, Crompton found that children’s ideas were beginning to formalise around the concepts of investigations, space, environment and nature. However, children will not comprehend NOS unless teachers develop their understanding of science (Harlen, 2013).

Whilst education researchers may understand what they believe NOS to be, in a Western Australian study, Murcia and Schibeci (2010) bemoaned the fact that few trainee primary teachers fully understood what the term ‘nature of science’ really meant. The authors felt that this lack of comprehension would inhibit the trainees’ teaching ability as they would convey outdated ideas of what science really is. They suggested that these same outdated notions continue to be held by school leavers and mature-aged students in Australia. Murcia and Schibeci concluded that trainee primary teachers, and indeed other science teachers, need support in understanding this term and should have specific discussions and CPD training to deliver the ‘working scientifically’ strand of Western Australia’s Student Outcome statements.

Furthermore, Hanuscin, Lee and Akerson (2011) argue that understanding NOS is a critical component in scientific literacy, helping individuals become informed citizens. Osborne and Dillon (2010) consider NOS as offering the best explanations about our material world at any one time. They, too, feel that people need to know how the planet works, and that NOS should be high on any school curriculum. Interestingly, they suggest that science knowledge handed down through generations – local, traditional practicalities – can be as valuable as the developed world’s scientific knowledge.

It is rare for secondary schools to actually teach NOS (Reiss, 2015) and probably even rarer for primary schools to do so, so few children have a real understanding of what science is by the time they leave school. This is significant as it means for example, that not only will many adults lack an understanding of the relationship between the natural world and how humans affect its systems through their economic, social and political habits, but neither will they appreciate that increased scientific knowledge may cause linked relationships to change, e.g. scientists are discovering more about the way ocean current movements affect climate change. Salehjee and Watts (2015) suggest that a combination of in-school and out-of-school experiences should form the basis of an understanding of NOS, whilst Metz (2015) asserts that our current scientific and technological expertise brings to the fore many issues, for example: reducing carbon dioxide emissions through changing energy technology; health issues related to hygiene and diet; and agricultural cloning, to name but a few of the all-important issues about which world citizens should have informed opinions.

A Royal Society of Chemistry’s booklet (2001), written at the onset of the 21st century to help secondary teachers faced once again with curriculum changes, increased the range of ideas implicit in the term ‘nature of science’. The author, Dorothy Warren,
suggests there are many factors influencing the nature of scientific ideas: influences from war and technology as well as from politics, public opinion and legislation, hence including very different concepts from what is normally conceived to be NOS, concepts which she proposes should be discussed in secondary science.

So, if NOS is considered by curriculum makers as being so important (and it has always been included in the English National Curriculum), why is it not being taught more in schools? Donnelly (1999) felt that some science teachers emphasised established knowledge because they perceived uncertainty as threatening. Hickey and Robson (2013) believed that many primary teachers regarded science as a body of facts to be taught not appreciating that scientific knowledge is constantly being reviewed and changed. The latest edition of the ASE Guide to Primary Science (Howard, 2018) suggests that NOS is a starting point for Early Years Foundation Stage (EYFS) teachers to enable children to understand their world and encourage them to make sense of it. Once these ideas have been fostered at an early age, they can be built on in primary school. Ratcliffe (2004) found that NOS is low in teachers’ thinking at primary and secondary level. Erduran (2014) suggested that NOS does not capture authentic science, stating that NOS needs to be interdisciplinary in order to meet the present-day needs of learning. Tsai (2002) asked serving teachers in Taiwan for their definition of NOS and found that 57% held the traditional view that science was factual and fixed.

The University of Waikato in New Zealand produced a website (sciencelearn.org.nz, 2011) for New Zealand teachers, which really identifies NOS. On this website an eminent education professor, Derek Hodson (2009), suggests that teaching science is like an anthropologist looking at a different culture. He likens the special characteristics of the culture of science as being similar to those of a distinct tribe with particular knowledge, practices, attitudes and values (www.sciencelearning.org.nz, 2016). NOS has its own special characteristics, values and assumptions and scientific knowledge has to fit these. Hodson proposes that the five most widely recognised tenets of NOS are appropriate for teaching in both primary and secondary schools and lists them in language that serving teachers can understand. They were derived from the ideas generated by Ratcliffe’s (2004) Delphi project:

- The tentative nature of scientific knowledge
- The empirical nature of scientific knowledge
- The inferential, imaginative and creative nature of science
- The subjective and theory laden nature of science
- The socially and culturally embedded nature of science.

(www.Sciencelearn.org.nz/nature of science, 2016)

However, as with other researchers, Hodson (2014) reaffirms that NOS needs to be taught explicitly (Lederman, 2017) as it is not acquired by learners through traditional science lessons. Educators now recognise the importance of communication to NOS (Russell & McGuigan, 2018). They suggest that classroom discussion of science evidence from the media can be developed as a way of getting children to think critically about new scientific concepts.

Using earth science in the primary school can be a fitting way to introduce ideas about NOS as children are familiar with everyday concepts of weather, landscape, soil and
local ecology. Teachers need to provide learners with a structured ‘way of thinking’ so learners can evaluate what is useful, plausible and meaningful to them and are thus enabled to understand arguments. In their science study Bartholomew et al. (2004) asked teachers to implement NOS into their science lessons and found that at least one teacher used global warming and the greenhouse effect, both earth science concepts, to introduce NOS in an elementary (primary) class.

A more recent pilot study in Sweden (Hkr.diva-portal.org, accessed 2016), carried out by the University of Malmo, identifies the fact that NOS has been in the Swedish science curriculum for some time, but that little is known about teachers’ views on teaching NOS. The study shows that teachers themselves are uncertain about NOS. This study recognised that the teachers found science too “subjective, difficult and abstract” for year 3 (age 7-8) children to grasp. A three year follow-on study aims to develop strategies to help teachers through training so that NOS will be seen as a way to challenge traditional images of science.

If we expect our citizens to be sufficiently informed to participate in socio-scientific decisions, surely we must include NOS as part of our training programme for all teachers of science (Abd-el-Khalick & Lederman, 2000), so that input about NOS becomes a necessary part of secondary science and, perhaps more importantly, is explicitly included in primary science teaching. To this end, new data from Initial Teacher Training (2017) courses suggest that NOS is now being included in most English teacher training at both primary and secondary level.

2.2.2 What is earth science?
Earth science has many and varied definitions from the simple “any of the sciences dealing with the earth” (Chambers, 2016) to the more complex Geological Society of America (GSA) education definition which states “Earth science is an integrated science, bringing together biology, chemistry, and physics as they apply to the workings of Earth”. The GSA goes on to outline the applied nature of earth science and how it can help learners see the relevance of the subject matter to their everyday lives and their communities. Moreover, the Earth Science Teachers Association (ESTA) based in Britain, the teaching profession’s own organisation, further develops the GSA statement by stating that earth science is an integrated study of the Earth’s history, composition and structure, its atmosphere and oceans and its environment in space (ESTA, 2018). ESTA suggests that earth science knowledge is very relevant to children in particular (McCrory & Worthington, 2018) because most human activities are interrelated with the planet Earth, and so basic knowledge about how our planetary systems work is vital if we are to live equitably with and preserve our environment. Earth science therefore brings together the three conventional school sciences and physical geography, but stresses the importance of human interaction. Earth science knowledge is, ESTA states, the key to the development of informed scientific literacy. Earlier, Thompson (1979) had suggested that the word ‘geology’ was too narrow to be used as a subject name when what was really being studied was earth science or earth science systems.

The UCL undergraduate prospectus for an earth science degree (2017) states the course outline as being “to understand how our planet works, at depth and at the surface, the ideas and principles of Biology, Chemistry, Physics, Mathematics and Geography are integrated in the exciting and stimulating studies which make up Earth Sciences”, confirming the integration of the many subjects comprising earth science.
today, with the specification of mathematics in a way that makes sense for a research-intensive university. The prospectus outlines how earth scientists contribute beneficially to society in many ways. Firstly, they monitor geohazards, such as earthquakes, volcanoes and tsunamis, as well as weather and climatic problems: droughts, floods, hurricanes and other potential life-threatening risks (Climate Action Summit, 2016). Secondly, they research, discover and attempt to manage world resources such as minerals and hydrocarbons, in order to manage sustainability. Additionally, they oversee groundwater stores and ensure pollution-free water supplies; they investigate the strength of bedrock for buildings, roads, tunnels and foundations for dams, and they also plan for environmental sustainability (Di Capua et al., 2016). Currently, all branches of earth science are suffering from a dearth of career scientists, especially earth scientists, and many are being employed in Britain from overseas (Perkins, 2013).

For the purpose of my work, I shall use the ESTA definition of earth science, since this starting point of integrating earth science and its systems is an excellent way of introducing science to young children. My ‘importance of earth science’ diagram (Figure 1.1, p15) shows how earth science links permeate all subject areas, in line with the GSA and ESTA definitions.

2.3 Why teach science in schools – general points

2.3.1 Background to school science

Historically, science in primary education in England was not seen as really necessary until well after World War Two (Wellcome Trust, 2008), although early education philosophers had long promoted some sort of scientific thinking: St Anselm, Erasmus and Descartes all saw the need for children to develop ‘enquiring’ minds. Later, Comenius, Rousseau and Pestalozzi understood that children learnt well in a practical environment, acquiring knowledge by exploring, touching, feeling and being in the outside world (Robins, 2012). Modern primary education has many links with these pioneer thinkers, and their ideas are seen as the basis for science learning in early years and primary education today.

The earliest school science lessons, mainly for older children, in the late 1800s, were chiefly for those able boys thinking of science as a career, though later mechanics was introduced as a useful subject for other boys, whilst girls were taught domestic science (Waring, 1985). The 1960s in Britain saw increased interest in primary science with the rise in the need for scientists and technologists (Shallcross et al., 2002), when it was perceived that not enough science was being taught in secondary schools to fulfil the demand for these professionals. Primary science teaching at that time was biased towards the biological sciences and it was felt that primary science could be improved with the introduction of more physical science (Wellcome Trust, 2008). Roden and Ward (2005) felt that teaching science in school was important to produce well-balanced individuals but was often ‘stuffy and full of facts’ and needed to capture primary children’s interest. However, although Nathan Isaacs of the Froebel Foundation (1962) advocated science in primary schools, he warned it should not replicate secondary science saying that the “best service primary schools can render to the cause of science education is to leave it alone” (as cited in Wellcome Trust Report, 2008). Isaacs had earlier suggested (1949) that knowledge acquired in primary school should build upon knowledge cumulatively gained from birth, particularly enabling learning about the world in which children live.
Primary science in the 1970s became prominent at the behest of primary teachers, under the guidance of the School’s Council 5-13 programme, a working body containing at least 50% primary teachers. This period saw a rise in the profile of primary science as well as in the quality of science work taking place in schools. Grants were available to support teacher development; the British Association Young Scientists clubs and Young Investigator schemes began. Wynne Harlen was an avid promoter of primary science at that time and remains so today. However, the National Curriculum took over control of curricula (1988) and lost with it much of primary science teachers’ enthusiasm and sense of professional responsibility (Peacock & Dunne, 2014). Today, the incumbent government along with employers and other advisers, though few teachers, decide on curricula.

2.3.2 Reasons for having science in school curriculum

Isaac’s (1962) ideas about science were very forward looking as he was one of a group of early thinkers suggesting that the adult population of a country should be scientifically literate. Primary science was seen as providing the opportunity for children to understand and interact with the natural environment, to learn skills so as to be able to discuss environmental issues, to develop scientific attitudes towards evidence, and also learn the language of science (Harlen, 2008). This would seem to form a good foundation for adult scientific literacy.

By the mid 1980s, the government of England, Wales and Northern Ireland decided that although some ten subjects were to be included in its first National Curriculum for 5-16 year-olds, science was seen to be important enough to be designated a ‘core’ subject (Wellcome Trust, 2008) alongside English and mathematics. So whilst Isaac’s ideas endorsed the need for the population to be scientifically literate so that they could be ‘demotic citizens’ (Solomon, 2013) with the ability to recognise and understand scientific evidence on many environmental, economic and political decisions, just as important was the growing need for the country to train more engineers and scientists to staff the new technological and scientific industries that were developing in the late 20th century (Charlton, 2013; Broughton, 2013) if we were to remain a major world economy. The SMF7 estimated that in 2013 the UK was some 400,000 STEM individuals short in the workforce and although the purpose of learning science should not be wholly for employment purposes, it can be a valuable contributor to the economy (Giles & Hayman, 2014). Professor John Perkins’ review of engineering skills in the UK (BIS, 2013) pointed out that by 2020 there would be a need for 830,000 more scientists, engineers and technologists, largely to replace those who would be retiring. He suggested that we need to encourage young people to embark on scientific careers now (2013), if we are to have any chance of reducing this dearth.

It has been argued that probably the optimum way to increase the number of potential scientists is to gain children’s interest at an early age (Allen, 2014), and then build on this interest through later schooling. This means that primary science needs to be attractive as a subject to children and one way to make it so is by making it relevant to their everyday lives (McCune, 2009). Howard (2016) also suggests relevance at primary level is important in encouraging future interest.

However, the importance of science in a school curriculum cannot and should not be just for the economic benefit of the country. Science as a subject has much to offer in

---

7 SMF: Social Market Foundation report on the state of British economy, written by Broughton (2013)
the form of intellectual activity and, if taught in appropriate ways, will benefit the population by enhancing critical thinking skills and teaching problem-solving skills. The current English primary science curriculum component ‘working scientifically’ (DfE, 2014) states that it promotes a broad, balanced view of science. The Confederation of British Industry (CBI) (2018) would like to see education much broader that just providing “rote learning and results”. The CBI points towards the need for well-rounded individuals prioritising thinking, questioning, creativity and teamworking; all of these skills can be gained through primary science if taught in an investigative fashion. Primary science, in particular, is vital in preparing our future citizens for the changing world to which we will need to adapt (Serret & Earle, 2018), through an appreciation of our planet’s systems and its response to human intervention.

2.3.3 Education, politics and the curriculum
These days the education provided by most countries has moved away from the Victorian ideal of what might be appropriate for a gentleman. Young (2014) states that there is now a political challenge in the UK by the government and our wider society to propound an entitlement to knowledge. He writes that to some extent governments can influence what is taught, when and to whom, by reducing budgets and restructuring maintenance grants for low income families. Now that Local Education Authorities have been disbanded, being replaced by Local Authorities with a smaller role in education, Young suggests that market pressures and parental choice have most influence on curriculum. Education is seen as the way forward for economic growth (Stacey et al., 2018) and science in particular has taken on a specific role. Fast-moving changes in technology have transformed science education and research by the International Association for the Evaluation of Educational Achievement (IEA) (Stacey et al., 2018) states that The World Bank and OECD now view education from an economic perspective. Gray (2018) suggests that the present science curricula are no longer appropriate to the needs of children in this fast developing technological world with its many changing issues. He proposes that science curricula should have an approach based on sustainability of our planet. Within English schools, politics plays an important role. In many cases, primary schools promote themselves through their English and mathematics results as these are shown in national comparisons through SATs results. Hence more lesson time is being devoted to English and mathematics, and although science remains a ‘core’ subject in name, lesson time for it has reduced (HMCI, 2016). The status of science within a primary school is the prerogative of the School Management Team and the time made available for science study usually denotes its significance to this Team.

2.3.4 General aims of a school science curriculum
Science is currently (2016) given ‘core’ status in the English Primary National Curriculum, where its aims are expressed as the ‘development of knowledge and conceptual understanding of scientific processes, methods and implications through scientific enquiry’ (DfE, 2013). Core status should mean that science is given equal teaching time with the other core subjects, English and mathematics (McCrory & Worthington, 2018), although science, unlike the other two core subjects, is now, in terms of reported assessment, teacher-assessed rather than through national SATs results. One argument for science having this core status in the curriculum was well explained by Millar and Osborne (1998) when they declared that since science dealt with major themes affecting the world and everyone – spread of disease, climate change and more – it was important for children to have an understanding of science which could
be built on later in adulthood. The English National Curriculum (DfE, 2013) was devised to introduce pupils to the essential knowledge that will be needed to become educated citizens. This curriculum should reinforce Harlen and Elstgeest’s initial ‘big ideas’ proposition (1992) and the later publication (Harlen et al., 2015) that understanding the small issues in one’s own back yard could lead to an awareness of global phenomena and global issues. However, Coppard (2016) suggests that the English science curricula does not flow from the primary ‘Big ideas’ through to more specific science concepts at secondary level. Children begin to develop intuitive ideas from an early age (Driver, 1991) which do not always agree with accepted ideas. These ideas are challenged as they advance through school, but may not be rejected, persisting into adulthood (Coppard, 2016). Coppard suggests that there needs to be some change in the structure of the present English science curriculum, linking primary science more coherently with secondary school studies.

Having established that it is necessary to have science in the primary curriculum, the next questions to be explored are what kind of science is appropriate and relevant for the primary age group and who will deliver it. However, Reiss (2007) suggests that the whole purpose of school science education needs to be clarified and perhaps it might be best to look at the aims of education before identifying what is needed in school science.

Jenkins (2004) advocated that science, technology and society (STS) programmes encouraged students to think and talk about political, moral and ethical ideas, but this is perhaps too complex for all primary children even though the National Curriculum in England states that all programmes of study need to be considered from social, cultural, moral and spiritual viewpoints (DfE, 2013). Shaw (2003) suggested that primary children can benefit from this inclusive discussion which may lead to higher order thinking skills. Hodson (2003), too, felt that the STS movement had tried to broaden the concept of science but that this motivation in early science teaching was often lost by the time children reached secondary school. Another project proposed in 2003 and funded in several European countries suggested teaching socio-scientific issues (SSIs) as a way of helping pre-service teachers engage in scientific discourse and encouraging them to use more discussion to help understanding in the classroom (Evagorou et al., 2011; 2014). Again, the SSIs recommended by Evagorou et al. (2014) included political and moral dilemmas which help link science to everyday occurrences, and, it was hoped, would make learners more critical consumers of science. However, this project has not found favour with teacher training establishments and it seems that only Britain and Denmark were prepared to unleash controversial issues in classrooms at the time.

Other research suggests that whilst the world has moved on technologically and scientifically, science education has remained as education for science rather than education in science (Osborne, 1998) and that science has now become a risk that we all need to understand, a point reiterated by Gray (2018). A yet to be published article by Levinson (2018) suggests that there is need to look at STS again; he cites the issues of technology requiring the mineral coltan, which is mined under shocking conditions for both the miners and their environment, and suggests that school science barely reflects ‘life’. He goes on to propose that there are many controversial social issues linked to science which require understanding by young people but which are not generally discussed in schools. We should no longer believe in the infallibility of
science, but rather make our own decisions based on our own knowledge and appreciation of the facts. The latest moves in European science education point towards looking at an ‘education through science’ approach (Holbrook et al., 2014), a real change in education philosophy, whereby science becomes more meaningful and relevant to an individual’s present and future concerns. The acquisition of science skills should go along with the acquisition of critical thinking and other key education competences outlined by the European Union (2006), moving science away from subject-orientated lessons. However, the IEA’s research into globalisation of science (Stacey et al., 2018) suggests that there are mechanisms driving education as a whole, and specifically science, which are tied not just to technology but also to politics. The idea of science knowledge as a mechanism for economic growth is becoming increasingly important. Science curricula are being adjusted accordingly.

The English EYFS (2018) programme introduces children to ‘The World’ as one of the 17 early learning goals (Standards & Testing Agency, 2018). Here, young children are encouraged to explore their local environment and have every opportunity to investigate and ask questions through (albeit organised) play. However, KS1 loses the cross curricular, informality and exploratory approach to the environment with ‘science’ becoming a specific subject within the curriculum (DfE, 2013; McCrory & Worthington, 2018) and spontaneity can become lost. By KS2, despite the Department for Education stating the curriculum is not prescriptive, in reality schools mostly teach closely to the designated science curriculum in order that they can be seen to comply with requirements by LEAs and Ofsted.

Our present English science curriculum content has been debated long and hard over the years, but mainly at secondary level (Jenkins, 2004; Reiss, 2007). The 2013 National Curriculum states that the curriculum should provide the basic entitlement to knowledge to enable children to become educated citizens (DfE, 2013). Essentially though, the science in the curriculum has not changed much since it was introduced into schools in 1904 (Jenkins, 2004; Gray, 2018), despite some researchers and educationalists suggesting that primary science doesn’t need to be reliant on physics, chemistry and biology (Tolmie, 2012), but could, in fact, take a different stance altogether (Littledyke et al., 2000). At the present time, the English primary science curriculum still places its emphasis on physics, chemistry and biology as specific subject areas in the curriculum, examples being forces, properties of materials and living things in their habitats (DfE, 2013), but the document also states that the curriculum is not meant to be prescriptive. The thinking here is that children should develop some understanding and learn some initial science concepts which are built on throughout primary school, then expanded on in secondary school.

The current National Curriculum (DfE, 2013) reflects ideology ascribed to Jerome Bruner (1960) in his ‘spiral curriculum’ (McCrory & Worthington, 2018). This thinking is based upon the idea of building on underlying principles in the curriculum, where concepts are initially introduced at a simple level, and are revisited later in the child’s education with increasing complexity. However, there has been little empirical evidence to ascertain the effectiveness of the spiral curriculum (Johnston, 2012). As an idea this works well in subject areas that rely on previous knowledge in order to advance by building up knowledge with practice, for example in mathematics and learning languages. English primary science curricula have long used the spiral curriculum idea, but much of the current primary curriculum does not lend itself to moving from very
simple ideas to more complex ones until children reach secondary schooling. The science curriculum has a very wide topic base, and in primary school concepts are generally introduced and worked on until children achieve mastery in that concept. Another concept is then introduced, but generally this has few links with the previous one. By the time a topic is reintroduced, perhaps two years later, children have all-too-often forgotten the essentials of what they learnt, even if they achieved mastery, sometimes merely remembering the topic name. There are many topics within the curriculum which at first glance do not appear to be related. However, earth science is one subject which can link many topics and can be a starting point from which knowledge and understanding is easily enhanced. For example, if beginning at EYFS with the idea that water in puddles can disappear, in KS1 practical investigations can look at differing weather conditions to see how quickly puddles disappear, whilst at KS2 pupils could begin to think about evaporation and where the water goes. This would lead into the water cycle, and eventually at KS3 into the physics and chemistry involved, where children are thirsting for novel experiences (Allen, 2014). Other science topics, for example ‘forces’, could use earth science examples as a starting point, using ‘wind’ or ‘water’ as a force.

Millar and Osborne (1998) pointed out that science at primary level should be raising awareness of the potential value of science by helping primary children to understand simple facts about the world, but they still felt that there was little regard for current issues: items children could be interested in like the spread of disease, or climate change. They felt that the whole science curriculum needed a clear statement of aims, outlining the reasons for it being a valuable subject to study with clear purposes understood by teachers, parents and pupils.

It was also thought in the 1990s that science had been too segregated from other subjects and there needed to be a more flexible approach to the curriculum, perhaps linking ideas through topic work (DfES, 2003). Harlen and Elstgeest’s original ideas from the 1980s have been discussed numerous times over the intervening years, but were brought to the fore again in 2015 with a publication endorsed by the global network of science academies (Bell et al., 2009). At their international conference in 2009, the Global Network of Science Academies (iap) group of science education experts identified the key issues that a student should come across during their schooling that would be relevant to everyday life. The outcome was the document ‘Working with big ideas of science education’ (Harlen et al., 2015), which identified fourteen core ideas these experts felt should comprise a science curriculum. Each idea was split into sections to be taught to specific age groups. This brings to mind the spiral curriculum, but because the Big Ideas (Harlen, 2015) vary in scale and understanding levels the material is not repetitious, despite building on previous understanding. Many of these ideas have an earth science base. The authors felt that school science education had not kept up with changes in the modern workplace which require science to be integrated with engineering, technology and mathematics, as well as aware of social issues.

In the United States of America educationalists were overhauling their science curriculum, and the Next Generation of Science Standards (NGSS, 2013) has proposed and forty states have accepted, a substantially new science curriculum from K-12 based around Life Science, Earth Sciences, Physical Science and Engineering including mathematics and literacy. This is an integrated curriculum, linking science
and engineering practices with core concepts and ‘cross cutting ideas’ (NSTA, 2013). These cross cutting concepts are seen as a way to link ‘the different domains of science’ so that patterns, systems, cause and effect (and more) can be studied together, rather than only as separate disciplines. One such unit is based around hazards, and works on the relationships between the earth science and physical science background, linking it with social issues (life science) and engineering practices.

These educationalists have at last recognised the importance of the position of earth science as identified by the Geological Society of America (GSA) (geolsoc.org, 2016). Its website argues that earth science is an essential subject in the school curriculum from kindergarten to year 12 (year 4-12 in England) as it covers the basic knowledge required to understand environmental challenges and natural resource limitations. The GSA suggests that it is critical for everyone to appreciate the interaction between humans and the earth’s systems, so that they are aware of potential social consequences – for example, those caused by climate change and soil erosion. The GSA regards earth science as an applied science subject which enables learners to see the relevance and links between science and everyday life in their own communities, and as such proposes that it should have equal status with other sciences. The editor of the American National Science Teachers Association magazine Scope, page 2, (2016) was “heartened” to see the increase in earth science content in the new curriculum, hoping this will improve students’ appreciation and understanding of the complexities of the planet’s systems.

The Royal Society of Biology recently published a report (Glackin & King, 2018) which laments the loss of all environmental education from the 2014 English National Curriculum at secondary level and stating that on the whole there is no real support for environmental education in formal schooling. The report suggests that young people should be given the opportunity to think widely about environmental issues at all scales, and the chance to debate these issues. Currently, environmental issues are only taught within geography or science if teachers make time or have a particular interest, and the report feels this is not acceptable, since there is need for future generations of children to be able to participate in debates concerning environmental risk from an informed view. It is notable that what the Royal Society of Biology terms ‘environmental science’ is very similar to much of what earth scientists would term ‘earth science.’

2.4 What should be in a school science primary curriculum

2.4.1 What should be included in the school primary curriculum?
Given that primary science needs to interest, motivate and be relevant to children, deciding what should be in the curriculum is critical. The current progressive curriculum, where topics are re-introduced every two years or so, assumes that children will remember what they previously learnt. Remarkably, there is little research into the impact of repetition in the primary science curriculum although it does warrant mention by Murphy and Beggs (2003) who suggest that repetition contributes to the decline in children’s positive attitudes towards science around age 10 in Northern Ireland. Howard (2016) reiterates this point, hinting that secondary schools often miss the opportunity to build on previous primary science understanding and competences. Repeating the same work appears likely to contribute to a growing lack of interest by secondary pupils.
Anne Goldsworthy from Bath Spa’s TAPS project (2014) suggests that the new primary science curriculum (2013) varies little from its predecessor, although it has less content. Annette Smith, ASE Chief Executive, 2013, points out that there is still emphasis on chemistry, biology and physics as separate subjects, which do not necessarily relate to real world pathways (SCORE 2013) although it is not clear if this comment relates to primary or secondary science programmes of study. Sharp and Bowker (2004) pointed out that the National Curriculum had not given much thought to what primary children were interested in and enjoyed, and that there was no real reason why there should be progression through all science topics from primary school through secondary school. However, Hansen (2015) was more optimistic that Ministers were encouraging teachers to consider new approaches, and the latest HMCI report (Spielman, 2018) proposed a move away from inspections focusing on outcomes in terms of test results. The curriculum, it was suggested, gives a school purpose, but HMCI had found that school curricula needed skills as well as a knowledge-based curriculum, and science is a particularly effective subject to help develop skills. HMCI point out that applying skills to knowledge deepens understanding and is therefore essential to curriculum design.

Teachers often find that children only remember that they worked on a topic but not what they learnt, and are frequently put off by going over earlier work. It would seem logical then to try a different approach. The Science Processes and Concept Exploration (SPACE) project (Russell et al., 1993) linked local Liverpool teachers into small teams that worked together, using their own wide range of expertise. Initially, teachers were asked to establish children’s ideas about ‘living things sensitivity to their environment’. This phase included such topics as evaporation and condensation – which could be taught through earth science as children would be aware of puddles drying up (evaporation processes) and precipitation falling – linked to condensation. Two of the themes titles were ‘earth’ and ‘weather’ and the third theme linked earth with weather. The earth theme was researched most rigorously according to the researchers and their conclusions were that the topic provided plenty of exciting and active investigatory material which engaged the participating children. It was suggested in the SPACE project that some of the earth scientists’ technical language and concepts were appropriate for primary children. Whilst it was not always possible to use investigative work, there were many available media resources which could be used to stimulate the children and used as starting points for discussion and elicitation of ideas; examples given were the structure of the Earth and glaciation. The results of this research programme were later used to develop some of the Nuffield Primary Science teachers’ guides, but these currently seem to have fallen out of favour.

The Science Processes and Concept Exploration project showed that earth science delivered in the right manner by starting with children’s ideas, proved popular and promoted successful primary science teaching. Many of these concepts followed on from the EYFS ‘the world’ activities where children were exploring their own locality. Perhaps it is time to return to earth science as the basis for primary science teaching.

2.4.2 The importance of earth science in a school science curriculum
As earth science has distinctive attributes which are not normally present in other sciences, it should have an important place within any science curriculum. Earth science requires retrodictive thinking (prediction of the past) for large-scale thinking and incomplete data sets (Frodeman, 1995; King, 2014). Earth science entails holistic thinking, when looking at interactions between the major earth systems, for example,
the water cycle or the carbon cycle. It necessitates high level three-dimensional thinking too and also involves long time perspectives. Fieldwork likewise makes different kinds of demands on observation and recording strategies not routinely required in other areas of science except biology, and high level skills of analysis and synthesis to understand multi-faceted issues (Frodeman, 1995). The Royal Society of Biology (Glackin & King, 2018) environmental education research asserts that curriculum developers do not recognise formally the role of environmental education but leave its inclusion to the vagaries of individual schools and their teachers, so that important knowledge is absent from lessons. The topics of climate change, sea level rises and associated hazards, as well as loss of habitats due to environmental changes, are important themes for the understanding of all future citizens if they are to participate in informed debate and decision making.

A number of research articles advocate earth science as being a ‘way-in’ to using investigations that employ enquiry skills (Osborne, 1998; Sharp & Bowker, 2004). Enquiry skills are listed as observing, pattern seeking, identifying, classifying and grouping, appropriate testing and secondary research (DfE, 2013). All of these are especially relevant to earth science, including observation, where recognising what is happening in the present day is seen as the key to what has happened in the past. Piecing together the clues that tell us how our planet formed and the changes that have taken place over millennia requires the enquiry skills used by earth scientists, as argued by Morris (2010) who maintains that all these skills are useful tools for life. An inquiry into ‘who might have lived on our school field between the Ice Ages’ sparked off a great day of observation, recording and interpretation in a Surrey school (Balmer, 2015), designed to enthuse teachers and children about science following a poor Ofsted review. In another study, Turkish children became highly motivated when investigating real life issues caused by schools being closed because of heavy snowfall, and used observed data from the daily weather to draw graphs and communicate their findings. The children seemed very involved with the opportunity to use their science skills ‘for a purpose’ (Serin, 2014). Similarly, children in Suffolk, England, were inspired when they tackled a real life local flooding problem, and devised methods to investigate the problems they encountered (Seeley, 2014).

With the global emphasis on climate change and sustainable development goals becoming an everyday topic in the news and other media (Climate Action Summit, 2016) many countries have seen the need to either add or increase earth science in their school curricula (Stacey et al., 2018). This need for earth science in education is widely argued for by such learned societies as the Geological Society of London and the Geological Society of America (GSA). The GSA produced a position statement in 2011 recognising earth science as essential knowledge for 21st century citizens and recommending that all schools, state and private, should include earth science studies from kindergarten to year 12. The Association pointed out that our planet is at a critical stage and it is necessary for its inhabitants to understand potential societal consequences of natural hazards as well as issues arising from misuse and overuse of resources and vital interacting systems, which could have disastrous effects if not understood, reiterating the European SSI framework idea (Evagorou et al., 2014). Hoffman and Barstow (2007) had carried out a curriculum survey of earth science topics in 50 US states and discovered that little earth science was being included in science lessons although it was supposedly being taught from kindergarten to year 12. Their study, produced for the Transportation Environmental Resource Council (TERC),
showed great variation in the depth and understanding of earth science in schools, in particular in ocean literacy, which they depicted as being essential to understanding weather, climate and sustainable global development. Hoffman and Barstow argued that earth science should be integrated with other science topics in order to increase science literacy. As such, the USA’s Next Generation of Science Standards (NGSS, 2014), written by teachers and teacher trainers including several earth scientists (www.nextgenscience, 2014), has issued new guidelines for teaching science and engineering, and earth science is one of the three science themes, although these guidelines are not compulsory. This is in great contrast to the latest English science curriculum (DfE, 2013) where, although more earth science has been included at primary level, albeit in geography as well as science, it has all but disappeared from the secondary science syllabus.

But whilst the curriculum planners in England have decided that science is to be “physics, chemistry and biology”, the Geological Society of London is in no doubt as to the great importance of earth science and in June 2015 issued its policy document Geology for Society in thirteen languages through the European Parliament (European Parliament, 2015). The original, published in Britain in March 2014, outlines the importance of thirteen geological issues such as environmental health, mineral resources, water and geohazards, amongst other issues, as being increasingly significant in everyday life and suggests that geoscientists must communicate their information better, since the general public really should be more knowledgeable so they can participate in informed debate. To this end, the Geological Society maintains there is demand for high quality education backed by good training and research funding to sustain earth science skills and its research base in the UK so that the country can compete internationally. The 2016 Government Tier 2 list of employment opportunities for overseas professionals identifies many geo-orientated careers where England cannot currently provide enough trained personnel to fill vacancies in these occupations. Earth scientists are increasingly in demand and this trend looks likely to continue, given the global emphasis on sustainability, climate change and environmental issues (www.gov.uk/tier2listing).

Much research has been done by the International Geoscience Education Organisation which has been conducting surveys to discover the amount of earth science being taught in primary and secondary schools since for many years (King et al., 2010). A survey of earth science within world school curricula in 2010 (King et al., 2012) showed great variation between countries in the amount of earth science that was compulsory or even present. New Zealand and South Africa included earth science in their general science programmes but the survey states that it was taught by science teachers with no earth science specialism, whilst a few countries in northern Europe included only small sections of earth science in their curricula. This is despite research suggesting that children have a high interest in earth science phenomena (Trend, 2005), particularly looking at past, present and future environmental implications, especially climate change. It was also found that boys were typically more interested in extreme catastrophic events (volcanoes and earthquakes), whilst girls were more interested in everyday earth science phenomena (environmental issues) (Trend, 2005). The Journal of Geoscience Education, which published these international comparisons of the amount of earth science being taught in school, suggested that as well as a lack of awareness of the potential of earth science for teaching science in schools, another
The different approaches to earth science teaching in school were logged in 2014 (IGEO, 2015), which showed that most countries stated they taught earth science as a compulsory part of their curriculum. Only in Malawi was earth science found to be an optional part of the curriculum (IGEO, 2014). As well as surveying whether earth science was being taught, a later survey identified the specific material being taught, and feedback received suggested that further countries were considering increasing the amount of earth science in their compulsory curriculum. An international earth science syllabus has now been developed and published, and feedback is awaited from the next IGEO conference as the syllabus is introduced across the globe (King, 2014). The International Geoscience Education Organisation (IGEO, 2015) continues to argue for a specific identity for earth science within school curricula, citing several examples from Harlen’s (2015) Big Ideas report as being a useful starting point for all age groups. The IGEO syllabus has the potential for improving earth science understanding of the past, present and future and can be developed within countries to suit their specific needs (IGEO, 2015).

The annual International Earth Science Olympiad (IESO) for secondary school students is aimed at raising public and student awareness of earth science issues and held its first competition in 2007 in India. The Olympiad meets in a different country every year (the 2018 event will be held in Thailand), hosting teenagers and adults and striving to improve our understanding of the Earth’s problems; its major aim is to enhance interest and improve the teaching of earth science (IESO, 2018). The IESO is one of the thirteen International Science Olympiads and its annual competition tests abilities in disciplines such as geology, meteorology, environmental science and terrestrial astronomy. Students who are winners of the respective national competitions are invited to participate in the IESO, and all interested countries are encouraged to contribute to it as well.

Northern Ireland is a rare example of a country that is making a concerted effort to increase the amount of earth science in its primary syllabus (Cowan, 2013) to help teachers bring physics alive. A series of lessons incorporating geoscience was being trialled in teacher focus groups and in 2016 was distributed to all Northern Irish primary teachers. Plans to communicate earth science to the general public across the whole of the island of Ireland have also come to fruition in 2016 (Lemon, 2016). In contrast, while Scotland’s new Curriculum for Excellence suggests cross-curricular teaching using a topic, e.g. weather, for primary children (Education Scotland, 2014), the Scottish curriculum has reduced the earth science content in its Higher syllabus because of too few teachers with the ability to teach it (Robinson, 2014).

In other parts of northern Europe, the problem is solved by allocating the subject to geography teachers (King, 2014), but southern European and Latin American schools still retain earth science within their natural science programme. As shown earlier in the 2005 survey (Trend, 2005), Western Pacific nations, Japan, Korea and Taiwan have up to one quarter of their science syllabuses as earth science, taught by highly trained teachers, whilst Australia and New Zealand struggle to get qualified earth science teachers at primary level (King, 2014). Canada, too, has minimal earth science in its science curriculum, suggesting that little curricular attention has been paid to the changing position of science (Hodson, 2003).
It seems that the newly emerging nations are placing more emphasis on earth science than more developed countries, with the exception of the USA which has proposed new guidelines in its Next Generation Science Standards curriculum (NGSS, 2014).

2.4.3 Earth science in the English National Science Curriculum
The latest English National Curriculum (DfE, 2013) for primary science continues to place considerable emphasis on enquiry skills in its ‘Working Scientifically’ and actually lists them. Many of these skills can be covered well by earth science teaching. Indeed, Turner et al. (2014) produced a guide and listed all of these required skills using geology, meteorology, space science, palaeontology and mineralogy as starting points from which children can observe, measure and record information, then begin to interpret their results and communicate their findings. The National Curriculum also identifies the need to introduce the nature of science (NOS) at all levels, and earth science is an excellent vehicle for explanation of NOS, including evidence of change in scientific theories, climate change being but one example (Russell & McGuigan, 2018).

Initially, the EYFS English National Curriculum (2018) advocates guiding young children to understand and make sense of their physical world by giving them opportunities to explore, observe and find out about the people, places, technology and the environment they live in, generally through play activities. This is earth science. These activities may be child- or adult-led and essentially introduce children to the world around them informally through practical earth science. At the EYFS stage there should be plenty of time allowed for children to ask questions, observe and talk about their environment (Beeley, 2012). Beeley suggests that the use of questioning techniques which are enabling (prompting the child to explore and discover) encourages their interest in science at this early age. Later, more formal lessons begin in KS1 which aim to increase the level of thinking, again using experiences, as suggested by Braund et al. (2018) when introducing terms such as ‘evaporation’.

Following the introduction of the 2013 English Primary National Curriculum (DfE, 2013), at KS2 it is required that in science children can compare and group rocks, and describe how fossils and soils form. Evolution and the earth in space are taught in year 5 and 6. Within geography it is expected that children can describe and understand the key aspects of climate, biomes and vegetation belts; and also rivers, mountains, volcanoes earthquakes and the water cycle. They should understand and describe the distribution of natural resources. All of these topics constitute earth science and can be integrated into cross curricular activities, linked with local events and items of world interest. Many of these topics are part of the Big Ideas framework advocated by Harlen et al. (2015), and earth science could also be taught, with some imagination, through forces, materials and changes of state as well as being included in ecology and sustainability. With the reduction in environmental education as shown by Glackin and King (2018) it is vital that children understand these major issues facing the future of the planet.

Some of the earth science aspects in the primary curriculum are later expanded upon in KS3 geography. KS3 geography demands detailed place-based exemplars of physical geography and requires a study of plate tectonics, time scales, rocks, soils and weathering and climate as well as basic landscape formation and hydrology (National Curriculum, 2013). Whilst within geography the curriculum specifies the need to understand the processes behind these hazards, it does not take the opportunity to relate these processes to chemistry and physics. The links and interactions are rarely
exemplified; for example, links are not made between the processes of erosion and the chemical make-up of rocks, nor between the underlying rock, soil and climate. The curriculum states that the emphasis is more on social than scientific issues (DfE, 2013). Weather and climate are touched on at KS3 but again not linked to the science. Few secondary geography teachers have a detailed understanding of the science of physical geography at KS3 (Ofsted, 2011) and students are rarely taught the how and why of these concepts, concentrating more on social issues. However, understanding the importance of social implications is a necessary part of earth science programmes and geography teachers are typically better (Ofsted, 2011) at this than are science teachers, but at the same time it is important to understand why and how these risks occur and whether human intervention is exacerbating these issues. Orion (2007) suggests that earth science be taught at all levels within relevant contexts and through constructivist strategies, integrating the outdoor environment with science concepts and focussing on both cognitive and emotional aspects of learning.

Currently, although much earth science is taught in England in the primary school, as detailed above, few primary teachers have the required science knowledge to be able to explain the science behind the concepts (King, 2011) and need more pedagogical as well as subject content knowledge support through CPD (King & Thomas, 2012). Inaccuracies in textbooks add to teachers’ misconceptions about earth science (Fleming et al., 2001), one area in particular being the explanation of the water cycle.

The previous English primary National Curriculum for Science (DfE, 2000) had stated that science should be taught through knowledge, skills and understanding, but was based firmly on biology, chemistry and physics topics, with a very small section about the Earth and beyond in KS2. It was felt that the Government’s emphasis on target attainment in the SATs tests teachers kept fairly rigidly to the stated curriculum to ensure their pupils were able to respond to the questions asked in these tests. Writers of the latest science curriculum thought that a revised science curriculum might enthuse children and teachers. However, the primary science curriculum introduced in 2013 has reverted back to Wynne Harlen’s original ideas of ‘working scientifically’, focusing on the enquiry skills of observation, pattern seeking, classifying, controlled investigations and research using secondary sources (DfE, 2013). It suggests children should be encouraged to look at everyday phenomena and increase the knowledge underpinning their own ideas of the world, proposing relationships and discussing their thoughts with their peers, using investigations to gather evidence. Once again this puts a considerable burden on primary science leaders who need more help in developing materials that staff can understand and teach effectively (Wellcome Trust, 2014). The new curriculum suggests using earth science examples as suitable topics, well documented by Smith (2016), although it does not call them earth science! It was suggested that a curriculum looking at local everyday phenomena, for example weather (DfE, 2013) might excite children and teachers. Harlen’s (2015) Working with Big Ideas report offers a way of providing relevance and opportunities to look at globalisation issues as well as taking out some of the content from the primary science curriculum, which has been described as being too crowded (Harlen, 2015). The Big Ideas are divided into appropriate sections for each key stage group. Eleven of these identified big ideas include at least eight with earth science content linked to other science disciplines, physics, chemistry or biology, at primary level. The final three ideas are linked to the nature of science (explanations and scientific theories), engineering
knowledge and ethical, social, economic and political considerations, all of which can usefully be viewed through earth science discussion.

Within a normal daily primary routine, earth science topics can be linked to mathematics and literacy as well as the humanities subjects, making them a useful starting point for many discussions (Skamp & Preston, 2015). The very fact that all children have some experience of the environment means that they can talk about and question it, so that it is an ideal way to start science topics. Here, effective teaching techniques can be introduced. Children have experience, knowledge and understanding of what goes on in their own environments, and will talk, promote ideas and question from experience. Teachers therefore have opportunities to use those observations that children may have, for example: how it rains; where specific plants grow; why potholes form in the roads during winter, all of which can encourage discussion and may foster ideas for practical work (Skamp and Preston, 2014).

Children should thus be encouraged to look at everyday phenomena and broaden their own ideas of the world (DfE, 2013), discussing their thoughts with their peers and using investigations to gather and explore evidence. Once again, though, this is putting a strain on primary science leaders who need more help in developing materials that staff can understand and teach effectively (Wellcome Trust, 2014) although Harlen’s ideas are mainly based on relevant issues and concepts which are known to children providing a basis on which to start discussion, for example weather and fossils. King (2008, 2012) suggested that teachers at all levels need good earth science CPD help in both subject content knowledge (SCK) and pedagogical subject knowledge (PCK), but especially teachers at primary level whose background in science is generally limited. This is reiterated by Ofsted’s (2013) report on Maintaining Curiosity in Science which suggests that improved training and updating of subject knowledge is needed in primary science in both SCK and PCK. Perhaps curriculum developers should be looking at turning the primary science curriculum towards everyday happenings, since examples of abstract concepts, such as forces, gravity and changes of state, can be taught using earth science (with some imagination). Earth science can and should play a bigger role in the primary curriculum than it does at present (IGEO, 2012).

2.5 When to teach science in the curriculum

2.5.1 Young children and the science curriculum aims
Children are inquisitive when they are young, and even as babies are fascinated by rocks and soil (Dungy, 2013). Serret and Earle (2018, p3) state that there is "an intuitive desire to make sense of the world from birth". From their earliest years, children make their own predictions and interpret their ideas about everyday happenings (Harlen, 1985). It seems, also, that science experiences at a very young age have a lasting effect on later attitudes towards science (Joyce & Farenga, 1999). Sylva et al. (2004) too showed that EYFS experiences have a profound and lasting impact on children, so it is vital to ensure young children have purposeful, well-planned opportunities for play Thus, children come to pre-school and school with a range of remembered experiences (particularly earth science related ideas) from which they have derived their own theories. Therefore, it would be fitting to channel their ideas and build on this early interest (Harcourt-Brown, 2011; Standards & Testing Agency, 2018).

Wynne Harlen suggests that the purpose of primary science should be to raise children’s inherent sense of curiosity towards science and point them towards problem
solving (Harlen, 2008), as primary science should be the starting point of a lifelong relationship, helping all of us to find answers to solve questions as we grow older (Serret & Earle, 2018) and to develop key life skills. Researchers have found that a positive primary science experience stays with children throughout their lives and this influences their thoughts and feelings about science (Jenkins & Nelson, 2005; Wellcome Trust, 2013, 2014) and can become a foundation for later interest or even further study. Since science deals with everyday issues on scales from local to international – for example, health, energy use, pollution, climate change (Millar & Osborne, 1998) – it is important that each of us has some understanding (science literacy), in order to be useful citizens able to make informed democratic decisions (Solomon, 2013). Because science is a practical subject, many basic useful activities can be learned such as changing fuses, removing stains, and storing food (Hickey, 2013) as well as essential enquiry skills which are an important part of almost every job, such as problem solving and communicating skills (Charlton, 2013). Dewey pointed out that young children are naturally curious and that science at an early age can inspire them, develop their curiosity and again encourage the development of skills that are useful and often necessary in later life (Dewey, 1916; Millar & Osborne, 1998; Wellcome Trust, 2013).

Parental interest and involvement, too, is an essential part of all primary education but particularly so in science (Royal Society, 2008). It is suggested that low socio-economic status (SES) families in the UK do not feel science is ‘for them’, and in particular, not for girls. The idea of ‘science capital’, proposed by Louise Archer et al. (2014), reiterates this: lower SES families often do not have the means to visit museums or science festivals, and may not see the educational benefits of scientific toys and reading as much as middle class parents. However, people have access to the many kinds of media through which earth science issues are continually being raised, which could easily be the basis of family discussion if the interest was raised in the classroom.

Although it is generally thought important to teach science at a young age, what is probably more crucial is to have well defined aims for a science curriculum and how to go about teaching it (Robins, 2012; Reiss & White, 2014). Science is a starting point for encouraging children to be active learners (Hickey & Robson, 2013). However, Hickey and Robson suggest that sound reasons should be stated for what is to be taught, alongside a clear understanding of why it should be taught. Evagorou et al. (2014) submit that these days SSIs, for example global warming, are very much part of children’s lives and so should be included in the curriculum.

2.6 How to teach science

2.6.1 Different educational teaching philosophies
There are a number of different teaching philosophies which have been advocated over many years: the chief ones can be categorised as traditional, progressive, positivism, process, and constructivist. Bruner, Piaget and Vygotsky’s ideas all play a part in the development of curricula, not just science. Bruner and Vygotsky emphasised the effects of a child’s social environment on their ideas, more than did Piaget. Bruner, especially, felt that education should facilitate a child’s thinking and problem-solving skills, which were seen as transferable. All three identified language as being an important part of conceptual understanding. Vygotsky and Piaget acknowledged the
importance of adults in the development of a child’s knowledge and understanding. However, Bruner and Vygotsky did not agree with Piaget’s stages of development, suggesting that development is a continuous process. Many of the ideas of these three educational philosophers have been incorporated in our current curriculum.

Since the introduction of the English National Curriculum for primary science in 1988, and possibly a little earlier in those schools who were using School Council 5-13 science programmes, there have been changes in the approach to teaching science, with moves away from traditional factual learning by didactic methods. Science was traditionally seen, as it is still is by some today, to be a series of facts and skills which had to be learnt. Research shows that girls in particular are alienated by didactic science teaching (Howard, 2016), particularly when testing by SATs dominated primary English science teaching. The Education Reform Act of 1988 identified science as a core subject within the National Curriculum, to be taught at all levels, stating that it should include not only knowledge but understanding as well. This brought about changes in the way schools were expected to teach science, encouraging children to have their own ideas about science.

Bryan (2011) reviewed two decades of literature on science teacher beliefs and the changes in thought of how, or if, teacher beliefs influence teaching. She analysed a range of studies that established the complexity of these teacher beliefs and whether the beliefs do influence how teachers view students and teach them. She also identified the difficulties of defining beliefs in the first place and changing espoused beliefs into actions. It seems, however, that many researchers have concluded that there is limited congruity between beliefs and practice, although this may become more evident with more teaching experience. What is interesting is that teachers frequently espouse curriculum changes but in practice interpret these changes to fit their personal beliefs.

The philosophy of child-centred teaching, a progressive philosophy, advocated that learning comes from finding answers to questions through investigation or experimenting (Hanly et al., 2015). Children’s own views would be tried out and it was hoped this would promote learning and understanding. Another philosophy, positivism, is teacher-centred with teachers providing ‘valid’ laws and concepts that can be tested and verified, though students are not expected (or allowed) to suggest their own theories. Process philosophies suggest that scientific knowledge is discovered through following scientific procedures, by problem solving and by ‘working on the process of verification’ (Tsai, 2002).

Constructivist approaches are both participative and student-centred, providing children opportunities to assess evidence, negotiate and make their own decisions from the evidence (Ross et al., 2010). Van Vondel et al. (2017) suggested that children’s scientific understanding was triggered when teachers asked questions rather than telling children the information. This seemed to enable more focus on constructive scientific understanding. Constructivist approaches include dialogic discussion which further moves away from the traditional didactic method of teaching, encouraging children to question, explore and debate ideas with their teachers and peers (Chin, 2007). The role of the teacher here is to try to get these ideas linked to everyday views and happenings, and this may identify misconceptions as concepts are discussed by the children themselves. However, it is recognised that children do not usually have enough prior experience to come up with necessarily meaningful scientific ideas and
need some help from teachers in assessing evidence in what can be called an intervention phase. Driver (1994), Ross et al. (2003, 2010) and others suggest that these phases commence by using an engaging starter activity, followed by finding out what children know about the topic under discussion. Next, the children are involved in some active learning activities, with perhaps some theory, leading on to interactive debate about the topic and, finally, a summing up of the ideas. In this way children can reform their ideas if necessary, to agree with any accepted scientific thoughts. It is well known, though, that whilst children may accept these new ideas within the classroom, they may well not assimilate them into their own knowledge and understanding (Allen, 2010). Constructivist views suggest that children make sense of their own worlds by investigating and adding to their own knowledge and understanding. These ideas may well be related in the child’s mind and though not necessarily accurate constitute the learner’s cognitive structure – how the learner links ideas together. As their ideas develop, young children begin to predict simple behaviour, for example they learn that some objects will float and others will sink. However, whilst it is considered to be beneficial for children to construct their own knowledge, ideas at variance with accepted science concepts often arise, alternative conceptions, which need to be corrected (Loxley et al., 2014, Skamp, 2015). Although it is important for young children to develop their knowledge, they do not have the ability to engage in much abstract reasoning and can often only see things from their standpoint. Their explanations may satisfy their own reasoning and may be valid for specific instances but will not bear scrutiny for explaining other phenomena. These ideas are often termed ‘children’s science’ (Osborne et al., 1985) discussed later in 2.8.3 p65. Traianou (2006) advocated the idea of small range and big range constructivists which depended on the soundness of a teacher’s scientific knowledge. Small range constructivists were those teachers with adequate conceptual understanding of a small range of concepts, which they would be happy to explain in a classroom situation. Those teachers with further understanding of the broad principles – Harlen’s Big Ideas (Harlen, 2015) – might, Traianou thought, be more confident at explaining overall concepts. They would be able to link physical phenomena with scientific concepts, e.g. earthquakes with forces and pressure changes.

Whilst it is generally felt by educationalists that allowing children to learn through investigative methods is highly desirable, there is no evidence that this produces better learning outcomes (Abrahams & Reiss, 2012), although it has been argued that constructivist approaches increase retention of knowledge better than traditional approaches (White, 2005). In practice, however, true constructivist approaches are difficult with class sizes of 30 or so children.

2.6.2 Strategies for teaching specifically in science

Early philosophers of education felt there was much to be learned through practical experience and working outdoors, examples being Descartes, Comenius and Locke’s suggestions about allowing a child to question, discuss and work outdoors with parents and Pestalozzi’s practical farming methods for his family (Robins, 2012). Rousseau (1911) felt that “education should accommodate the child not the child accommodate education”. Many of these early suggestions have contributed to today’s pedagogical theories of how to teach children, for example, ideas about dialogic teaching (Ágular, Mortimer & Scott, 2010) and questioning (Chin, 2007; Alexander, 2015). Comenius’ thoughts about conceptualisation (General Teaching Council for England (GTCE), 2010) and the notion that children would be more engaged in learning if their parents
believed and valued education are certainly still appropriate. Dewey (1916) considered that science should be taught through prediction and problem-solving activities. Earth science is particularly suited to this. Piaget’s and Vygotsky’s notions of children’s thoughts and early concepts being related to what is around them also fit with exploring everyday phenomena in earth science. Hence, the availability of a wide range of accessible local resources for earth science (soil, rock, weather, landscape), allows much of the physics, chemistry and biology content of the current primary curriculum to be taught using earth science as a basis. Piaget (1929) suggested that at age 7, children experienced a ‘take-of’ period in learning and primary children are thus at an appropriate age to develop and investigate ideas, especially if working with more knowledgeable adults or peers on new concepts, which Vygotsky (1978) advocated as being advantageous (his Zone of Proximal Development). Furthermore, Vygotsky (1986) appreciated that language is an important tool in science and the proper use of science terminology is difficult when children are young. But children can use everyday language which they understand to describe the earth science events they experience, rather than specific scientific language, which can be learnt as they mature. The 2014 English National Curriculum for science specifically mentions the teaching of appropriate science language in primary schools, although unfortunately, often difficult abstract concepts in science, e.g. forces, use common words in a different way from everyday usage. Harlen and Qualter (2004) emphasise the necessity for a child to experience a phenomena before using the scientific words.

Teaching is not just about knowing the subject, regurgitating content and expecting learners to absorb the ‘pearls of wisdom being offered’. The 21st century method of teaching is (or should be) very different from the didactic, factual teaching of earlier times, Victorian and early 20th century approaches, when children were taught to restate facts. Pedagogy can be defined as the discipline that deals with the theory and practice of teaching and how these practices can influence students’ learning (Chambers, 2000). It has greatly developed since the 1980s in England and is now a substantial part of teacher training courses (GTCE, 2010). Teachers are required to do more than just give information as it is necessary that children understand the reasoning behind scientific concepts and are able to apply this knowledge. That being the case, it is vital that teachers themselves understand what they are teaching, and this is a particular issue in primary science where many teachers do not have a science background (Goodrum et al., 2001). Hattie’s analysis of meta-analyses proposes six signposts to excellent teaching, gleaned from nearly 20 years of research based on over 50,000 studies (Hattie, 2009). He found that researchers agree that effective teachers teach by looking at issues through a student perspective and adapt their teaching methodologies for individual students through different strategies – suggesting that teaching is not just about knowing how to teach but also knowing when a student does not understand and adjusting one’s teaching accordingly. However, the primary science SATs of the 1990s and 2000s sometimes seemed to require a return to this factual regurgitation (Ofsted, 2011). This way of promulgating knowledge might have been appropriate in the Victorian era, but in today’s technological and scientific environment it is not.

Harlen and Qualter (2014) have researched and written extensively about teaching primary science and always start with children’s ideas from an early age. They see science as being a very important part of children’s education for life, since we all need to be informed citizens and science helps develop understanding, reasoning and a
positive attitude to life. Hence, they have suggested ten principles of science education; these delineate the aims and purpose of a school science programme, what the programme should develop, how learning experiences should reflect scientific knowledge, inquiry and deepen understanding, progression towards big ideas, assessment methodology, cooperation between schools and their local communities and programmes of learning for all, including teachers, teacher training and CPD (Harlen, 2010). Harlen and Qualter (2014) continually emphasise the importance of teaching science at primary level, and in the latest ASE guide to primary science teaching, Harlen (2018) stresses, yet again, the importance of using practices that work in the classroom and enable children to work scientifically.

2.6.3 Good practice in primary science teaching
Ofsted (2010), Wellcome Trust (2017) and many others all state that teachers should follow ‘good practice’ but it is not always the case that what this entails is spelt out in detail. Within schools, teachers collaborate on ideas which work well and adapt these for their own purposes (Ofsted, 2010). Further into this Ofsted report, the inspectors identify what they see as ‘good practice’ – a fully engaged class working constructively to a well-planned lesson with an enthusiastic teacher, who has stated objectives. The inspectors recognise the importance of other adults helping with the lesson to be well informed. It is suggested that good practice will provide effective assessment procedures, and that the teacher may have set targets for the children to achieve. Osborne and Dillon (2010) write that it is important for research to be engaged with the practice of science teaching, since there needs to be professional discourse which is more informed than personal experience. Science teaching should be ever changing, as science is in a continual process of change, and hence good practice should reflect this.

Sharp et al. (2017) identify a range of strategies that teachers can use to elicit children’s own ideas about topics before embarking on something new. If teachers can identify where each child is, prior to introducing a new concept, they are then better able to plan appropriate work and determine how much scaffolding children require. Good practice advocates that teachers should always set high expectations through inspiring and motivating children, with challenging lessons.

2.6.4 Pedagogical strategies
Osborne & Dillon, (2010). Define pedagogy as implying the whole philosophy and value system that lead teachers to make the choices in what and how they teach. Wyse and Rogers (2016, p168) identified a triangle of linking Curriculum, Pedagogy and Assessment with the ideas of learning and the learner. If these three themes are properly linked, they suggest, an engaged learner will advance to become an educated citizen. Today’s teachers need to relate to individual children and their learning needs in ways that enable the child to develop at his or her own pace. Teachers should engage children in constructing their own learning through goal setting (Skamp & Preston, 2015). Furthermore, Allen, (2016) considers that teachers should also appreciate that children’s early ideas are not necessarily misconceptions (and be conscious of helping young children to attain accurate scientific concepts through learning activities based on their own experiences. It is frequently suggested by researchers that topics should be introduced through concept maps, promoting discussion and identifying pre-set ideas (Harlen & Qualter, 2014), and that maintaining curiosity is vital to continuing progress (McCrory & Worthington, 2018). Hattie and Marzano (2015) agree on strategies to engage pupils and build up their self-efficacy
which, they say, will have an impact on later achievement. These days, pedagogical strategies are intrinsic to teacher training courses at all levels, from early years to upper secondary. The development of questioning strategies over recent years has led to the opening up of different ways of assessment, for example, the idea of Socratic questioning to identify pupil thinking and viewpoints leading to more critical thinking (Paul & Elder, 2007). Teachers are taught different questioning strategies to elicit information from their pupils, which is recorded even at EYFS to identify children’s assumptions to ascertain levels of development and progress through observation and discussion. At primary level, questioning is used to obtain information, to facilitate higher thinking skills and to encourage pupils to listen and question their own and their peers' understanding. Socratic questioning, in particular, is a way of exploring difficult concepts and encouraging deeper thinking and analysis.

Attained levels of knowledge and understanding can be assessed through different taxonomies; examples often used are the SOLO taxonomy developed by Biggs and Collis (1982), which can be used for any activity, and Bloom’s revised taxonomy (Anderson & Krathwohl, 2001). Both these taxonomies demonstrate the importance of understanding in the acquisition and application of knowledge. Where children are seen to be falling behind in their understanding, strategies such as ‘scaffolding’ can be used to help and encourage progress. Teachers need an armoury of teaching methods since it is now understood that children learn in different ways, so interactive teaching, enquiry-based sessions, individual and group work are used alongside more traditional approaches. Reflective practice is identified as an important habit for teachers to develop to ensure teachers are aware of what they are doing and saying and also why they are doing it (Wyse & Rogers, 2016; Pollard, 2014). Developing appropriate assessment strategies through evidence for formative assessment and encouraging even young children to identify and aim for specific goals are devices now used to encourage learners to be more involved in their own learning (James & Pollard, 2011).

2.6.5 Pedagogical content knowledge
The idea of ‘pedagogical content knowledge’ (PCK) was introduced by Lee Shulman (1987) in his presidential address to the American Educational Research Association. Shulman suggested that PCK included not only actual subject knowledge and pedagogical knowledge (e.g. classroom management and organisation) but also the specific knowledge of how to put over particular instances of content at an appropriate level: by understanding the cohort of learners, their culture and home environment. Berry (2013) looked at a number of related PCK studies and identified five components in which, she said, teachers should develop expertise with respect to all the science topics they might teach. These were: developing an orientation towards teaching science; knowledge of the science curriculum overall; knowledge of the pupils’ understanding of science; knowledge of assessment in science; and strategies for teaching specific subjects or topics within science. She pointed out that researchers frequently failed to acknowledge the difficulties faced by teachers trying to teach outside their subject area – and this is particularly relevant to primary science. The teacher’s own background and prior experience, as discussed later in 2.8.2 p65 about teacher attitudes, is very important, and although there are materials specially produced for primary science teaching, not all are suitable for every teacher (McKinnon & Lamberts, 2014).
Appleton (2002), too, had found that different activities suited different teachers when teaching science, and that not every teacher was happy with ‘hands-on’ practical work. In his Australian study, he reiterated Shulman’s PCK ideas, emphasising that there was a need for a ‘purpose’ when teaching something scientific. Many Australian primary teachers at the time used the Primary Investigations developed by the Australian Academy of Sciences, which involved practical work that the teachers found motivating and challenging. Appleton noted that if the teachers were interested enough, the activity being used was more likely to motivate and engage the children. However, he suggested that a circus of activities should be undertaken in small groups with fewer than six children, which would require considerable extra – probably parental – help in the classroom, not always available.

Palmer (2007) repeated Appleton’s research and went on to suggest that primary teacher trainees benefit from science methods courses linked to in-school practical activities during teacher training, rather than purely science content courses. He suggested there was a need for a radical change in initial teacher training programmes to accommodate this. In a later study (Palmer, 2008), he found that if trainees could attend science faculty sessions whilst on their training course, they benefited from improved knowledge which, when coupled with science methods training, increased both confidence and, in many cases, competence. He identified the fact that senior school students in Australia felt that physical science had a low intrinsic and strategic value and pointed out that science methods courses for trainee teachers, including confidence building running alongside some science content, could help trainee teachers to dispel these notions. He emphasised that trainee teachers should try to utilise children’s natural curiosity to enhance the children’s learning, not only in science but in all subjects, and found that school-based experiences during training also improved teaching confidence.

In the 2018 Association of Science Education’s latest guide to teaching primary science various authors, both researchers and primary teachers, suggest that teachers need sound science pedagogical knowledge in order to direct learning at this level. Science should be about enhancing knowledge skills and motor skills, enabling pupils to learn the language of science and understand how scientists work, by enabling children to work in the same way as scientists – posing questions, investigating problems and ideas and coming to conclusions which can be discussed. Enabling children to develop personal and team skills whilst learning science should also be part of a teaching skill.

2.6.6 Science subject content knowledge

Whilst PCK should be an important component of a primary teacher’s training, it is crucial that their subject content knowledge (SCK) is developed as well. Traianou (2006) found that effective science teaching depended on SCK and PCK, both of which linked to teaching confidence and self-efficacy. She insisted that a teacher’s own science understanding needed to be sound before the teacher could properly explain a concept to a class. Earlier surveys of primary teachers’ physics, chemistry and earth science subject knowledge had shown a number of inaccuracies, whilst many primary teachers also had misconceptions about biology. Holbrook, Rannikmae and Valdmann (2014) suggested a change in the philosophy of teaching science by promoting ‘more meaningful science’. Their ‘education through science’ philosophy promoted not only an appreciation of the science itself but the links between learning generally and science learning which developed personal skills, social/cultural appreciation and career development.
The Wellcome Trust (2017) acknowledged the difficulties faced by primary teacher training institutions in identifying and tackling the issue that fewer than one-third of trainees had studied science beyond GCSE, and trainee teachers stated that they did not feel particularly well prepared to teach science. It was, the trainees said, rare to have the opportunity to watch good science in practice in a classroom, which they felt would have been beneficial. The few trainees with a science background, to A level, generally have biology rather than other science experience. Within those institutions researched in the Wellcome Trust study, the different kinds of training institutions all placed more emphasis on science-specific pedagogy rather than content. Only the BAEd courses identify topics of concern to trainees and then include specific science content, this being taught by science specialists in most cases. Whilst it is not necessary for primary teachers to have science degrees, they do need some level of expertise; it was suggested that trainees could access content themselves through the various media and texts available.

2.6.7 Pedagogical Content Knowledge and Subject Content Knowledge in earth science
Earth science is particularly well suited to the use of suitable pedagogical approaches. All the ten principles of effective pedagogy outlined in the Teaching and Learning Research Programme (James & Pollard, 2011) can be realised through looking at local issues, most of which are of an earth science nature. Easily formulated investigations using these issues with the aid of simple resources offer a range of questioning opportunities based on children’s own local knowledge and experiences. These local issues can later be allied to the Big Ideas of science (Harlen et al., 2015), and findings can be discussed between children, and perhaps with their parents at home as well as with teachers in school. Working on local issues can also enhance cultural and community relationships. Children’s prior knowledge can be ascertained, so that evidence of learning can be assessed. Scientific skills will have been employed in collecting information about local issues and pupils’ perspectives of their environment can be sharpened. Community decisions about specific issues can be debated, for example traffic rat runs and the problems of vehicular air pollution.

Science should deal with ideas about the environment (Ross et al., 2010) and although the authors of that reference particularly look at secondary science, they argue that misconceptions about earth science and space should have been resolved in primary school. A whole chapter in their book is dedicated to ‘difficult ideas in earth science and astronomy’ – they declare that “pupils of all ages are fascinated by space and the make-up of the universe” (Ross et al., 2010, p139). The chapter then goes on to suggest a number of ways to teach earth science, but technically, it, too, has several inaccuracies as found by King (2010) in his analysis of misconceptions in earth science. This makes acquiring subject content knowledge by teachers, and especially primary teachers, all the more difficult, especially when textbooks, curricula and examination boards are not properly scrutinised by experts in specific fields. However, Skamp and Preston (2015), and Harlen’s Big Ideas (2015) offer accurate material and ideas for investigations.

2.6.8 Practical work in primary science
Much has been debated about practical work in science generally, especially in primary science, and it is suggested that practicals are not as effective as they might be at increasing knowledge (Abrahams & Millar, 2008). Nevertheless, if one purpose of practical work is to encourage enquiry skills, then linking scientific ideas to
investigations could promote better conceptual understanding (Abrahams & Reiss, 2012). What practical work often does do, though, is to increase the motivation and enjoyment of science, making science something special, distinct from other subjects (RSC, 2014). Children should, at least on some occasions, be allowed the opportunity to explore their own predictions and adapt investigations for this purpose rather than using ‘recipe’ investigations. This will entail more work on behalf of the teachers and more training, possibly like that produced by the ASE (Millar, 2009) and the ESEU (Lydon & King, 2009). When thinking of using practical work in primary science, an important factor to be taken into account is to outline the outcome required and ensure that clear aims and objectives are identified before starting (Beasley, 2014). The UNESCO (1992) sourcebook for science in the primary school, albeit now quite dated, identifies what makes a scientific activity, which includes communicating, trying out different investigations with the same materials, raising further questions and evaluating results (though not necessarily in that order). The sourcebook suggests that many teachers may lack confidence in allowing children to undertake practical work because they didn’t themselves have this opportunity in primary school. Another sensible point made is to ensure that enough time is available for the children to be able to explore their ideas when undertaking their investigations, and allow plenty of time available for reflection and reporting back. It is often this ‘tying up’ time which is overlooked when planning practical sessions, as well as not having enough time for discussion and questioning (Beasley, 2014).

2.6.9 Enquiry work using earth science

Enquiry skills are listed as observing, pattern seeking, identifying, classifying and grouping, appropriate testing and secondary research (DfE, 2013). All of these enquiry skills are especially relevant to earth science, particularly observation, where recognising what is happening in the present day is seen as the key to what has happened in the past. A number of textbooks advocate earth science investigations as being a ‘way-in’ to using enquiry skills based investigations. Skamp and Preston (2015) for example, use weather, environment, rocks and soils and the changing Earth as appropriate areas for investigation. As described previously, Morris (2010), Serin (2014), Seeley (2014) and Balmer (2015) all used local events to investigate and develop enquiry skills to great effect, with primary children becoming motivated when using their science skills ‘for a purpose’ (Serin, 2014). Even the editor of Primary Science suggested that the original ‘rock’ topic in the National Curriculum could be made into an exciting inquiry-based unit (Lievesey, 2014).

The SPACE programme (Russell et al., 1993) developed observation and data recording skills as well as thinking about changes and how to explain them. The programme went further and asked what children noticed about the effects of weather on people and their surrounding environment, and also questioned the children’s awareness of flood, drought, erosion and weathering. It was stressed that the important starting point (elicitation stage) of each topic was to find out the children’s initial understanding and knowledge and how they had come to these ideas. The study wanted to find out if it were possible to modify these initial concepts to develop a more scientific understanding of each topic (intervention stage). The researchers’ conclusions were that “earth science offered attractive possibilities for investigative approaches, and exciting possibilities for engaging children in absorbing and informative activities” (Russell et al., 1993, p147).
Harcourt-Brown (2011) carried out some small scale research on the earth science related topics of evaporation and condensation. Children discussed initial ideas about water and its different states before the teacher planned the lesson, and incorporated the children’s ideas into the lesson plan. Children in primary years 2, 4 and 6 (aged 6, 8 and 11 years) discussed water in its different states and investigated puddles drying out, water ‘disappearing from a glass’ and condensation on mirrors and the outside of a glass of cold water. They identified the two different processes of evaporation and condensation before they were linked together as a cloud forming process. However, Harcourt-Brown stated that teachers needed to be confident about these concepts themselves and should start from basics, identifying the fact that there is water vapour (gas) in the atmosphere at all times.

2.6.10 Questioning strategies in teaching science

Another essential aspect rarely given enough time in primary science lessons is the opportunity for children to question their teachers and peers about science concepts. Chin (2007) argues that dialogic discourse in the classroom fosters ‘generative thinking’. She recognises different levels of teacher questioning and the need to allow children time to think before responding to a question. Questioning should enable a teacher to discover what the pupils know about specific concepts and also should allow inter-child dialogue. There should be interaction between the teacher and the children with evaluation and feedback being given as the discussion develops. Obviously, this process needs to be time-limited for younger children, but the act of recording this information can help children and teachers appreciate what is learnt during any science discussion (Pedrosa-de-Jesus & Leite, 2014). Pedrosa-de-Jesus and Leite suggest that sometimes oral discussion may be started using an activity sheet or concept cartoon which can develop reasoning and higher thinking skills. Turner et al. (2011) discovered that when children just observed phenomena in a practical lesson – e.g. shadow length changes – this didn’t always lead to scientific inquiry unless the teacher encouraged questioning and made pointed suggestions to encourage the children to investigate further. Observing over time linked to discussion along with appropriate teacher questioning helped in pattern seeking. It is also important to allocate time after any investigation for children to discuss their results and assimilate their understanding (Wellcome Trust, 2017).

2.6.11 Questioning and learning strategies using earth science

Earth science offers good dialogic opportunities for continuing everyday investigations, particularly in England where weather is a constant topic of discussion. Primary children understand that weather changes frequently and imposes on their lives; two examples are not being able to play outdoors on rainy days and having to wear hats and sunscreen on hot days. Children are interested in these changes and will discuss weather freely, offering ideas and predictions – trying to connect with scientific concepts unknowingly (Agular, Mortimer & Scott, 2010). This leads to classroom discussion and questions which though the teacher may not have the answer, can lead to further ideas which could be investigated. Weather can be observed and recorded, data plotted and ideas or predictions advocated. Wellington (1988) identified these kinds of ideas as ‘knowledge how’ following on from ‘knowledge that’, identifying scientific phenomena. Looking at everyday materials both inside the classroom and in the playground offers more examples of earth science available within the experience of primary and pre-school children. These are the so called ‘concrete’ examples which all children will know, have experience of and be able to discuss with understanding.
Rocks and soils are easily available resources which link to other science areas and can introduce materials, through minerals, plant growth and environments through soils. Earth science topics are particularly useful as cross-curricular starting points (Russell & McGuigan, 2018) and for introducing social issues which are becoming more important in our world.

2.7 How we learn science

2.7.1 How learning occurs
Learning emerges from motivational and emotional factors associated with cultural and physical experiences, e.g. sight, smell, sound and touch (Dierking, 2002), and is a relatively short duration state that continually changes (Darby, 2003). It is personal, constructed over time, ever changing and mostly acquired from informal environments, not in school. Paris and Hapgood (2002) suggest that objects help learning and Faulk (2002) found that objects had specific meanings for visitors to museums, because of the visitors' personal experiences with them. Learning takes place through adapting one's own ideas and experiences subconsciously as one experiences more and different happenings (Allen, 2010) whilst Brown et al. (1997) stated that ‘learning in science was about trying to understand different perspectives – one’s own, other people’s and the community perspective’. One’s learning approaches change over time, and children specifically need a pre-disposition to learn, as they tend to be selective about what they are able to understand and absorb as they develop.

There are numerous approaches to encouraging learning but few that look at learners’ comprehension. The UNESCO (1992) sourcebook broached the idea of learning with understanding at an early age. Allowing children to debate their opinions and to develop strategies to test their concepts has been shown to be worthwhile (Russell, 1993). The more constructivist ideas of the 1980s (Russell et al., 1993) through the Science Processes and Concept Exploration (SPACE) and Children Learning in Science (CLIS) programmes tried to harness children’s own experiences to explain and sometimes correct certain misapprehensions, e.g. that a chicken is inside an egg or that a fully grown plant is inside a seed. More recently, Loxley et al. (2014) showed that getting young children to discuss their thinking about a topic before embarking on it can allow a teacher to identify experiences and inaccuracies. Harlen (2018) suggests that Inquiry Based Science Education (IBSE) helps children understand, by seeing and doing, rather than just memorising facts.

Teachers have the most powerful influence over learners and learning (Hattie, 2009), and should try to see how children learn through their (children’s) eyes, by being aware of the child’s abilities and individual ways that each learns. Wellington and Ireson (2012) suggested that the art of explaining something complex lay in breaking the concept into smaller, simpler ideas and rebuilding them back into the whole concept. These ideas would need to be accepted by children if they were to understand the concepts. Dillon (2010) asked what we (as teachers) know about children’s understanding of science. He indicated that children often only see what they are told to see, and that if they can’t see something, they presume it doesn’t exist; good examples being electrons and atoms.

For learning to take place, children must be mentally and emotionally simulated. Bruner (1986) emphasised the important characteristics of play for young children, suggesting
that play helped develop skills through exploring components and seeing how things work, not just by taking things apart and reassembling them. His work showed that exploration in children’s play can reduce the sense of failure and frustration, if it is self-initiated. Children should be allowed to adapt their own theories about concepts to the preferred scientific ones, and if enabled to construct their own problem-solving methods they learn more than if given specific investigation instructions (Brookes & Solomon, 1998). Story telling has been found to be a convenient starting point and can be used to introduce scientific words (Abrahams, Sharpe & Reiss, 2011). Concept cartoons and the compiling of group concept maps can evoke discussion and inquiry (Loxley et al., 2001) and properly planned questioning can bring out children’s real thoughts (Chin, 2007). The freedom to allow primary children time to devise experiments and carry them out, observing and recording data, develops inquiry skills (Pell & Jarvis, 2010) and is highly rated by the children. As mentioned before, the International Space Station (ISS) in 2016, evoked much enthusiasm amongst primary children, with many schools involved in devising experiments and meals for the astronauts (Grant, 2016), providing a stimulus for much science activity. Teachers, therefore, need to be facilitators, as well as knowledge banks, providing scaffolding within which their pupils can develop their own ideas, and be led into meaningful discussion (Loxley et al., 2014).

The learning environment (the classroom) needs to be considered, as well as the opportunities for learning (Leeming, 2015). Seating arrangements and the whole classroom layout are important; opportunities for children to work individually, with a buddy, or in groups is now recognised as important. Good teacher-pupil relationships and a climate where asking questions as well as answering them is acceptable also helps learning (Ofsted, 2010).

2.7.2 The importance of out of school influences on science learning

Whilst learning about science in school is important, possibly a greater influence on one’s early science understanding is gained through out-of-school events and often accidental encounters (Tal & Dierking, 2014). Children are exposed to a myriad of different scientific experiences in their everyday lives first hand outside the classroom from birth. These may be family orientated visits or school organised expeditions to local, national or even international museums and places of interest. Family derived science capital is seen as having a major influence on children’s aptitude for science (Archer et al., 2014) and this can be through playing with science toys as well as visits to science events. These many genres of experiences continue through life into adulthood. Bell et al. (2009) suggested that we learn cumulatively, building on our previous experiences as we mature – the idea of constructivism. Many experiences can be highly motivating and Tal and Dierking (2014) considered that children could learn from these if they are enabled to study them through the school curriculum, examples being visits to environmental concerns within their own local community – perhaps loss of habitat for a particular species in their area. Loxley et al. (2014) suggest that it is easier to learn more outside the classroom environment provided there are well defined aims identified by teachers and helpers.

The idea of learning outside the classroom is not new; the classical educationalists all understood its importance, but since the 1980s more organisations have begun to include education in their programmes (Ross et al., 2010). The National Parks Authorities, English Heritage, and the Royal Horticultural Society to name but a few organisations, have education programmes linked to school science curricula and their
websites offer programmes specifically for primary schools. Field Studies Centres offer science residential courses specifically linked to the English science curriculum at all levels. However, these trips are often expensive and beyond the purse of many primary schools. Perhaps more influential are parent organised outings to places of scientific interest in their own localities: science festivals organised by nearby universities (Royal Holloway University of London’s annual school’s science day attracts thousands of visitors), the annual Cheltenham Science Festival, BBC stargazing events, local Wildlife Trust open days, and of course, museums.

However, whilst school trips are not possible for all, the Forest Schools programme has been designed to offer all learners regular opportunities to achieve and develop confidence and self-esteem through hands-on learning experiences in a woodland or natural environment with trees, within the school day. The idea is based on the fundamental principle of respect for the environment in which the young people find themselves, giving them the opportunity to play, take risk and experience social interactions which will hopefully develop into continued and creative engagement with their peers (Forest Schools, 2017). The true ethos of a Forest School is based on the process of learning, using non-organised stimulating play, encouraging children to direct their own learning. A true Forest School approach has a set of principles to follow and trained tutors offer a range of activities: shelter building, habitat exploration, fire lighting and other pursuits. These, it is said, will: encourage self-confidence and self-esteem; improve motivation, language skills and communication; encourage co-operation and a positive attitude to learning; and provide an understanding of the natural environment and seasonal change. In a true 'Forest School' programme, specially trained Forest School tutors provide opportunities for children of all ages to participate, and it is suggested that participants join weekly activities over a long period of time to be able to view seasonal changes in the woodland.

Away from the school environment, Stocklmayer and Gilbert (2002) reflected that visitors to the Australian National Science and Technology Centre in Canberra were able to interpret an exhibit better if that exhibit reminded them of something they had experienced. If their memory and perception of an experience was aroused by the exhibit, visitors sometimes became more aware of their past science and technology learning. In their mission of education museums should enable their visitors, children and adults alike, to learn by offering exhibitions that motivate and build on prior knowledge and interests. New ways of portraying science and the work of specific scientists to the public through museums should be a cultural activity, and not just about raising scientific awareness (Durant, 1993). Lighting, interactive displays, the level of language used, labels, and contents all promote learning from an exhibit if delivered in an appropriate manner (Faulk & Storksdieck, 2005), accessible to everyone. All visitors come to museums with certain expectations, anticipating that they will benefit from the experience but also bringing their own ideas and knowledge. This can be reinforced particularly where children are allowed to handle objects and participate in investigations and role play (Faulk, 2002). Museums need to encourage ludic behaviour, be it symbolic or fantasy play, once children have become familiar with an object and what it can do (Paris & Hapgood, 2002). However, museums do need to ensure that their exhibits are at appropriately designed literacy and understandable levels for the age of their participating public.
As well as visiting museums and zoos, science learning centres are popular places for some parents to spend time with their offspring. In small learning science centres, Brookes and Solomon (1998) observed how children reacted to problem solving when they identified an issue they wished to solve. It seemed that the children learnt more when not under pressure to achieve a result and when they were given a free rein to design their own investigation rather than being given instruction. Brookes and Solomon also found that children with learning difficulties blossomed in this environment and equated this to Bruner’s ideas about important characteristics of play, where children had dominance of means over ends and were less likely to become frustrated or worried about achievement (Bruner, 1986).

The Wellcome Trust (2012) carried out a study of both adults and children that examined informal science learning approaches, and found that 54% of those questioned gained most of their informal science understanding and knowledge passively from watching television. Few gained knowledge and understanding actively by visiting zoos (25%), science museums (22%), lectures (12%), science discovery centres (11%), or science festivals (3%). Whilst there may be some accessibility issues for active informal science learning, e.g. distance to activities, it was found that low income families in particular, felt that science was not for them and that social and cultural barriers needed to be breached rather than financial barriers.

Ross et al. (2010) re-emphasise the need to make science part of everyday learning particularly for Early Years (EYFS) children if we really want to help them understand their environment. The Standards for EYFS children (2009, 2018) suggest that outdoor environments offer stimulating opportunities and experiences for young children and that they should be encouraged to explore their local environments, through their learning goal ‘the world’. This leads to increased self-esteem and confidence at this early stage in their development and makes them aware of the world around them and its every day changes. Tal and Dierking (2014) showed that there was plenty of evidence in the USA to suggest that science is ‘everywhere, every day, all around us’ and edited a second whole edition of the Journal of Research in Science Teaching devoted to learning science in everyday life – a follow on from articles in 2003. They felt that many of these outside experiences were highly motivating and that perhaps there should be an effort made to include them in the school curriculum so that all children could benefit from them. Tal and Dierking quoted the (USA) National Research Council report (Bell et al., 2009) which stated that research was trying to understand the importance of real world science learning as part of lifelong learning in science. Solomon’s (2013) market town study showed that people were frequently not aware of the science in their everyday lives.

Children spend far more of their time awake away from school, hence activities such as gardening, hiking, and holidays all contribute to their science experiences though often not many of these are seen as being scientific (Gokpinar & Reiss, 2016). Children and adults can accumulate much information from the media (television, newspapers, radio) and other forms of mass communication. David Attenborough’s Planet Earth 1 and 2 series has appealed to all ages and promoted all factions of science. Recently, Tim Peake’s space station exploits enchanted many hundreds of primary school children because they were able to see and hear him directly from the space capsule (www.stem.org.uk, 2016) and there is a much greater understanding of gravity in many primary schools because of his broadcasts (Grant, 2016). Children have contributed
experiments to space missions (Clements et al., 2014) and a number of schools participated in seed growing experiments comparing plants grown from seed that had spent time in space with plants from earth bound seed (www.stem.org.uk, 2016). Commander Peake’s exploits in space have inspired many youngsters to think about science as a future career.

The recent (2014 and 2016) British Citizen Science activities (Edwards, 2014, www.nesta.org.uk/digital-social-innovation), which involve all ages collecting scientific data of a wide variety of issues, have created enormous interest in science activities linked to some television programmes and other media items. The numbers of children and older people contributing to wild life surveys, bird counts and weather watching projects are calculated at being over one million participants in the UK.

Earth science is essentially a subject children can participate in out of the classroom and in their local environment. Resources are constantly available, constantly adapting – as in the weather and seasons, and all around us (landscape). Hence it is an ideal science subject for ongoing everyday learning in and out of the classroom.

2.7.3 Setting goals to encourage learning
Another suggested way of increasing learning activity is for the teacher and pupil to set learning goals and targets for the pupil, whereby the pupils are actively involved in their own learning process (Holbrook et al., 2014). This is often referred to as formative assessment or Assessment for Learning (AfL). There is a large amount of literature on both formative assessment and AfL, but the difference, if any, between them for the purposes of this thesis is negligible. Following early initiatives in schools and colleges prior to 1998, there has been much research into this kind of assessment. Black and William (2005) looked into ways of making learning more effective. Black et al. (2005) suggested that marking was not usually a very effective way of improving learning as it often did not help the learner by giving feedback on the way the learner was working but just gave an indicative grade. It seemed that there needed to be a change in the role of both teacher and learner for positive learning to accrue from assessment if it were to enhance learning. A large study by Pedder and James (2012) identified five strategies that could be developed to support learning through assessment procedures which were found to enhance student attainment. These were through: clearly identifying learning objectives, and criteria for success; promoting classroom discussion, activities and tasks that would elicit learning; providing feedback to help learners move forward; encouraging learners to work with and teach each other; and making learners owners of their own learning. Whilst it was acknowledged that learners frequently merely wanted to ‘get through the school day’ in order to embark on other activities, it was concluded that this kind of teaching methodology was encouraging; whilst not especially designed for teaching science, it could be a useful step forward to enhance learning. Teachers themselves would become learners as their role became more interactive, and learner would need to adapt to this environment.

Hodson (2014) proposed that there needed to be a distinction between specific goals for learning science: whether they are just about learning science, learning about science, doing science or learning about socio-scientific issues. These ideas were quite different from earlier approaches to the teaching of science and Hodson intimated that inquiry approaches were not always the most effective way to learn science; that other techniques should be incorporated into learning. What he did stress, however, was the importance of identifying clear outcomes – whether the approach is by explicit or
implicit means – and the necessity of children understanding the nature of science (NOS). Along with other researchers, Lederman (2014) in particular, Hodson states that NOS must be taught; it is not acquired implicitly. Hodson (2014) goes into detail about learning mechanisms, suggesting that socio-scientific issues are best taught by confronting these issues. There needs to be clarity in defining the specific purpose of each learning experience and he advises that different types of approach are necessary for learning to take place and for children to achieve the three distinctive kinds of enhanced science learning, conceptual understanding, procedural knowledge and investigative expertise.

2.7.4 The importance of play in learning
Play in early childhood and informal science at a young age has been shown to have an important influence on lasting scientific interest (Joyce & Farenga, 1999). Joyce and Farenga’s study agrees with earlier ones that these early science experiences stay with children for life and may encourage thoughts towards scientific careers. They also suggest that girls miss out on science experiences because they do not, and are not, allowed to explore as much as boys, and propose that the environment is a useful setting for investigations.

Different kinds of play for learning have been identified, specifically at EYFS, identified as child-initiated activities, where children are creative and can find their own ways of doing things; adult-led activities, which give the opportunity to further explore some of the ideas already identified; and adult-led play, where children are organised and told what to do (Hansen, 2015). Each of these types of play has opportunities and limitations, and EYFS programmes need to provide a balance of all three.

Enquiry-based learning proposes that children engage in classroom inquiry through being enabled to investigate ideas by developing their own methodology. In practice, this means allowing children to plan enquiries rather than follow strict ‘recipes’ or instructions planned by the teacher. The children have the opportunity to explore their own questions and theories. However, this is rarely within the teacher’s comfort zone (Loxley et al., 2014) and is seldom practised. But given key questions to probe, and children’s own motivation and curiosity to discover answers, this method can actively engage children in science. Children need to see science as a subject they can contribute to, in order that their impression of science does not link it to factual information which is fixed in stone (Hickey & Robson, 2013). Earth science is particularly well placed to do this with plenty of simple local questions to investigate.

2.7.5 Teacher learning
Teaching is a continuous learning process for all those concerned. Primary science requires constant updating because of the changing curriculum and the changes in roles and responsibilities of teachers. Spiritual, moral and cultural ideals are also embedded in the English National Curriculum. Teachers need to know how children learn in order to be able to provide suitable materials for appropriate levels of progress since it is now better understood that child development is not consistent at a particular age (Howard, 2018). It is also recognised that there are different ways of learning and one model of learning may not fit all children (Howard, 2018). In science, particularly, children have ideas about events and happenings which it is now more usual to identify before trying to impart new concepts; learning will only occur if children can relate new ideas to their own thinking, otherwise they will revert to their own suppositions after the lesson (Sharp et al., 2017).
The Donaldson Review identified issues concerning teachers’ learning in Scotland and stated that there was a need for better support for Scottish undergraduate teacher trainees (O’Brien, 2012). The review specifically identified problems trainee teachers face including the need to improve their numeracy and literacy skills. Donaldson made some 50 recommendations and suggested that teachers need to be ‘reflective, accomplished and enquiring professionals’. An open consultation looked at his recommendations, asking for views from teachers themselves and other stakeholders. His idea of a five-year B.Ed. degree with less emphasis on crafts and technical skills would lead to a more rigorous selection approach to trainees, and the use of school staff to assess trainees when on placement. Teachers in Scotland need to continue research as ongoing training, and it has been suggested that this could be valuable for primary teachers in England, although time would need to be made available.

The Wellcome Trust (2017) recognises the importance of continual training through CPD in science, particularly for science leaders in primary schools, who can then convey changes to their colleagues. A further important issue which is now better built into science is the use of language. Many scientific words do not have the same meaning in science as when they are used in everyday language (Osborne & Dillon, 2010), for example the words ‘force’ and ‘energy’, and it is necessary that teachers explain the scientific meaning where necessary (Osborne et al., 1982). Many children do not have experience of specific environments other than their own locality, e.g. the seaside with beaches and sand, woods and forests, rural or urban locations, and it is now deemed important to give children such experiences through visits. The Forest School idea is becoming a more common venture for children in many schools (Hoath & Spring, 2018) and teachers themselves have to learn how to teach in this environment.

2.7.6 Continuing professional development
Continuing professional development (CPD) is a way of raising and maintaining educational standards and in some cases keeping teachers up to date with current subject knowledge (Adey et al., 2004). Adey’s research looked mainly at the long term changes in secondary schools that could be achieved through professional development aimed at cognitive acceleration but his research did not feel that short (e.g. one-day) CPD could have a lasting impact on teaching or teachers. However, Ofsted (2013) reported that whilst CPD could considerably support primary science teachers, most of the primary science leaders in schools had not received adequate training in science or leadership. The Association for Science Education in their primary guide (2018) suggests that all teachers need science CPD which is more effective if the CPD is sustained over time. However, this does mean that Senior Managers must recognise the importance of science teaching in their schools (Turford & Turner, 2018) and allow appropriate time release for study.

A Scottish science education initiative was undertaken in 2006 to try to develop science throughout the country by training established teachers to be trainers able to deliver CPD sessions. Doyle (2009) analysed the outcomes which showed that an initial cohort of 50 teachers trained in Earth and Space materials delivered programmes to some 900 teachers in two years. These programmes were evaluated using Guskey’s five critical levels of professional development and it was found that teachers were able to discuss issues important to them. This discussion was helpful in clarifying points and the CPD sessions encouraged network links and collaboration between primary and secondary teachers. This training method, though initially expensive, proved to be a
cost effective and sustainable way of promoting both knowledge and pedagogy. (Doyle, 2009). Later research has begun to show that appropriate CPD in general science and earth science can really help teachers (Lydon & King, 2009; Abrahams, Reiss & Sharpe, 2011), but often science CPD is more about general teaching and learning rather than science content, and the take up of CPD by primary science teachers is low (Ofsted, 2011). Science subject leaders stated that they would welcome more science CPD (Wellcome Trust, 2013) as they appreciate the importance of good science teaching in primary schools. The ‘Getting Practical’ programme aimed at improving teachers’ science ideas and practical work through CPD, and this programme concluded that whilst there was a need for CPD, teachers also needed support from the Senior Management Team within their schools (Abrahams, Reiss & Sharpe, 2011). The Association for Science Education (ASE) offers science teachers Science Charter status if they comply with the appropriate criteria and suggests that this recognises a teacher’s expertise and skills in science. Meanwhile in Scotland, the Donaldson Review (O’Brien, 2012) recommended that teacher learning be seen as a continuing process, with teachers having to engage in further study after qualification leading to Chartered Teacher Standard with time being made available for studying.

2.7.7 Self-efficacy in teaching science
There has been a considerable amount of research into teacher self-efficacy which Zimmerman (2005, p388) defined as referring to the “belief about one’s personal ability to achieve certain goals”. Bandura (1977) had earlier defined self-efficacy as coming from four different sources which he named mastery, vicarious learning, social persuasion and internal physiological mechanisms. Basically, he was suggesting that a person’s self-efficacy is dependent on how well they can grasp experiences which help them progress at their own pace, their ability to identify themselves with achieving peers, the ability to acquire learning skills and the capacity to have a positive outlook on their own performance.

Teachers require self-efficacy to develop pedagogical content knowledge in science at primary level (Shallcross et al., 2010; ASE, 2012) and the lack of science self-efficacy is an issue in teaching science at primary level (Kazempour, 2014). Children, too, can suffer from low self-efficacy especially in science where they often think science is for ‘clever’ children only (Wellcome Trust, 2014). In all cases, but especially in those cases where children have low science self-esteem, it is essential that primary teachers themselves have confidence in their ability to teach science despite frequently only having studied science to GCSE level (Shallcross et al., 2010). Weak primary science teaching can be the result of insufficient knowledge as well as other factors – e.g. limited resources and space – but is often due to lack of confidence. Appleton (1995) pointed out that frequently it was not lack of knowledge that led to loss of confidence but a teacher’s own poor self-image, with some teachers feeling that children knew more about science than they did. Teachers need to be interested in science and take advantage of the mass of information available in order to boost their self-image and hence their confidence (Lunn & Solomon, 2000).

2.7.8 Need for appropriate earth science CPD
The above problems relating to inaccuracies in primary science texts reiterates the need for sound initial teacher training in science generally and suitable follow-on CPD, so all teachers, but specifically primary teachers with their usually minimal science
background, can acquire accurate knowledge and appropriate pedagogical content knowledge (Lydon and King, 2009). The latest Wellcome Trust report (2017) highlights the need for more primary science CPD and time to be allocated for attendance. Lydon and King (2009) point out that short CPD programmes can be beneficial in raising self-confidence and hence self-efficacy if taught in an appropriate way, as, for example, happens on the one-day earth science courses provided by the Earth Science Education Unit (ESEU). The emergence of reliable websites for earth science, e.g. earthlearningideas.org has also provided knowledge and suitable ways to teach earth science ideas, which again can help raise self-confidence.

Little research has been undertaken into primary science CPD, but some research of short duration secondary science CPD programmes has shown positive outcomes where the CPD is domain-specific in certain areas of physics and chemistry (Scott et al., 2010). The ESEU workshop primary and secondary CPDs are domain-specific and link well to the five ‘effectiveness’ pointers suggested by Desimone (2009). These were identified as: content-focused; active learning; coherence; adequate duration; and collective participation. The ESEU workshops teach the core theory of earth science and enable the participants to become learners themselves, thus allowing participants to focus on learning. (Many CPD sessions are based around sharing good practice rather than learning new content.) The ESEU workshops were specifically designed to provide both subject content knowledge and pedagogical content knowledge for non-specialists who were having to teach earth science at either primary or secondary level. Scott et al. (2009) showed that for secondary physics and chemistry science teaching, short courses were often beneficial in improving teacher knowledge and confidence and sometimes led to improved student achievement, not just in the short term, but frequently in the long term, as a result of changes in teaching approaches.

2.7.9 Motivation
Motivation can take several forms: intrinsic reasoning, that is doing something for its own sake; or extrinsic reasoning, doing something as a means to an end. Getting children motivated to participate in the activities desired by any teacher is part of the skill of teaching. If children can be persuaded, or can see that a science activity has a purpose that is meaningful to them, then they will often become wholly involved. A good example of this is documented by Serin (2014) who used heavy snowfall data connected to school closures to stimulate primary children to use meteorological data to think about who else would be affected as well as school children. He found the pupils became very involved with the opportunity to use their science skills for a purpose. Similarly, in a lesson using local flooding episodes in Suffolk, a primary teacher found her class related better to world flooding issues because of their own experiences (Seeley, 2014). In both cases the motivation was intrinsic.

Unfortunately science in some primary schools became, in motivating terms, very extrinsic and it was thought that withdrawing the year 6 SATs in 2010, might allow more imaginative work to take place. For one reason or another, this has led to science in primary schools losing out on time in curriculum as English and mathematics have been deemed more important, and whilst this has removed the pressure on children to ‘learn’ for the test, in reality it means little science is being taught in many primary schools (HMI, 2016).
2.7.10 Summarising learning strategy ideas
There are many and different strategies by which teachers can inspire learning to take place, but to sum up a discussion about teaching and learning strategies, Fitzgerald (2012) stated that there was "no one way of effective primary science teaching. Beliefs, and knowledge have a significant influence on teachers and how they teach, but context cannot be ignored. The impact of teaching is reflected in student engagement and their consequent learning of science" (Fitzgerald, 2012, p111).

This seems to me to be a realistic starting point for developing a curriculum for primary science which incorporates the necessities for good understanding of scientific concepts alongside initial cultivation of scientifically literate citizens.

2.8 Attitudes towards science

2.8.1 Children's attitudes towards science
In order to teach science effectively it is necessary to understand current attitudes towards the subject. The adult attitude towards science in England is too often based on what was learnt at school – physics, chemistry or biology – and whether we enjoyed our school experience (Perera, 2014). Further post-school science information is mostly gleaned by adults from various media and is a mix of real and fake science, leaving many people unsure what to believe (Sosabowski, 2017), so it is rare that adults outside the professional scientific or engineering career sector appreciate science as part of everyday life (Solomon, 2013). If this attitude persists after nearly thirty years of compulsory school science then surely there are issues that need to be identified and tackled about the input of science in our school curriculum. As children we inadvertently and advertently pick up unspoken feelings and attitudes about almost everything from our parents. If parents are interested in science, then they tend to encourage this interest in their children (Kaya & Lundeen, 2010). Sun, Bradley and Akers (2012) suggested that important international and economic issues call for better understanding of science and the interplay between the world’s different systems and human intervention. They state that there is a need for future generations to understand these complex interactions which should be initiated in childhood, for example, thoughts about conservation, waste disposal and environment protection. Parental influences boost confidence and self-efficacy in their children in all subject areas not just science, so it is important that we find ways of encouraging parents to be more pro-active in science education. Parents with low socioeconomic status (SES) seem to feel that science is only for the most able pupils, and children in schools in deprived regions said that school science was not relevant and that they found physics particularly hard (Royal Society, 2008). Archer and De Witt (2014) have studied children’s attitudes towards science careers and show that only 18% of year 6 children (age 10-11 years) aspire to become scientists, despite some 72% agreeing that science is interesting. They point to the perception of school science as a ‘difficult’ subject, lacking relevance. Families seem to be the main influence on aspirations to take up science careers; children aged 10-14 stated that their parents felt it was important that they learn science because scientists did valuable work. If family members were involved in science and engineering it was more likely that children would be interested (Collinson, 2014). Archer and De Witt (2014) emphasise the importance of what they term ‘science capital’, identified as ‘what you know; how you think; what you do’ with science which gives one a ‘science identity’. Their current research is looking into how to build science capital into primary children’s lives. Another new project entitled ‘Thinking, Doing Talking Science’, offers children more
time to discuss and reflect on their science studies. Initial outcomes from the first phase of this project suggest that pupils develop a more positive attitude towards science as well as gaining higher order thinking skills because their investigative work was more focused on a specific objective (Hanley et al., 2015).

2.8.2 The importance of teachers’ attitudes towards science
Teachers, too, have a significant influence on their pupils’ attitudes towards science (Royal Society, 2010). Positive teachers may convey their attitudes to their pupils, inspiring confidence by enabling pupils to question and investigate (Aalderen-Smeets et al., 2013), particularly in EYFS and early primary teaching (Sharp et al., 2017). The Netherlands are trying to measure these teacher attitudes towards teaching primary science through a four point framework. This framework not only includes subject content knowledge and how to teach it, but more importantly, the emotional attitude of the teacher in the lesson – their feelings of anxiety or enjoyment, which will permeate through the lesson (Aalderen-Smeets et al., 2013). In an earlier study, Pell and Jarvis (2001) attempted to monitor children’s attitudes towards science because they felt that attitudes would affect the children’s overall attainment. They - Pell and Jarvis - along with others, found children’s enthusiasm for science begins to wane towards the end of primary schooling, and suggested there needed to be a change in approach to teaching primary science (Osborne et al., 2003). The overuse of worksheets and abstract concepts and the need for joined-up thinking in science was identified by Allen (2016) as areas that should be addressed if children are to be engaged with science beyond age 9. Murphy et al. (2013) revealed the necessity of looking at children’s views to include the relationship of science to life outside school. They (Murphy et al.) proposed a significant change in the Irish curriculum, to include pupils’ experiences.

Research also shows that primary science teachers’ own attitudes towards science are very much influenced by their primary science experience (Kazempour, 2014). Positive teacher attitudes based on good primary experiences coupled with influential science methods experiences lead to self-efficacy and confidence. However, negative teacher attitudes due to low self-efficacy, self-doubt and little effective training, can become an obstacle to teaching as the teacher struggles to interest pupils in a subject they do not enjoy. Bulunuz and Jfarrrett (2010) showed that trainee teachers were more confident in their science teaching if they had had memorable science lessons in primary school. Many of the teachers in their American study could not remember any science lessons at primary age.

2.8.3 Children’s science
The concept of ‘children’s science’ is interesting. Teachers need to consider children’s opinions carefully before trying to instil new concepts (Osborne et al., 1983). Children have very clear ideas about events and happenings and how these occur (Gilbert et al., 1982). Children’s science is composed of those experiences and the explanations children derive for themselves at a very young age, which enable them to develop views about their world and how things came about. In order to implement possibly more accurate notions, teachers must first understand each child’s viewpoint, since any new ideas being introduced will not be assimilated unless they can be reconciled by the child with their original views. However, it seems that frequently, although children may accept a new idea in a lesson, they may well revert to their original understanding once the lesson is over (Sharp et al., 2017).
2.8.4 Alternative concepts in science

Researchers have noticed that children’s interest in science appears to start at a very early age; one of the first words frequently used is ‘why?’ Piaget (1929, p172) noticed that movements of any kind intrigued babies, and they watch and play ‘disappearing/appearing peek-a-boo’ games when they are very young. Children’s ideas of the world they live in are based on their limited experience of life (Harlen, 2013), an example being that the Sun and Moon seem to follow them around as they are visible wherever the child may be. Gradually, infants begin to recognise patterns: day and night, and later seasons, as they become more aware of daily life.

There are a number of things that influence children’s early scientific ideas, not least the drawings in picture books where the Moon is frequently depicted as a crescent and stars with points (Harlen, 2004). As well as visual interpretations, children’s everyday language is often in conflict with adult and school science language. Our adult language and scientific language confuse everyday words which a child interprets differently (Loxley et al., 2014); the word animal, for example, to a child means something four-legged and furry, whilst informed adults understand that humans, too, are animals and the scientific definition contains a far wider group of creatures (Osborne et al., 1983). Teachers therefore need to be more careful when talking to young children and try harder to explain the language we use rather than just assuming that they understand.

Children’s concepts are based on what they see, hear and observe and the reasoning they work out for themselves, this is sometimes termed ‘children’s science’, as opposed to ‘scientists’ science’ (Osborne et al., 1983). These initial ideas are well entrenched before children start primary school (Allen, 2010) and teachers should try to identify and build on these ideas, not totally dismiss them as being wrong. Some ideas may be far more complex than teachers expect (Traianou, 2006) and children will only change their thinking if their original idea is not fulfilling a need. Any new idea needs to satisfy the child’s reasoning, be easily understood and able to solve future problems or it will be discarded outside the classroom (Allen, 2010). It is suggested that before teaching any science to young children, it is advisable that teachers find out what the group know and understand about a topic (Harlen, 1985; Osborne, 1985). These thoughts can then be used in discussion before investigating more accurate concepts of the scientific world. Using puddles drying out is an everyday happening which can later be linked to a bigger concept that of evaporation for instance (Harlen, 2013).

Each of us has our own image of how the world was formed, where we have come from and how life interacts with our own environment. These ideas are inherent from early childhood and stay with us until we can accept other explanations (Osborne et al., 1983). A child’s view of life is dependent on their early experiences and how these experiences fit their own reasoning and understanding (Osborne et al., 1983). Many adult views of the planet’s processes are often at odds with more accepted scientific interpretations because the adults have held on to their childhood assumptions (Hann et al., 1992) since no other explanation better clarifies their understanding. An example of this is the misunderstanding of links between ice melting and sea level changes, where plausible accurate information is hard to come by. Allen (2010) states that it is easy to identify these ‘misconceptions’ but far more difficult to dislodge and replace them. He cites Posner et al. (1982), who suggested that the only way to change ideas was if the new explanation was easily understood, actually worked and could solve future problems. Unfortunately, many adults still mistakenly see a scientist’s role as just
gathering data and looking for patterns in that data to explain something that has happened (Dillon, 2010). Rarely is a scientist’s role seen as aiming to develop new knowledge, rather than reinforcing old memes.

There are various ways in which a teacher can identify these alternative concepts. Teachers are now beginning to understand the importance of identifying alternative concepts prior to trying to teach and develop new ideas (Royal Society, 2010). The President of the Royal Society in its 2010 report recommended that greater focus was needed on understanding how children’s reasoning develops and how they form initial ideas. Osborne et al. (1983) had already suggested discussing ideas in the classroom before embarking on a new topic, either through the use of concept cartoons or dialogic circles, two simple ways of identifying children’s initial beliefs. Ross and Littledyke (2003) reiterated the importance of teachers’ understanding of children’s science concepts and proposed using an ‘issues based approach’ which could enable wider environment issues to be understood in the classroom. They also advised that trainee teachers be helped to identify their own alternative concepts which could form a barrier to their own understanding. Teachers need to understand concepts completely so they are confident about explaining any new concepts to children when trying to supplant fixed ideas (Harcourt-Brown, 2011). If teachers want to change children’s ideas, it was suggested that they need to place as much emphasis on the children’s ‘wrong’ ideas as well as discussing correct concepts (Pine, Messer & St John, 2001).

2.8.5 Public attitudes towards science
Public attitudes towards science were collected by the Ipsos Mori poll in 2014 and again in 2016 for the British Association of Science and the Department of Business, Innovation and Skills, with some interesting results. The 2014 poll showed that science was still seen as being biology, chemistry and physics from school days, and only 6% of those questioned felt well informed about science. These polls both suggested that people were generally very trusting of the work being done by scientists and engineers and that scientific research was important for the country. However, work carried out to try to involve the public more actively in specifically genetic technology found that whilst the public trusted scientists in their work about cloning and gene technologies, when asked to become more actively involved in decision making, they were less inclined to accept the technology (Barnett et al., 2007). Similarly, many US citizens feel that scientists are exaggerating the issues surrounding global warming, despite the supporting evidence pertaining to carbon dioxide emissions, and are loath to pay the price of changing to renewable energies because they mistrust the scientific evidence (Reiner et al., 2006). When significant world-affecting decisions have to be implemented, attitudes towards science and scientific findings need to be understood at local, national and international level, making the understanding of science by current and upcoming generations more important. It is essential therefore that primary children have good scientific teaching in this technological age. Donald Gray (2018) suggests that all school science curricula need to be updated to be more relevant to the present technological age and acknowledge human influence on world systems, like climate change, so that future citizens are better informed of their responsibilities for a sustainable world.

2.8.6 Barriers to learning science
Other different barriers besides attitudes towards teaching science exist. Female attitudes towards science are still seen as a barrier by some girls who do not see enough women scientists as role models (Cole, 2014), although this attitude is
improving with the increase in female TV presenters, particularly in astronomy and space documentaries. However, the latest PISA science report (2015) (Osborne & Millar, 2017) shows that in the United Kingdom an almost equal percentage of 15 year-old girls (24%) and boys (25%) now expect to go into scientific careers (OECD, 2015). One newly qualified teacher suggested that teachers, too, often need to overcome large barriers to make primary science teaching effective, but believes these can be eliminated by a ‘can do’ attitude by the teacher using familiar examples, especially everyday objects, such as rocks and weather (Turner, 2012). Smith (2015) identifies a range of barriers to progress at all stages in the investigation process. As mentioned previously, the use of everyday words in scientific language can cause misunderstanding, and care needs to be taken to ensure the terms used are understood within the context which they are being used (Sharp et al., 2017). The general feeling that science is ‘difficult and only for clever pupils’ (Whitfield, 1979; Archer et al., 2015) is another attitudinal barrier that needs to be broken down before science can be enjoyed by everyone. A barrier may well lie within the classroom environment and teacher’s approach (McCrory & Worthington, 2018). Ross et al. (2004) suggested that there was a barrier in secondary science between ‘school science’ – that learnt in the classroom – and the real world, particularly at GCSE level. Furthermore, they state that school science is often a series of unrelated topics, not linked to what is happening in the outside world, and this is also true of the primary science curriculum. Until science is appreciated as a subject that gives us an understanding of our surroundings and everyday life, there will be an uphill challenge in teaching it at all levels but most importantly at pre-school and primary school.

2.9 The way forward

2.9.1 The new USA earth science curriculum
The latest science curriculum in the USA suggests linking earth science with engineering and human activity. Students are expected to be able to analyse and interpret data on natural hazards, for example, and communicate their ideas and research to the rest of their class. This is very different from earlier approaches where the focus was on learning content. The curriculum specifies the need to ask questions and look at cross-cutting concepts, using disciplinary core ideas and science and engineering practices at all levels in the curriculum (NGSS, 2013). The hope is that this new curriculum will anchor learning in the real world, making it meaningful by using interesting phenomena (earthquakes, volcanoes, etc.) and foster curiosity and a sense of wonder in science. These new ideas about teaching and learning appear to follow on from the TERC 2007 report in an attempt to improve earth science literacy. However, unfortunately this new curriculum is not statutory in the USA and it seems fewer States are implementing these new ideas than had been hoped.

2.9.2 Concluding ideas
My review of the relevant literature has revealed a wide range of important issues. Teaching science is more complex than teaching most other subjects because of its social, moral and ethical implications, its links to cultural and traditional beliefs and the inherent ideas brought to the learning process by young children. Particularly, in early years and primary level teaching, it seems necessary for teachers to relate to their pupils’ understanding before providing enabling experiences to help them make sense of their worlds. Only then will the children be ready to take on new concepts, and with further experience adapt these concepts to fit in with their own thoughts. This is one
reason why earth science is such a good basis for science in the primary school as it
deals with everyday occurrences, known to the children. My passion for earth science
and its significance for children as they begin to appreciate the world in which we live
have led to my overall research title statement ‘the potential of earth science for the
development of primary school science’. This statement will be researched through my
four research questions (RQs):

  RQ1: To what extent does a trainee primary teacher’s own childhood science
      experience affect their approach to science teaching?

  RQ2: What do primary teachers think of science and how do they consider it
      should be taught?

  RQ3: Can earth science help primary teachers to be more confident about
      teaching science?

  RQ4: Can earth science enrich primary children's science?
3 Methodology

3.1 Introduction

3.1.1 General introduction

At present, the 2014 National Science Curriculum (DfE, 2013) in English primary schools places an equal emphasis on biology, physics and chemistry, from year 1. Whilst this should provide a balanced introduction to science, it does mean that primary teachers of science (few of whom have had much science education beyond GCSE, at age 16) are expected to teach a very wide range of abstract and demanding topics, in part through an enquiry\(^8\) science approach. This thesis is predicated on the belief that earth science can play a significant role in improving primary school science in England. By keeping the biology content mostly as it is (plants, invertebrates and some human biology) and introducing much of physics and chemistry, for example, forces and evaporation, as scientific concepts through the medium of earth science, primary teachers would be able to help their pupils investigate news and local events in their science lessons. Science would then become relevant to young children because the content would be more accessible to them, through topics such as rocks and soils, weather and climate, volcanoes, earthquakes and space. Furthermore, the important enquiry skills can be more meaningfully taught through this subject matter and, by releasing primary teachers from the more abstract aspects of physics and chemistry, they too might become more enthused and confident in their teaching, achieving the ‘Working Scientifically’ aim of the English National Curriculum (DfE, 2013).

Whilst there are many issues that could potentially be investigated within the area of primary science teaching, I have chosen to focus on a small but vital aspect, the potential for using earth science to develop primary science understanding. My proposal is that by using an increased number of earth science concepts to illustrate scientific ideas, eg changes of state of water into snow, ice, water vapour and clouds, scientifically enthused primary teachers could enable children to more easily accept science concepts through relevant experiences. I hypothesise that intervention lessons using earth science content can help teachers gain self-efficacy and thus assist children in understanding concepts and learning scientific skills, for example, those of observation, recording and data collection. My aim is to encourage more understanding and appreciation of science by primary pupils, through tackling the issue of low primary teacher confidence in the teaching of science, by identifying appropriate and feasible teaching and learning strategies.

3.1.2 Research aims and questions

My research seeks to determine whether primary science teaching can be improved, and thus children’s understanding of science, through teaching earth science. This section discusses how the aim will be explored through identifying pertinent questions.

The literature review has revealed a number of pointers as to why there are issues with the teaching of primary science in schools worldwide, and many of these are relevant to English schools. These issues, coupled with my own observations over many years, have prompted the formulation of my research questions to answer my overall research aim, which is to determine the potential of earth science for the development of primary

---

\(^8\) The word ‘enquiry’ rather than ‘inquiry’ is used here since this word is used in the English National Science curriculum. There does not seem to be any systematic difference between the usage of the two words.
school science. The four research questions (RQs) proposed at the end of Chapter 2 are:

RQ1: To what extent does a trainee primary teacher’s own childhood science experience affect their approach to science teaching?

RQ2: What do primary teachers think of science and how do they consider it should be taught?

RQ3: Can earth science help primary teachers to be more confident about teaching science?

RQ4: Can earth science enrich primary children’s science?

The methodology uses mixed methods (Cresswell, 2009), predominantly qualitative with the remainder quantitative. Throughout, the data collection is based on convenience sampling (Ritchie, Lewis & Elam, 2003), because of the nature of the contacts and their accessibility. Although there are disadvantages with convenience sampling, one advantage is that it has led to a high response rate from each of the groups involved, trainee teachers and primary science leaders, as they felt involved. In each case the samples are homogenous (Robson, 2011).

One advantage of using more than a single method of data collection to answer a question is that it may enable a degree of triangulation. Cohen et al., (2011) state that triangulation is one of the most effective ways of answering a research question, suggesting that since the different data sources view the research questions from several aspects, the analysis will benefit from the range of information which will add to the validity of the conclusions. This use of a range of data therefore helps maximise the trustworthiness of the outcomes if several data sources all point to much the same conclusion.

The following sections present and discuss the different methodologies used in my data collection. Overall approval was received for me as a doctoral student through the official IOE channels for ethical approval, and the BERA ethical guidelines (BERA, 2011) have been adhered to in all cases. Permissions have been sought and granted by the owners of data; schools have offered me access to classrooms, given me permission to hold and audio-record conversations with children, teachers and teaching assistants and use the photographs they have given me. In places, I use photographs which show children’s faces as it is important to be able to see their expressions when they are working. The school has allowed me to use the photographs taken during the pilot in 2015. The children cannot be identified from the photographs. All questionnaires have been introduced with an explanation that the process is voluntary and that anyone can withdraw their help and the information already given at any time. Each respondent was given my email address for further contact, should they wish to do so. I hold a current DBS certificate for working with children. There have not been any ethical issues arising from my data collection.

I have collected my various data in the same way each time so that these data are as reliable and valid as I can make them. All names used throughout are pseudonyms.

---

9 DBS Disclosure and Barring Service certificate: essential if working with children, a Government-issued certificate.
The methodologies for each data source are discussed in the following order:

- Teacher trainee questionnaire about their childhood experiences of science
- Primary science leaders’ questionnaire beliefs on what primary science is and how it should be taught
- Intervention lessons
- ESEU data collection
- SATRO primary earth science workshop data.

3.1.3 Researcher’s background

My work as a facilitator, teaching earth science workshops within the ESEU, gave me access to the evaluation forms completed by primary trainee teachers which had not been used for any previous research. The sponsors of the ESEU workshop programme were very pleased for the information to be used. Similarly, the SATRO primary earth science workshop evaluation forms were made available for me to use by the Company’s Trustees, since I had devised and built up this programme over some fifteen years. My contacts with teacher trainee establishments, local schools near my home and the Surrey Primary Science Leaders’ Network group all came about because of my work with both the ESEU and SATRO during the period 1997-2016. These institutions have been very supportive in allowing me access to training sessions, teachers, trainees and children to collect data.

3.2 Methodology behind the data collection

3.2.1 Trainee primary teacher questionnaire about early childhood science experiences

Suggestions have been made that positive childhood science experiences make a lasting impression on us all (Avraamidou, 2017). Hence, ensuring children connect with science at the Early Years Foundation Stage (age 3-5) and in primary school is something that should be aspired to (Royal Society, 1985). Science at this age (3-11) should be relevant and use concrete resources (Harlen, 2008) so that a positive lasting impression is made.

Research suggests that many primary teachers have little recollection of what they learnt in primary school and that they were often not particularly interested in the kind of science that was being taught in school (Bulunuz & Jarrett, 2010). McCrory states that her trainee teachers only remember any ‘wow’ science from their primary school science lessons (McCrory & Worthington, 2018, p 146) and I also found this to be so when questioning new BAEd and primary PGCE students in 2016/17. Indeed, in England many teachers over the age of 35 may not have had any formal science lessons at primary school since their primary education was before the introduction of the National Curriculum. This lack of memorable early science experience, together with often low science capital (Archer, 2014) gained as a child, means that many of today’s primary teachers may have low self-efficacy in science. Other identified areas of concern were that even trained primary teachers still have limited knowledge and understanding of the science they are expected to teach (Harlen & Holroyd, 1995) and, in some cases, have misconceptions held since childhood (Allen, 2010). In order to answer RQ1: ‘To what extent does a primary teacher’s own childhood science experience affect their approach to science teaching?’ I aspired to investigate teachers’ early background in science through a questionnaire given to trainee teachers early in
their initial teacher training courses. I only surveyed new trainees as I wanted to gather opinions before they had any primary science training sessions which might influence their responses.

Many primary teachers worldwide lack a background in science education (Appleton, 2003; Fitzgerald, 2012; King, 2015). Studies in Scotland and Australia showed that a lack of science content knowledge can lead to primary teachers trying to avoid science lessons, or only integrating a little of the subject into topic work where they did not need very extensive knowledge (Appleton, 2002; Harlen, 1997). It has been shown that good early science experiences in school (Kazempour, 2014) and at home (Johnston, 2005) contribute greatly to the self-confidence of primary teachers when faced with a national curriculum. Skamp & Preston (2015) felt that some teachers’ backgrounds and their own conceptions of science had a significant influence on pupils and that it was really necessary to recognise this. However, Bulunuz and Jarret’s (2010) study of elementary trainee teachers in the USA suggested that a positive science environment in childhood was vital for promoting science interest and confidence in primary science teaching. Their study was based on previous work by Joyce and Farenga (1999) who had explored the attitudes towards science of high ability middle school students, aged 9-13, and found that children’s perceptions about science were well-developed before the age of nine. Joyce and Farenga (1999) had taken a previous investigation by Anne Roe (1952) which showed that eminent physicists had been stimulated in elementary school to become scientists. However, there have been many changes in primary science since then including the implementation of a National Science curriculum in primary schools in 1988. Guichard too (2007) showed that studies into the backgrounds of several renowned scientists and engineers had indicated they had developed a deep interest in science in their primary schooling when aged only about 6 or 7 years old. These findings highlight the importance of positive science experiences at primary schools. Bulunuz and Jarrett felt that too often the background of elementary teachers was lacking in positive childhood experiences, and interviewed prospective primary trainee teachers about their early science feelings.

My experiences over my career of working with primary teachers have led me to believe that the lack of a positive, logical, early science experience by many current primary teachers (of all ages) influences their confidence in science teaching. I suggest that this could be due to being taught abstract science concepts when they were children and not fully understanding these concepts. It has been suggested that some science misconceptions in adult understanding arise from ideas acquired in primary school (Skamp & Preston, 2015). To examine this hypothesis that early primary science experiences are significant in promoting an early and lasting interest in science, I decided to emulate Bulunuz and Jarrett’s interview technique through a questionnaire. It was not feasible to interview individual trainees because of the distances I would need to travel. Thus in order to reach a suitable sample of trainee teachers, I have adapted Bulunuz and Jarrett’s questions, which included some from Joyce and Farenga’s project, to suit the English education system, and asked groups of trainees for their help from a range of institutions in which I had worked.

3.2.2 Primary Science Leaders’ (PSL) questionnaire
The beliefs and feelings that primary science teachers have about science have been found to be very important in the way they approach science in the classroom as identified in my literature review (2.6.1, p46). It has been suggested that prior experiences are significant in how a person feels about science and, also, that primary
teachers’ teaching of science is influenced by how they learnt science (Kazempour, 2014). The implication is that knowledge about primary teachers’ beliefs and feelings should be noted during training and efforts made to improve teachers’ self-efficacy (Bandura, 1977) through their training programmes. Bryan’s (2011) review of research into teacher beliefs identified the difficulties of influencing these espoused beliefs in order to effect directed changes in curriculum, as it seems that teachers marry curriculum changes into their beliefs not vice versa. The nature of science seems to be one of the areas where teachers have difficulty in assimilating new ideas, possibly because of their own experiences of learning as children (Yerrick et al., 1997).

Studies in USA by Hanuscin, Lee and Akerson (2011) and in Australia by Murcia and Schibeci (2010) have highlighted the importance of NOS and the necessity for teachers to understand NOS in order to deliver primary science effectively, make sense of socio-scientific issues and appreciate contemporary cultural science. Erduran (2014) felt that the nature of science should be interdisciplinary if science teaching were to contribute in any way to meet present-day scientific literacy requirements. It is through these interdisciplinary approaches that earth science can contribute effectively to the understanding of the nature of science using local examples familiar to primary learners.

Kind (2012) suggested that even with a science degree, a secondary science teacher could still feel ‘out-of-their-depth’ when teaching outside their subject specialism, partly by not having current knowledge, so how much less confident are primary teachers likely to feel with no specific science background? Kind went on to say that primary teachers often have similar alternative conceptions and beliefs about science ideas to the pupils they are teaching, linking back to their childhood, and need much help in accessing both subject matter knowledge (SMK) and pedagogical content knowledge (PCK) in order to be able to teach science comprehensibly to their pupils. Avraamidou (2017) found in a case study that an energetic teacher with a love of science emphasised her personal philosophy about science learning through active engagement and continual reinforcement of how scientific concepts related to everyday life.

Tsai (2002) collected information on teacher beliefs about the nature of science and how best science could be taught and learnt in Taiwan. Tsai had interviewed 37 Taiwanese teachers asking for their beliefs about teaching and learning science and their beliefs about the nature of science. His study found that the majority of his participants were traditionalists – in accordance with the teaching methods typically used in China and the Far East – with very few admitting to progressive or constructivist approaches. Here, in England, the present primary science curriculum is written in a way that promotes (or at least permits) constructivist ideas and suggests using local examples. I wanted to discover whether today’s English primary science teachers are using progressive and constructivist approaches or teaching in a mainly traditional (didactic) way. As it was not practical for me to visit a large enough sample of primary schools to interview teachers individually, I have used a questionnaire based on Tsai’s work to gather responses from primary science leaders who were attending updating primary science networking groups in Surrey. However, these teachers are not a representative sample of all primary teachers; some may have opted to attend the sessions; others will have been sent by their schools.
Every primary school in England must have an appointed primary science leader (PSL) who may or may not have any science background; the Royal Society of Chemistry Report (RSC, 2014) stated that only 6% of PSLs had a science degree. PSLs are responsible for ensuring the science curriculum in their school is planned and taught effectively; each PSL should be available to help their peers deliver this science plan. PSLs should appreciate the importance and relevance of science, particularly in the lives of children, and be prepared to help their colleagues with pedagogy and subject content knowledge by ensuring they themselves are continuing to access relevant, high-quality CPD (Wellcome Trust 2017).

Most PSLs are class teachers with some interest in science (Wellcome Trust, 2015). They are responsible for ensuring science is properly taught in their school and should therefore keep themselves updated about current science teaching ideas. PSLs in Surrey were particularly fortunate as Babcock4S (a company delivering educational in-service programmes in the county) provided three updating primary science meetings annually for teachers in four different parts of the county, catering for some 120 teachers, for a fee! (There are however, about 240 state primary schools in the county, so this service only reaches about one-half of the schools.) I was able to attend these meetings and asked for volunteers to complete my questionnaires based on Tsai’s study.

The current English primary science National Curriculum (DfE, 2013) emphasises understanding of the nature, processes and methods of science, suggesting that children should explore science in a practical way. Whilst it does not specifically direct pedagogy, the text hints at primary science being taught in a more constructivist way. PSLs’ responses to my questionnaires should show whether this is happening, or whether primary science teaching is mainly didactic.

Tsai analysed the responses by coding them using twenty or so descriptor words, based on the earlier study carried out by Koballa et al., (2000) which identified clusters of perceived connections, resulting in three categories: traditional, process and constructivist. I analysed the data collected from the Surrey PSLs in a similar fashion to show whether current primary science teaching is in keeping with the thinking behind the present primary science National Curriculum and also to elucidate what teachers think about the nature of science.

3.2.3 Intervention lessons
Teaching and learning processes have been much discussed by researchers and those involved in both teaching and learning (Robins, 2012). The general conclusion is that there are numerous ways of teaching and learning which suit different individuals, (both teachers and children), possibly with similar outcomes (Hattie, 2012). Appleton (2002) showed that Australian primary science teachers who were reluctant to teach science, were enthused by an Australian Academy of Sciences programme known colloquially as ‘science that works’. Here, practical integrated science themes helped teachers build up both science content knowledge and pedagogical content knowledge, improving self-efficacy (Bandura, 1977). These themes had to be interesting and motivating to the teacher as well as their pupils.

I propose that stimulated and enthusiastic teachers who understand their subject and have pedagogical knowledge of how to convey information will be more effective
teachers than those who are merely dictating facts. The Scottish Council for Research in Education (Harlen, 1995) looked at just this issue, after their new subject area ‘Environmental Studies’ guidelines were published. This study was of 33 primary teachers who felt they did not have enough training to teach science but found that discussing everyday science topics with colleagues helped them understand these topics better giving them the confidence to teach (O’Brien, 2012). Primary teachers have to teach a wide range of subjects to their pupils but not all teachers will be science specialists (Ofsted, 2013). Indeed, many will not have studied any science since GCSE (RSC, 2014) although they will have absorbed a certain amount of scientific information from the media and other post-school sources. Much of science is abstract, but earth science, rocks, weather, and soil particularly, surrounds us as concrete resources (Smith et al., 2012). If primary teachers use these tangible resources to teach science, primary children will have some notion and thoughts about the topics from their own experience which they can draw upon. Knowledgeable teachers can then utilise these experiences to extend understanding and hopefully correct misconceptions. Kuhn (1989) identified the role of the primary science teacher to be one that orientated children’s naïve ideas towards correct ones. However, Pine, Messer and St. John (2001) felt that whilst there was plenty of discussion about the problem of weak primary science teaching, little was being done to help teachers practically.

Children learn if they are stimulated and motivated, and if they can integrate any prior experiences with new encounters (Hickey & Robson, 2013). It is therefore important to listen to their understanding of topics and try to relate new learning to this. Since it is intimated that an interesting primary science experience lives with children throughout their lives (Wellcome Trust, 2014) earth science is particularly valuable as a learning medium because children have knowledge and experience of everyday happenings and materials which can be brought into the classroom (Serin, 2014; Seeley, 2014). Children may be able to access new concepts more easily if they are enabled to use their local knowledge experiences, such as local flooding issues due to heavy rainfall.

My objectives in planning this third part of my research were to see if by teaching primary teachers an earth science topic of which they had no knowledge or understanding, the teachers could become enthused and confident enough to stimulate their pupils’ learning. The teachers would teach the pupils using their new understanding and knowledge and the increase in the pupils’ knowledge and understanding would be noted. Any increased knowledge and understanding would be identified through the use of SOLO and Bloom’s taxonomies. Such intervention lessons can be used as a way of researching the impact of a specific teaching programme and the purpose behind these intervention lessons was to establish the potential of an earth science topic generally considered ‘boring’ by Year 3 primary teachers.

Parts of my methodology draws on a grounded theory approach (Gibson and Brown, 2009) in particular the intervention lessons. Intervention lessons are used as a way of introducing a particular topic which is often misunderstood by the learners (Jimerson et al., 2007). In this particular case, the teachers also had little knowledge or understanding of the topic, soil.
3.3 Secondary data collection

Secondary data were collected to further interrogate the argument for teaching earth science in schools as pilot results showed positive feelings towards science, particularly earth science, from both trainee teachers and pupils. Two groups of data have been used, the first collected from evaluation forms completed by trainee teachers participating in ESEU primary workshops, and the second from evaluation forms completed by children after taking part in a SATRO rock and soil or fossil workshop.

Ofsted (2013) stated that where primary science teachers and science leaders had received subject-specific science CPD sessions, primary science teaching was more effective, in Ofsted’s words “more likely to be outstanding”. Australian primary science teachers affirmed that short (up to four-hour long) CPD workshops increased their self-efficacy and had a positive influence on their science teaching (McKinnon & Lamberts, 2014). However, previously Adey et al., (2004) had suggested that the only short CPD courses that would have any real impact on teaching would need to be very specific, perhaps on software applications or assessment methods. The Wellcome Trust report (2013) found that where science subject leaders had received science CPD they could better help any primary teacher in their school who was struggling with science. Shallcross et al., (2010) suggested there was a need for good integrated science CPD which included background information as well as specific-subject knowledge and pedagogy. Abrahams et al., (2012) also felt that there was a need for CPD, especially for practical work which they thought did not always have clear objectives but was often used to provide a ‘fun’ lesson. There was a need to make practical work more effective, and their Getting Practical CPD programme was designed to support practical work in science.

The primary earth science workshops I taught were specifically designed to meet the needs of non-science primary teachers. Evaluation of similar secondary ESEU workshop data by Lydon and King (2009) showed that this CPD gave teachers both subject content knowledge and pedagogical knowledge, increasing their confidence and effectiveness. Changes to most of these teachers’ teaching methods were long term, as shown by a follow up survey carried out a year after the workshop (Lydon & King, 2009). I analysed the ESEU data collected from the primary trainee teachers’ evaluation forms using thematic coding after the idea proposed by Braun and Clarke (2006). Some of Guskey’s ideas of the range of experiences that teachers could be expected to benefit from a CPD were identified as the themes from the collected data. These themes were the participants’ reactions, their learning and the proposed use of the new skills and knowledge gained from the CPD activities (Guskey, 2000).

The SATRO children’s workshops were held in schools and attended mainly by year 3 (age 7-8) children. Some of the SATRO rock and soil workshops were sponsored by local industries which had connections with earth science. Again, analysis of the comments on the SATRO children’s evaluation forms was used to identify themes. I have taught trainee teachers, teachers and children in these workshops, therefore my involvement extends beyond ‘researcher’ to ‘participant’ as well. It is partly because of my experiences in these roles that I am so intrigued by the issues surrounding primary science teaching and learning.
The participants in the SATRO workshops vary in ethnicity and background and, despite the children being based in one of the so-called ‘home counties’, they are typical of the English population as a whole. Some come from low socio-economic groups with peers from higher groups; their parents range from highly paid professionals to those in low paid non-professional positions or on benefits; there are a wide range of ethnicities. An evaluation form devised by SATRO for the sponsoring companies is completed at the end of the workshops.

Both sets of workshops include many of pedagogical strategies seen as requisite in current teaching practices. They offer enabling systems for assessment, for discussion through questioning, for development of ideas and further investigation by pupils, and for cross-curricular linkage. Teachers can adopt and adapt the workshops to their own style, suitable for their classes as there is much flexibility in the resources offered. Higher thinking skills can be developed as children absorb the content and add it to their comprehension.

3.4 Links between the data sources and the Research Questions

Table 3.1 shows how the six data sources link to the four Research Questions. As can be seen, the various data sources contribute to the research questions and some contribute to several questions. Data collection for data sources 1, 2, 3 and 4 took place between October 2015 and January 2017. The ESEU evaluation forms are from workshops undertaken in 2009-2015, and the SATRO workshops took place in 2013-2015.

Table 3.1 The relationship between the research questions and data collection.

<table>
<thead>
<tr>
<th>Data source 1 Questionnaire to Trainee Primary Teachers</th>
<th>Data source 2 Questionnaire to Primary Science Leaders</th>
<th>Data source 3 Interviews with primary teachers &amp; observation of intervention lessons</th>
<th>Data source 4 Discussion with Yr3 primary children about science</th>
<th>Data source 5 Evaluation of trainee teacher workshops (ESEU)</th>
<th>Data source 6 Evaluation of children’s workshops (SATRO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ 1</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RQ 2</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RQ 3</td>
<td></td>
<td>Yes</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>RQ 4</td>
<td></td>
<td>Yes</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

All primary data were collected specifically for my thesis and initiated by me. The collection of some of the teacher trainee data for RQ1 was collected with help from the trainees’ resident tutors. Data collection procedures are more thoroughly explained in the following chapters.
4 Data collection and findings from trainee teacher background science experiences questionnaire

4.1 Introduction

The objective of the first of my data collections is to ascertain the background primary science experiences of trainee primary teachers in order to answer my first research question (RQ1): To what extent does a primary teacher’s own childhood experience affect their approach to science teaching? I was also interested to see if the term ‘earth science’ was mentioned by these trainees as part of their primary science experience.

Dewey (1916) suggested that childhood interests often stimulate later adulthood interest in science. I feel this is relevant to primary teachers’ attitudes towards science teaching. Many eminent scientists, among them Darwin, are reported to have enjoyed scientific activities as children which made positive impacts to their later scientific careers (Keynes, 2015; Guichard, 2007). Avraamidou (2017) tries to uncover the events and experiences that had been key in individuals making the decision to become elementary (primary) teachers in USA and then specialise as science teachers. She relates how one of her respondents was inspired by her science teacher in primary school and how another teacher in her study stated that her mission in life would be to make primary science memorable for her pupils (Avraamidou, 2017). Her study also identified negative feelings towards science gained in school by her teacher participants, because of ‘boring’ teaching methodology.

I aspired to gain information about any memorable primary science experienced by four different sets of trainee primary teachers in England by using an approach similar to that used by Bulunuz and Jarrett (2010), described in 3.2.1, p72. My questionnaire was only completed by new trainee teachers as I did not want my respondents’ responses to be influenced by any new learning they may have encountered since commencing their courses. The questionnaire (Appendix 1) was completed by trainee teachers participating in four different training programmes so that it provided a sample of responses with a range of backgrounds, cultures and ages. The four teacher training programmes were a School-Centred Initial Teacher Training (SCITT) programme based in East London, a Teach First group and a PGCE group, both based at a London university, and a BAEd group at another university in the south of England. All participants were volunteers. They were neither asked names or ages. The SCITT group’s ages ranged (by inspection) from mid-twenties to forties. These trainees were from several different countries and cultures. The majority of the Teach First group were in their thirties. The PGCE group were aged between 21 and 50 (as stated by their tutor) whilst the BAEd students were all in their first year of training and aged 19-20 years (by inspection).

Bulunuz and Jarrett (2010) asked their participants whether they had a high enjoyment (HE) or low enjoyment (LE) of science. I was only able to do this with my first group of participants, the SCITT group, before they completed the questionnaire because of time factors. When I checked their oral responses against their response to the questionnaire question about enjoyment of primary science, they were exactly the same. I have therefore assumed that the other groups would respond similarly.

10 SCITT teacher: training taking place in schools under a mentor
11 Teach First: trainees working as paid teachers, learning on the job with short college input
12 PGCE: trainees on courses after graduating with a degree
13 BAEd: a 4 year teacher training course with teaching practices
The questionnaire was divided into sections, requesting information about:

- Overall primary science experience
- Science in Year 6 science (final year in primary school)
- Science clubs in primary school
- KS3 science courses
- KS3 science fairs
- KS4 science courses
- Outside influences on science when participants were young
- Childhood science activities and experiences.

The questionnaire was completed in silence. Participants given sufficient time to think through their answers. Parts of the questionnaire were in Likert format and thus suitable for the responses to be analysed using an SPSS statistics programme. All other written responses were transcribed in order to analyse them. Seventy five trainees completed the questionnaire: 26 from the SCITT, 10 from Teach First, 24 on the PGCE course and 15 from the BAEd group. However, not every participant responded to each question. After the initial question, asking whether the respondents had enjoyed their primary science experience, I divided the data into two groups as explained above, according to whether the respondents stated that they had had an enjoyable or unenjoyable experience in their primary science. The data were entered into an SPSS statistics package, the means and standard deviations of the responses to each question in both groups determined, and then t-tests carried out to see if there were any significant differences between the two groups' responses to each question. This mode of analysis replicated that of Bulunuz and Jarrett (2010).

4.2 Results from the first part of the questionnaire about primary school science

The first part of the questionnaire asked respondents about their memories of primary school science and their enjoyment of their primary science experiences. Thirteen of those completing the questionnaire did not respond to this question. Only ten of the respondents actually replied that they could not remember any primary science and these were mostly in the SCITT group who were the older trainees and a number of trainees from overseas. However, two of the youngest of the trainees (in the BAEd group) stated they could not recall any primary science. These BAEd trainees, if in a state school in England, must have been taught science under the 1989 National Curriculum which included primary science, so it was interesting that they did not have any memories of primary science. When questioned ‘How would you describe your general primary science experience?’ 83% of the participants responded. Of these, 45% stated that they enjoyed primary school science, 39% rated their experience as satisfactory and 16% stated they did not enjoy it at all. I have interpreted this as 45% with high enjoyment and 55% with low enjoyment of those who responded, although 17% of the respondents did not reply. In response to the next two questions asking whether respondents found their best year in primary school science firstly, fun, and secondly, interesting. Sixty percent of those who responded deemed primary science as fun and 54% as interesting. It may be that one particular teacher was more inspiring than others over the whole primary experience, since this response seems rather contradictory. Not everyone completed this section however, with only two-thirds of my participants ranking their experiences.
The respondents’ data were then divided into two groups: those who expressed a high enjoyment in science (termed the HE group) and those who expressed a lower enjoyment in science (the LE group). In my opinion, science in primary school should be dynamic, memorable and enjoyable but this was found to be so for only 27% of the SCITT group, 38% of the PGCE trainees, 50% of the Teach First trainees and 43% of the BAEd trainees (Figure 4.1). The SCITT and Teach First groups are sometimes training to be teachers after another career, a career break or redundancy and it would be logical to presume they are coming into teaching as a vocation. They may have enjoyed primary science themselves or developed an interest later but opted for a different career initially. However, my data do not bear this out for the SCITT group, many of whom were married women who may feel teaching is a convenient career whilst they have young children or recognise the importance of teaching as they watch their own children develop. BAEd primary trainees are generally people who have had a long-held ambition to become primary teachers, perhaps because they enjoyed their primary education including science, as can be seen.

**Figure 4.1 Bar graph of percentage teacher trainees from different training courses who enjoyed their primary science**

```
<table>
<thead>
<tr>
<th>Trainee Group</th>
<th>Percentage Enjoyment of Primary Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCITT</td>
<td>30%</td>
</tr>
<tr>
<td>PGCE</td>
<td>40%</td>
</tr>
<tr>
<td>Teach First</td>
<td>50%</td>
</tr>
<tr>
<td>BEAd</td>
<td>40%</td>
</tr>
</tbody>
</table>
```

I then analysed the data using SPSS. The data were 75 completed questionnaires. I ran t-tests on 37 of the variables comparing the HE and LE groups; three were not suitable for testing, because of the type of data gathered. Only two of these 37 t-tests were found even to approach statistical significance (at the 5% level). The question asking respondents how they would describe their best year in primary school science showed a probability of there not being a significant difference between the two groups of about 8% (t=-1.45, N=50, p=0.0762). This finding was similar to that from the question asking about participants’ enjoyment of year 6 science with the likelihood again being around 8% of there not being a significant difference between the groups (t=-1.46, N=50, p=0.0751). For all other questions in the survey there was no significant difference even at the 10% level between the responses of the high and low enjoyment groups.
The fact that there was so little difference between the two groups was surprising. I had anticipated the HE group to be more enthusiastic about their experiences than those who professed a low enjoyment of their primary science experiences.

Many respondents stated that they could not remember what they had most enjoyed in year 6 (age 10-11) of primary school science. Of the 50 participants who did respond, the following science topics were recorded as being most enjoyed, (the percentage given is of those who answered the question):

- Animal and plant biology by 14 (28%)
- Earth and space by 12 (24%)
- Electric circuits by 8 (16%)
- Human biology by 5 (10%)
- Other individually mentioned topics 11 (22%).

For those respondents who remembered their primary science experience, it was generally found that their overall experience was mediocre with an average value of 2.7 on the Likert scale of 1-5 (3 being average). Animal and plant biology was the topic most enjoyed in year 6, mentioned by 28% of the trainees. Earth and space topics were liked best by 24% of the participants, but only the BAEd trainees remembered the practical work of electrical circuits which may not have been a component of the earlier curricula.

I was surprised that nobody mentioned earthquakes, volcanoes, dinosaurs or fossils, so perhaps these were not seen as ‘science’ topics, or rarely taught in primary science despite being popular topics with children. Neither did anyone mention any local environmental topics, e.g. flooding, coastal erosion, weather or droughts. I had thought these might have been memorable to them and have been discussed in primary schools. The topics mentioned seemed to reflect the wording of the current National Curriculum, and hence did not necessarily include out-of-school science events.

In this first section, trainees were asked about science clubs in their schools. Few (20%) remembered their primary schools running after-school science clubs. However, even in schools where there were clubs, these respondents rarely attended, with only four respondents stating they had attended and enjoyed these sessions out of 43 replies (9%).

4.3 Results from the questions about secondary science

The section 2 of the questionnaire asked about the trainees’ enjoyment of science in their secondary schools and shows a decline in enjoyment in science after KS3, during the GCSE years. All participants had to take a science at GCSE level.

The section asking trainees about their favourite KS3 science subject was answered by 59 respondents and the rankings are shown in Table 4.1.
Table 4.1 Preferred subject rankings at KS3

<table>
<thead>
<tr>
<th>Subject</th>
<th>Ranked 1 (n=59)</th>
<th>Ranked 2</th>
<th>Ranked 3</th>
<th>Ranked 4</th>
<th>Ranked 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>35</td>
<td>6</td>
<td>10</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Physics</td>
<td>5</td>
<td>4</td>
<td>13</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Earth science</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Chemistry</td>
<td>7</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>IT</td>
<td>4</td>
<td>2</td>
<td>13</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

Biology, although not now identified as plant or human biology, remained the favourite subject at KS3. However, earth science was identified as a first choice by 8 of the 59 respondents and as a second choice by a further 9 trainees, despite the fact that many did not recall studying earth science as a subject and only ranked biology, physics and chemistry. Earth science would have been integrated in the science curriculum within physics and possibly the chemistry, and would not have been identified as a separate science by many trainees, just another topic.

Respondents’ rankings of their enjoyment of their GCSE science experiences are shown in Table 4.2.

Table 4.2 Most enjoyed subject rankings at GCSE level by trainees

<table>
<thead>
<tr>
<th>GCSE Subject (n=59)</th>
<th>Ranked 1</th>
<th>Ranked 2</th>
<th>Ranked 3</th>
<th>Ranked 4</th>
<th>Ranked 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>24</td>
<td>9</td>
<td>19</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Physics</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Earth science</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chemistry</td>
<td>7</td>
<td>14</td>
<td>9</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Double science</td>
<td>26</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Double science was introduced at GCSE level in 1986, with the first examination in 1988. Whilst double science appears to have been the most enjoyed science, it was typically often the only science studied in England. However, those who did study separate sciences still ranked biology as their most enjoyed subject. Physics did have some enthusiasts but overall was the least enjoyed subject (in terms of being ranked first or second). Chemistry again ranked highly as the second most enjoyed science, though the numbers are small. The numbers taking earth science are particularly small as very few schools offer the subject at KS4, though it is more often offered at KS5. The significance of biology will be discussed in Chapter 8.

It is notable that only eight of the 73 respondents recalled visiting a science fair whilst at secondary school and only one person said they had visited more than one fair. The respondents commented that these fairs had not been career-focused, and only four students had enjoyed them. However, 39 of the 74 respondents felt that their parents had been supportive of science whilst they were at secondary school, and later data showed that most had visited science museums. These respondents had high science capital (Archer 2014). Field trips were not seen as a particularly important part of the
secondary science experience with only 39% rating them as important. In my experience students had frequently found field trips one of the more exciting events of a school year. Non-school science experiences were rated more highly by 49% of the respondents who stated that these experiences stimulated their curiosity more than primary school lessons.

4.4 Results concerning non-school science activities

Bulunuz and Jarrett (2010) organised their data by looking at the counts of activities for the three variables in the questionnaire identified as:

- Important childhood/youth science activities
- All science-related activities
- Weighted all science activities.

I organised my data in the same way as Bulunuz and Jarrett so that my findings could be compared with their work. I then ranked the results and compared percentage interest in childhood activities as shown in Table 4.3.

**Table 4.3 Order of preferences of important childhood play activities**

Notation used: DB = my study, B&J= Bulunuz & Jarrett study; N/? = number of recordings out of number of participants

<table>
<thead>
<tr>
<th>Activity</th>
<th>DB N/75 importance in childhood</th>
<th>B&amp;J N/53 (importance in childhood)</th>
<th>DB Rank</th>
<th>B&amp;J Rank</th>
<th>DB % interest</th>
<th>B&amp;J % interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Playing in sand</td>
<td>31</td>
<td>46</td>
<td>1</td>
<td>2</td>
<td>41</td>
<td>87</td>
</tr>
<tr>
<td>Playing with Lego</td>
<td>25</td>
<td>43</td>
<td>2</td>
<td>3</td>
<td>33</td>
<td>81</td>
</tr>
<tr>
<td>Using building blocks</td>
<td>19</td>
<td>37</td>
<td>3.5</td>
<td>6</td>
<td>26</td>
<td>70</td>
</tr>
<tr>
<td>Using doctor/nurse kits</td>
<td>19</td>
<td>36</td>
<td>3.5</td>
<td>7.5</td>
<td>26</td>
<td>68</td>
</tr>
<tr>
<td>Exploring outdoors</td>
<td>16</td>
<td>40</td>
<td>5</td>
<td>4</td>
<td>21</td>
<td>75</td>
</tr>
<tr>
<td>Caring for pets/animals</td>
<td>14</td>
<td>39</td>
<td>6.5</td>
<td>5</td>
<td>19</td>
<td>74</td>
</tr>
<tr>
<td>Visits to science museum</td>
<td>14</td>
<td>36</td>
<td>6.5</td>
<td>7.5</td>
<td>19</td>
<td>68</td>
</tr>
<tr>
<td>Taking things apart</td>
<td>13</td>
<td>32</td>
<td>8.5</td>
<td>11</td>
<td>17</td>
<td>60</td>
</tr>
<tr>
<td>Visits to zoos etc</td>
<td>13</td>
<td>48</td>
<td>8.5</td>
<td>1</td>
<td>17</td>
<td>91</td>
</tr>
<tr>
<td>Planting in garden</td>
<td>12</td>
<td>33</td>
<td>10</td>
<td>10</td>
<td>16</td>
<td>62</td>
</tr>
<tr>
<td>Making models</td>
<td>11</td>
<td>13</td>
<td>11</td>
<td>19</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Using chemistry kits</td>
<td>10</td>
<td>9</td>
<td>12</td>
<td>21</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>Involved in risky play/explosions</td>
<td>9</td>
<td>14</td>
<td>13.5</td>
<td>18</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>Camping</td>
<td>9</td>
<td>27</td>
<td>13.5</td>
<td>14</td>
<td>12</td>
<td>51</td>
</tr>
<tr>
<td>TV nature/science documentaries</td>
<td>8</td>
<td>34</td>
<td>16</td>
<td>9</td>
<td>11</td>
<td>64</td>
</tr>
<tr>
<td>Stargazing</td>
<td>8</td>
<td>27</td>
<td>16</td>
<td>14</td>
<td>11</td>
<td>51</td>
</tr>
<tr>
<td>Making kitchen chemicals</td>
<td>8</td>
<td>22</td>
<td>16</td>
<td>17</td>
<td>11</td>
<td>42</td>
</tr>
<tr>
<td>Beach combing</td>
<td>6</td>
<td>27</td>
<td>18.5</td>
<td>14</td>
<td>8</td>
<td>51</td>
</tr>
<tr>
<td>Looking after house plants</td>
<td>6</td>
<td>25</td>
<td>18.5</td>
<td>16</td>
<td>8</td>
<td>47</td>
</tr>
<tr>
<td>Making science collections</td>
<td>5</td>
<td>30</td>
<td>20</td>
<td>12</td>
<td>7</td>
<td>57</td>
</tr>
<tr>
<td>Snorkelling/Scuba diving</td>
<td>3</td>
<td>11</td>
<td>21</td>
<td>20</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>Going to science club</td>
<td>2</td>
<td>6</td>
<td>22</td>
<td>22.5</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Computer programming</td>
<td>0</td>
<td>6</td>
<td>23</td>
<td>22.5</td>
<td>0</td>
<td>11</td>
</tr>
</tbody>
</table>
Only the science preferences in childhood were ranked for both studies; other childhood play activities were discarded as in the Bulunuz and Jarrett study. A Spearman’s rank correlation was carried out to see if there was a significant correlation between my trainees and Bulunuz and Jarrett’s groups. It was found that the value of $r$ was 0.800 and $P$ was 0. This indicates a highly significant correlation between the two sets of data.

If the order of preference for childhood activities were divided into quartiles, certain differences can be seen in what was important to those brought up in England against those in USA. In the upper quartile, five of the six activities were the same but the percentages of participants were quite different. These activities were playing in sand; playing with Lego; exploring outdoors and using building blocks. Bulunuz and Jarrett (2010) found that their highest ranked childhood non-school activity was visiting zoos, nature centres and aquaria, whereas this activity was ranked ninth by my trainees. My trainees’ most remembered important activity was playing in sand, ranked second in the other study. Many children in England have the opportunity to play with sand in pre-school activities, at home or in local play areas. Within this quartile the other activity preferences were the same, although as stated, the percentages varied. In the second quartile, however, only half the responses recorded were the same: these were visits to science museums, taking things apart and planting seeds and plants in the garden. These activities are generally available to all children; most primary schools make annual visits to some sort of museum a priority for their pupils. Furthermore, many schools have garden areas even in city schools, offering planting opportunities even if children themselves have no garden at home. Making models and using chemistry kits were relatively popular with my study group, just falling into the second quartile, but both these activities fell into the least popular group, the lowest quartile, of the American study. The third and fourth quartiles activities were very similar with science clubs ranking very low down the scale. However, the percentage participant activity was much lower in my study throughout showing a considerable difference between the groups. This may have been due to changes in the kinds of toys available in the two countries, access to parks or museums, or even weather conditions. My trainee responses do not appear to be very scientifically orientated and, as suggested, already perhaps those who were interested in science did not take up primary teaching. Many of today’s youngsters (aged 6-10) seem to enjoy making collections (Tunnicliffe & Veckert, 2011) frequently of rocks, minerals or fossils, aided by free gifts from children’s magazines. Children are given opportunities to experiment in school science clubs which are now more popular in primary schools than they once were, and often seem to enjoy taking things apart to find out how they work. There are eight after school science clubs in primary schools near my home. Saturday science clubs are popular in my home area, run by individuals and sometimes local museums (Godalming Museum, Guildford Science Club).

When comparing my trainees’ preferred non-school science activities as children and as adults by using Spearman’s Rank, there is no significant correlation between these activities ($r=-0.196; P=0.37$). My sample of trainees appears not to have been very interested in science activities as children or as adults. Table 4.4 shows the data used for the Spearman’s Rank calculations.
Table 4.4 Importance of science activities to my sample when children and when adults

<table>
<thead>
<tr>
<th>Activity</th>
<th>DB N/75 (importance in childhood)</th>
<th>DB Rank (importance in childhood)</th>
<th>DB adult rank (importance as adult)</th>
<th>DB N/75 (importance as adult)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Playing in sand</td>
<td>31</td>
<td>1</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>Playing with Lego</td>
<td>25</td>
<td>2</td>
<td>12.5</td>
<td>4</td>
</tr>
<tr>
<td>Using building blocks</td>
<td>19</td>
<td>3.5</td>
<td>20.5</td>
<td>1</td>
</tr>
<tr>
<td>Using doctor/nurse kits</td>
<td>19</td>
<td>3.5</td>
<td>22.5</td>
<td>0</td>
</tr>
<tr>
<td>Exploring outdoors</td>
<td>16</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Caring for pets/animals</td>
<td>14</td>
<td>6.5</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Visits to science museum</td>
<td>14</td>
<td>6.5</td>
<td>8.5</td>
<td>7</td>
</tr>
<tr>
<td>Taking things apart</td>
<td>13</td>
<td>8.5</td>
<td>20.5</td>
<td>1</td>
</tr>
<tr>
<td>Visits to zoos, aquaria</td>
<td>13</td>
<td>8.5</td>
<td>8.5</td>
<td>7</td>
</tr>
<tr>
<td>Planting in garden</td>
<td>12</td>
<td>10</td>
<td>12.5</td>
<td>4</td>
</tr>
<tr>
<td>Making models</td>
<td>11</td>
<td>11</td>
<td>15.5</td>
<td>3</td>
</tr>
<tr>
<td>Using chemistry kits</td>
<td>10</td>
<td>12</td>
<td>15.5</td>
<td>3</td>
</tr>
<tr>
<td>Involved in risky play/explosions</td>
<td>9</td>
<td>13.5</td>
<td>12.5</td>
<td>4</td>
</tr>
<tr>
<td>Camping</td>
<td>9</td>
<td>13.5</td>
<td>3.5</td>
<td>11</td>
</tr>
<tr>
<td>TV nature/science documentaries</td>
<td>8</td>
<td>16</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Stargazing</td>
<td>8</td>
<td>16</td>
<td>3.5</td>
<td>11</td>
</tr>
<tr>
<td>Making kitchen chemicals</td>
<td>8</td>
<td>16</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Beach combing</td>
<td>6</td>
<td>18.5</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>Looking after house plants</td>
<td>6</td>
<td>18.5</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Making science collections</td>
<td>5</td>
<td>20</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>Snorkelling/Scuba diving</td>
<td>3</td>
<td>21</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Going to science club</td>
<td>2</td>
<td>22</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>Computer programing</td>
<td>0</td>
<td>23</td>
<td>12.5</td>
<td>4</td>
</tr>
</tbody>
</table>

I had speculated that the importance of these activities would have changed markedly by the time my trainees were adults and at college and this proved to be the case, although very few of the activities identified were truly of a scientific character. The activity ranked first by my sample as adults was watching media nature and scientific documentaries, with snorkelling and Scuba diving (possibly more of a hobby than a scientific activity) ranked second. Bulunuz and Jarrett did not rank their adult preferences so it was not possible to compare them.

### 4.5 Summary and conclusions

Overall, the results from this questionnaire showed that most of the teacher trainees in the survey had had few enjoyable experiences in their school science and seemingly no memorable events in their local communities that were recognised as 'science.' Their own primary science experiences had resulted in a few stimulating memories but their secondary experience seems to have been on the negative side, not enthusing them to continue with any further science studies. Biology, it seems, was the most enjoyed subject throughout primary and secondary school. My sample may not have necessarily recognised certain science experiences as being science, in common with the idea that science is biology, chemistry and physics learnt at school. Earth science is not a separate subject in the curriculum in England as it is in USA and therefore is not identified specifically by my respondents.
In the USA, Bulunuz and Jarrett found that more than half (58%) of their trainee teachers began their course with a high interest in science stemming from their primary school experiences. My data showed that a high interest in science in primary school was recollected by only 45% of trainees before they began their training. My study found no significant differences at even the 10% level, of trainees on starting their primary teacher training courses between those who had a high enjoyment and those having a low enjoyment of science at primary school.

The Bulunuz and Jarrett study looked at trainees in one USA state only identified as a southern, urban area. My trainees were at establishments in the south of England but had come from all over the country and in some cases further afield.

My study differs in a number of respects from that of Bulunuz and Jarrett. First, my sample was larger (75 as opposed to 53), and was composed of four different groups of trainee teachers, rather than all being in the one college. The students in my study varied in age, religion and culture (some Muslim and Chinese) as well as in ethnicity. Nevertheless, the subject most enjoyed in Bulunuz and Jarrett’s study was also biology, as in my study. Only four of the respondents in my study had gone on to study science at degree level: one in biology, one in forensic science and two in sports science related degrees, which at just over 5% is about the present norm for primary trainee teachers.

In my study, science was not an important part of these teacher trainees’ experiences of non-school activities either when they were of primary or secondary school age. My study found that only 17% of respondents stated that they enjoyed science as adults and less than half (45%) had enjoyed science in their primary schools. The latest Public Attitudes to Science report (British Association of Science, 2016), shows that 25% of the 16-24 age group state they are uninterested in science, and 16% of those aged 25-29 are uninterested, too, the typical age groups of those presently training to become primary teachers. As adults, few of my participants (17%) ranked science hobbies as important to them now, their science interests were confined to looking after pets and watching TV nature or science documentaries. Possibly some differences between my study group and the Bulunuz and Jarrett group could be explained as cultural differences between England and USA. The trainees in my study had very different interests in their younger days with visits to zoos being much less important than in the USA. My trainees who responded preferred playing with Lego and building blocks or playing at doctors and nurses. Changes have also taken place in the way children play, with English children using more computer games since the early 21st century.

I postulate that perhaps primary teaching does not generally appeal to those people specifically interested in science, who may well go on either to enter scientific careers or to teach secondary science. Although it is not necessary or perhaps even desirable for primary teachers to have a degree in science (Royal Society, 2010) it is all the more important that those who are teaching science in primary schools are confident and enthused by science and have basic scientific knowledge in order to be able to correctly inform and pass on their interest and knowledge to their pupils through their own enthusiasm.
5 Data collection and findings from the primary science leaders’ survey

5.1 Introduction

In order to answer RQ2: ‘What do primary teachers think of science and how do they consider it should be taught?’ data were collected between October 2014 and June 2016 from primary science leaders (PSLs) employed in Surrey primary schools, who were attending four different networking sessions based in Reigate, Guildford, Ripley and Ashtead. The networking sessions were organised by Babcock 4S, a company providing education services in Surrey. Primary schools opted to attend these sessions for a fee, but there were only places for 30 teachers on each session. Hence, the sample is limited to those schools which were interested enough to send their PSLs and who could afford to pay.

I initially attended the three meetings of the group based in Reigate during 2014-2015, the results of which were used as a pilot. These data provided interesting results, so I attended the three meetings of the three other networking groups. These meetings were held in the academic year 2015/2016.

5.2 Method

Three questionnaires were devised, based on research carried out by Tsai (2002) as described in 3.2.2 p73 and are shown in Appendix 2. At each of the three meetings, each PSL was asked to complete a different questionnaire. The first questionnaire asked teachers about their beliefs of how they felt it best to teach science; the second questionnaire asked about their beliefs of how they thought science was best learnt by primary pupils; and the third asked for the PSLs’ own beliefs about the nature of science. (It should be noted here that the teacher responses are not necessarily of how they are teaching but how they feel or think science should be taught and is best learnt by the children.) For the pilot phase, carried out in 2014-2015, the questionnaires were given out to each group of teachers at the beginning of their network sessions, a different questionnaire at the start of each of the three meetings. Time was made available to answer the questions before the meeting started so that the teachers could consider their responses. Generally, the teachers answered the three questions on each questionnaire within five minutes but then sat quietly until everyone had finished. The teachers did not discuss their responses. All the teachers in the pilot survey had been taught in a pupil in a primary school in England and had spent some years in their current posts, however they told me that none of them was a science specialist. So order that I would be able to use the data, each teacher needed to complete the three questionnaires so they could be collated to give a complete response. For the pilot, a total of only 15 questionnaires, one from each workshop, were fully completed by the attendees because many schools sent a different or new PSL to each meeting.

The second tranche of data was collected during the 2015-2016 academic year. Similarly to those trainee teachers who responded to the questionnaire about their childhood science experiences (p81), this group of teachers were varied in ethnicity. They also varied more in age than the pilot primary science leader group and (consequently) the length of time they had been teaching. A large majority were female: out of the sixty who completed all three questionnaires only three were male,
more than reflecting the gender imbalance in the present primary teaching cohort across England (DfE, 2015, p7). Data collection took place in October 2015, February 2016 and June 2016, from each venue and at the start of each session, as in the pilot. The three questionnaires were given on separate occasions, so the respondents’ reactions would be less likely to be referenced to their previous comments.

As previously discussed (3.2.2 pp73, 74 Tsai (2002) studied Taiwanese teachers’ beliefs and attitudes towards teaching science in an environment used to didactic teaching. Primary science teachers in England should be more familiar with progressive or constructivist ideas (discussed in 2.6.2 p48) and the purpose of this part of my research was to identify the beliefs and feelings of current teachers to see if these were traditional, process-orientated (as defined by Tsai) or constructivist. Although some 120 PSLs took part in the networking groups on each occasion, and every one fully co-operated by completing a questionnaire at each meeting, just 60 PSLs attended every meeting in their area and answered all three questionnaires. Only these questionnaires were used in my analysis.

5.3 Findings from the PSL questionnaires

The data have been tabulated in various ways, similar but not the same to those used by Tsai (2002). Tsai’s paper did not show an analysis of each individual question, but just divided the responses into his three categories of traditional, process and constructivist. I have chosen to look at the responses to each question individually as well as categorising each questionnaire as this gives more insight into the current feelings and beliefs of local PSLs about teaching science. These responses are discussed first, followed by a categorisation similar to that used by Tsai.

5.3.1 Findings from Questionnaire 1
The first questionnaire asked three subquestions on teachers’ beliefs:

(i) What do you think makes successful science teaching?

(ii) In your view what is the best way to teach science?

(iii) Describe what the ideal teaching environment would look like in your opinion.

The most frequent responses to the first subquestion are indicated in Table 5.1. There were 32 different points made by these teachers in response to the question, but they fell into eight main groups. Table 5.1 shows PSLs’ replies to Questionnaire 1 subquestion (i): What do you think makes successful science teaching?

Only the most frequent responses are shown in the all the following tables.
Table 5.1 PSLs’ replies to Questionnaire 1, subquestion (i), n=60

<table>
<thead>
<tr>
<th>Points made by PSLs</th>
<th>Number of responses</th>
<th>Percentage of teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher knowledge</td>
<td>32</td>
<td>53</td>
</tr>
<tr>
<td>Children asking questions</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>Teacher enthusiasm</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Investigations</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Practical sessions</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Real life experiences</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Time to explore</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Engaging children</td>
<td>8</td>
<td>13</td>
</tr>
</tbody>
</table>

The responses to subquestion (i) showed that slightly over half the PSLs (53%) felt that having in-depth scientific knowledge brought about successful science teaching, this was the single most cited answer. Twenty seven percent commented that allowing children to pose questions made for successful teaching; these PSLs fall in Tsai’s constructivist group. Twenty five percent felt that delivering science enthusiastically was an important contributor to successful science teaching. Fitzgerald (2012) suggested that successful primary science teaching should be a process of questioning and finding out by the children themselves, in a practical way led by knowledgeable teachers. The responses to this question suggest that about half of these PSL participants believed in this approach. There is research evidence to suggest that children remember more science if the results of relevant practical investigations are in line with their own thinking (Russell et al., 1993).

The responses to subquestion (ii) are shown in Table 5.2. Table 5.2 shows PSLs’ replies to Questionnaire 1 subquestion (ii): In your view what is the best way to teach science? In their responses, teachers used the words ‘practical’ and ‘hands on’ as well as ‘investigative’. The responses have been counted under each of those headings.

Table 5.2 PSLs’ replies to Questionnaire 1 subquestion (ii), n = 60

<table>
<thead>
<tr>
<th>Points made by PSLs</th>
<th>Number of responses</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical</td>
<td>29</td>
<td>48</td>
</tr>
<tr>
<td>Hands-on</td>
<td>19</td>
<td>32</td>
</tr>
<tr>
<td>Investigations</td>
<td>19</td>
<td>32</td>
</tr>
<tr>
<td>Questions exploring children’s own ideas</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Relevant issues</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Investigating children’s questions</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Child orientated investigations</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Fun, enthusiasm</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

The PSLs’ views on the most effective way to teach science were very similar to the way they believed successful science teaching could be achieved. Some 48% of the respondents felt that a ‘practical’ method to teaching science encouraged children to be involved (Hickey & Robson, 2013) amongst others, and 32% used the term ‘hands-on’ as the best way to teach science, especially when using investigative lessons (mentioned by 32%). Enabling children to explore their own ideas was seen by 20% of
the participants as a useful teaching tool. Fifteen per cent believed that science should be relevant (Russell et al., 1993; Smith, 2016) and 13% that it should be child-orientated, echoing ideas from Piaget. However, as the points made in response to the third question (Table 5.3) show, there were limitations of resources, space and time which would inhibit these practices. In reality, large class sizes and the lack of space or equipment frequently restrict what teachers can do in practice, and their ideals may have to be tempered to their classroom situations.

Table 5.3 shows PSLs’ replies to Questionnaire 1 subquestion (iii): Describe what the ideal teaching environment would look like in your opinion.

Table 5.3 PSLs’ replies to Questionnaire 1 subquestion (iii), n=60

<table>
<thead>
<tr>
<th>Points made by PSLs</th>
<th>Number of responses</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Need resources, e.g. equipment &amp; display materials</td>
<td>38</td>
<td>63</td>
</tr>
<tr>
<td>Need space</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>Need outdoor area</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>Children asking questions</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Environmental area to explore</td>
<td>8</td>
<td>13</td>
</tr>
</tbody>
</table>

When asked in this subquestion to write what they felt would be the ideal teaching environment, 63% of PSLs responded that there was a great need for everyday equipment, preferably so that each child could have their own; and for resources and good display materials which are up-to-date. A dedicated space for science was deemed necessary by 30% of the respondents, some mentioning that a science laboratory was needed to be able to set up investigations, whilst 27% wrote that outdoor space was the ideal environment in which to study science. These points were elaborated by PSLs who commented that they felt it would be beneficial to have an area where experiments could be left for several days, without everything having to be tidied away at the end of each lesson, and where children could go to finish off investigations in their own time, or make further recordings. My sample felt that cross-curricular links with mathematics and English would be enhanced (Kelly & Stead, 2013) if children could return to check investigations rather than having to rely on their observations taken in a short science lesson before writing up their conclusions; similarly, other subjects (numeracy, literacy, geography, history, RE) might benefit from the opportunity to revisit an investigation and allow further discussion.

5.3.2 Discussion of Question 1 responses
The HMCI’s\textsuperscript{14} monthly report for May 2016 (HMCI, 2016) stated that primary science teaching was variable and that there was a link between teachers’ subject knowledge and how well pupils were developing “scientific skills”. Certainly, my sample shows that the Primary Science Leaders had many positive constructivist and process-orientated beliefs about what makes for successful science teaching. However, my data show that the PSLs’ beliefs about the best way to teach science and the way they were able to implement their teaching was not always possible because of lack of resources and time restraints. This is backed up by the latest, 2017, Wellcome Trust Report, where only 57% of primary teacher respondents stated they felt they had enough science

\textsuperscript{14} HMCI Her Majesty’s Chief Inspector (of schools)
equipment for all their pupils, and the time available for teaching science was too short, with 54% of schools having less than two hours dedicated time for science each week. Some improved basic environment and time allowances would be required before the PSLs’ beliefs could be put into practice more fully. This was illustrated by Devine et al. (2013) who found frequent mismatches in beliefs and practice in their Irish teacher study. In Devine’s study science leaders confirmed that they believed SCK was important and implementing questioning methodologies key.

Bryan (2011) showed that there was no single way to define teacher beliefs, since each individual teacher held their own beliefs which, over time, became more difficult to change. Each teacher’s belief is presumed to affect the way they teach. Bryan identified several kinds of beliefs, with espoused beliefs being those that teachers state but do not necessarily apply. Many of the points made by the PSLs’ responses indicate espoused beliefs, although there are often genuine reasons for not implementing them.

5.3.3 Findings from Questionnaire 2
The three questions asked in the second questionnaire were:

(i) What do you think makes successful science learning?

(ii) What do you think the responsibilities of students are when learning science?

(iii) What is the most important determinant for success of learning science?

Table 5.4 PSLs’ replies to Questionnaire 2 subquestion (i): What do you think makes successful science learning?

<table>
<thead>
<tr>
<th>Points made by PSLs</th>
<th>Number of responses</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hands on experiences and investigations</td>
<td>39</td>
<td>65</td>
</tr>
<tr>
<td>Children asking questions</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Children having relevant experiences</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Problem solving and discovery</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Having engaged children</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Inspiring learning experiences</td>
<td>7</td>
<td>12</td>
</tr>
</tbody>
</table>

The questionnaire uses the word ‘successful’ as in Tsai’s questionnaire. Looking at their responses, the PSLs have interpreted ‘successful’ as ‘effective learning’. The comments made about what makes for successful (per Tsai) learning were wide ranging with 65% of PSLs believing that hands-on experiences and investigations were necessary coupled with children asking and following up on their own questions. PSLs identified using relevant experiences as examples were also important (as previously mentioned in the teachers’ beliefs about teaching), with 18% of PSLs mentioning this. Problem solving and discovery sessions were identified as successful ways of learning by 15% of PSLs but the experiences gained from these sessions needed to be inspiring (12%). Another point mentioned by 12% of PSLs was that children needed to be engaged in what they were doing in order for successful learning to occur (White, 2005). Overall, 52 different points were made about what PSLs’ thought would make
for successful learning, including ensuring children were aware that there were no right or wrong answers, allowing time for children to work at their own pace and having flexible teaching styles.

Table 5.5 presents PSLs’ replies to Questionnaire 2 subquestion (ii): What do you think the responsibilities of the students are when learning science?

### Table 5.5 PSLs’ replies to Questionnaire 2 subquestion (ii), n=60

<table>
<thead>
<tr>
<th>Points made by PSLs</th>
<th>Number of responses</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working within health and safety rules</td>
<td>24</td>
<td>40</td>
</tr>
<tr>
<td>Asking questions</td>
<td>21</td>
<td>35</td>
</tr>
<tr>
<td>Working as a team</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Looking after the environment</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Linking previous knowledge to new work</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Using equipment properly and safely</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Being inquisitive</td>
<td>7</td>
<td>12</td>
</tr>
</tbody>
</table>

Sub-question 2(ii) produced a narrow range of responses with 40% of the replies stating that the children needed to be responsible for their own and others’ safety. PSLs felt children should look after the environment and use equipment properly and safely, points linked to working with care. However, quite a few PSLs (17%) felt children should work in teams and this was a responsibility the children should take on. PSLs also thought children should be responsible for asking questions, being inquisitive and linking the work they were undertaking with previous knowledge.

Table 5.6 shows PSLs’ replies to Questionnaire 2, subquestion (iii): What is the most important determinant for success of learning science?

### Table 5.6 PSLs’ replies to Questionnaire 2 subquestion (iii), n=60

<table>
<thead>
<tr>
<th>Points made by PSLs</th>
<th>Number of responses</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Being curious and questioning</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>Teachers being knowledgeable and confident</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Children being able to use their own learning</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Children understanding what they have learnt</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Engaging lessons</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Relevance of the science</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Appropriate resources</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

From the PSLs’ written responses, the most important determinant for successful science learning was deemed to be a ‘questioning’ environment (27%) where children would feel confident and curious enough to ask questions or when teachers were posing relevant questions (Chin, 2007; Alexander, 2015). The 2014 English primary science National Curriculum suggests this is a useful way to explore science and it
seems that the PSLs would prefer this practice to be followed. The responses showed that 17% of the sample believed that primary science provides an opportunity to allow children to interpret their learning in 'hands-on' situations that are applicable to everyday life, suggesting that this would help children understand more about the world they lived in, and the concepts that were being taught (Hickey & Robson, 2013). Another comment made by 15% of the PSLs was that teachers themselves must be enthusiastic and confident in their knowledge and understanding of the work being tackled. Traianou (2006) wrote that there had been an emphasis on primary teachers having good subject knowledge in recent years, but she suggested that they also needed good understanding and the ability to teach this knowledge, that is pedagogical content knowledge (Shulman, 1987). Traianou’s ideas are mirrored by these PSLs who wrote that science needed to reflect everyday life occurrences for children to understand the science. The range of responses to this question was small, perhaps reflecting some confusion caused by the wording of the question, although 37 different points were noted.

5.3.4 Discussion of Question 2 responses
PSLs believe that successful science learning occurs through ‘working scientifically’ and therefore is very much in line with the National Curriculum (2014) ideal. Smith (2016) suggests that this approach can be very beneficial with great impact on progress as children become engaged and develop skills, which are not only applicable to science. Having an enabling classroom environment where children are being curious and questioning raises further ideas and investigations, and enables critical thinking. Using relevant issues in the local environment, with easily available resources, brings children closer to their neighbourhoods and communities with a better understanding of everyday challenges (James & Pollard, 2011; Skamp & Preston, 2015) to assist them in becoming active citizens.

As the PSLs were the science co-ordinators in their schools, they were rightly concerned that children be aware of health and safety issues, and the importance of using equipment correctly, (Wellcome Trust, 2017).

When looking at comments to both the first and the second sections of my questionnaire, there are several responses that occur in all the answers. From Question 1 subsections i and ii, and Question 2 subsections i and iii, teachers identified the following four points that they believed would make for effective science teaching:

- Children being curious and asking questions; and using the children’s questions to identify investigations
- Using hands-on investigations
- Using real life experiences of relevant issues
- Engaged children.

Whilst these comments are not necessarily the most important responses for each subsection, an espoused theme can be detected (Bryan, 2011): teachers’ beliefs about effective teaching and learning of science are mostly constructivist.

5.3.5 Findings from Questionnaire 3
The third questionnaire asked for the PSLs’ views about the nature of science and was specifically designed to identify the teachers’ understanding of the word ‘science’ and the main characteristics of scientific knowledge – in other words, to try to discover
PSLs’ views about the nature of science. The three subquestions were phrased in the following way:

(i) What do you understand by the word science?

(ii) What are the main characteristics of scientific knowledge?

(iii) What are the differences between scientific knowledge and other knowledge?

Table 5.7 presents the PSLs’ replies to Questionnaire 3 question (i): What do you understand by the word science?

Table 5.7 PSLs’ replies to Questionnaire 3 subquestion (i), n=60

<table>
<thead>
<tr>
<th>Points made by teachers</th>
<th>Number of responses</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>The investigation of the world around us</td>
<td>45</td>
<td>75</td>
</tr>
<tr>
<td>How the world works</td>
<td>27</td>
<td>45</td>
</tr>
<tr>
<td>Biology</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Chemistry</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Physics</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Curiosity</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

One of the current primary science National Curriculum aims is that children develop an understanding of the nature, processes and methods of science (DfE, 2013). It is therefore important that those teaching science should have a clear understanding of the nature of science themselves. Most of the PSLs (75%) stated that they understood the word ‘science’ to mean the investigation of the world around us, but few mentioned the fact that science was dynamic, and ever-changing, whilst 45% mentioned that they thought science to mean how the world worked. However, 23% still gave very traditional answers to this first question, defining science as physics, chemistry and biology, and saying things like science was “all facts to be learnt”. This perhaps aligns with the statement made in the National Curriculum for Primary Science document (p3) that “scientific knowledge and conceptual understanding be through the specific disciplines of biology, chemistry and physics”.

Table 5.8 presents PSL’s replies to Questionnaire 3 (ii): What are the main characteristics of scientific knowledge?

Table 5.8 PSLs’ replies to Questionnaire 3 subquestion (ii), n=60

<table>
<thead>
<tr>
<th>Points made by PSLs</th>
<th>Number of responses</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working scientifically</td>
<td>17</td>
<td>28</td>
</tr>
<tr>
<td>Explaining the world</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Understanding why things happen</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Providing evidence of why things happen</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Predicting something will happen</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Biology, physics, chemistry</td>
<td>8 each</td>
<td>13</td>
</tr>
<tr>
<td>Theories</td>
<td>7</td>
<td>12</td>
</tr>
</tbody>
</table>
The PSLs identified a wide range of points but the ones they identified as the main characteristics of scientific knowledge are generally regarded as scientific processes or methods. There was no real demonstration of an understanding of the characteristics of scientific knowledge, including that it is provisional; i.e. capable of changing based on new evidence. Fifteen per cent of replies stated that a characteristic of scientific knowledge is providing evidence of why things happen. This question links in with the third question – the difference between scientific and other knowledge (Table 5.9).

Table 5.9 presents PSLs’ replies to Questionnaire 3 subquestion (iii): What are the differences between scientific knowledge and other knowledge?

Table 5.9 PSLs’ replies to Questionnaire 3 subquestion (iii), n=60

<table>
<thead>
<tr>
<th>Points made by PSLs</th>
<th>Number of responses</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific knowledge is tested</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Scientific knowledge is verified</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Scientific ideas can change</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Scientific knowledge identifies how/why things work</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Scientific knowledge is concepts and theories</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Other knowledge is culturally based</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

Responses in Table 5.9 point more towards characteristics of scientific knowledge and hardly any PSLs were able to answer the question, many leaving blank spaces on the questionnaire. A few PSLs actually wrote that they did not think there was any difference between scientific and other knowledge (5%) and 5% wrote that they “were not sure” that there was a difference. This is a rather disturbing response since if PSLs cannot identify what scientific knowledge is, they will not be able to help their peers or their pupils come to an understanding of the importance for every citizen to be scientifically literate in this scientific and technological world. More encouragingly, a few (7%) identified the fact that science has its own language which sets it apart from other knowledge.

5.3.6 Discussion of Question 3
Overall, the third questionnaire showed variable responses for the PSLs’ understanding of the nature of science, characteristics of scientific knowledge and indeed the differences between scientific and other knowledge. Some of the points made were traditional, that scientific knowledge was tested and verified, and only 13% stated that scientific ideas can change. PSLs did not seem to recognise the provisional nature of science, which is quite important when teaching children as their ideas should be seen as being constructive in developing new theories (Warren, 2001). Often children see issues from a viewpoint which can be helpful for adults who look at things through more complex eyes, It is important teachers understand that these viewpoints are children’s ideas and not necessarily misconceptions. PSLs need to have a clear view of what science is, so they can better teach science to their pupils. Hopefully, by supporting children’s questioning and allowing investigative practices to take place children (and
teachers) will become more aware of the way that scientific knowledge is built up over time.

5.3.7 Discussion of all three questionnaires
When the responses to all three of the questionnaires are looked at together, some patterns about the beliefs and feelings towards teaching, learning and the Nature of Science (NOS) of this sample of PSLs begin to emerge. Table 5.10 shows how often the same points were made by teachers about their beliefs and feelings of how successful teaching and learning of science takes place.

Table 5.10 Teacher beliefs about teaching and learning

<table>
<thead>
<tr>
<th>Comments made about:</th>
<th>Q1/i</th>
<th>Q1/ii</th>
<th>Q2/i</th>
<th>Q2/ii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher having in depth knowledge</td>
<td>53%</td>
<td></td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>Children posing questions</td>
<td>27%</td>
<td>20%</td>
<td>18%</td>
<td>25%</td>
</tr>
<tr>
<td>Using investigations/hands-on/practical</td>
<td>23%</td>
<td>48%</td>
<td>65%</td>
<td></td>
</tr>
<tr>
<td>Relevance of topic</td>
<td>18%</td>
<td>15%</td>
<td>18%</td>
<td>13%</td>
</tr>
<tr>
<td>Enthusiasm by teacher</td>
<td>10%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of resources</td>
<td>63%</td>
<td></td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Availability of space/environmental area</td>
<td>30%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabling problem solving/discovery learning</td>
<td>13%</td>
<td>15%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curious children/engaged children</td>
<td>13%</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspired learning experiences</td>
<td>12%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understandability of session</td>
<td></td>
<td>13%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>Staying safe – being responsible</td>
<td></td>
<td>40%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Percentages are calculated as the number of teachers who gave that response out of the total participating (n=60). The most important view is that children should be able to ask the teacher questions during a lesson; this response crops up in every questionnaire. Research suggests that appropriate questioning by the teacher and between the children and teacher encourages critical thinking and higher thinking skills (Turner et al., 2011). Perrot (1982) suggests that if teachers provide an environment which encourages discussion, sometimes prompting or asking for clarification of a response, this can lead to higher-order thinking. Van Vondel et al. (2017) showed that understanding was often increased when teachers asked questions rather than telling children facts. Chin’s (2007) and Alexander’s (2015) idea of ‘throwing back’ questions (that is, asking children to explain their replies) to the class and getting responses between children seemed to increase ideas and more thinking. The teacher can also identify the children’s alternative ideas and see which children need scaffolding in their understanding. Communication through questioning is seen as being the key to effective teaching and learning.

Using relevant topics also figures highly in responses by my respondents; they believe that relevance is necessary for effective emplacement of concepts, and using local subjects and children’s experiences can encourage involvement and hence understanding of scientific themes at primary age (5-11). Many researchers have made this point (Russell et al., 1993; Alexander, 2009; Harlen et al., 2015; Skamp & Preston; 2015) and the National Curriculum (2014) encourages teaching that uses the world around children.
The responses to my questionnaires have highlighted many points about how experienced teachers view effective teaching and learning. Many PSLs themselves are not confident where their beliefs lie, which is concerning given that they are the leaders of science in their schools to whom their colleagues should feel confident to turn for advice. The report by the Wellcome Trust (2017) identifies the characteristics required by a Primary Science Leader as someone who values science and understands the importance and relevance of science in everyday life. My PSLs did value the relevance and importance of science but most need help to be able to implement their beliefs more effectively.

Teachers believe that practical, hands-on investigative work is an effective way of teaching and learning, and the National Curriculum for Science (2014) stresses this. Bates’ (2015) group of trainee teachers suggested that being competent in subject knowledge was high on their list of qualities required by a professional teacher. Over half of this sample of PSLs believed that such subject knowledge was most important, as seen in response to question 1/i. The availability of resources does figure highly in the beliefs and feelings that the PSLs have regarding effective science teaching and learning. However, having the children curious and engaged does not seem so important, though many researchers cite this as necessary for learning to take place (Nottingham, 2016; Pollard, 2014).

The Nature of Science questionnaire produced some worrying results as shown in Table 5.11.

**Table 5.11 PSLs’ responses about NOS**

<table>
<thead>
<tr>
<th>Nature of Science is about:</th>
<th>Q3/i</th>
<th>Q3/ii</th>
<th>Q3/iii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigating the world</td>
<td>75%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asking how the world works/how things work</td>
<td>45%</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Biology/Physics/Chemistry</td>
<td>23%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curiosity</td>
<td>6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working scientifically</td>
<td>26%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding how the world works</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Providing evidence</td>
<td>15%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>Predicting</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theories and facts</td>
<td>12%</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Testing evidence</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science ideas can change</td>
<td></td>
<td></td>
<td>13%</td>
</tr>
</tbody>
</table>

If these responses are viewed alongside the proposal in the National Curriculum for Science (DfE, 2013), then they might be considered appropriate as the document states that the phrase NOS “specifies understanding of the nature, processes and methods of science” (DfE, 2013). However, this does not reflect the generally accepted ideas about NOS as suggested by Ratcliffe (2004), Hodson (2009) or Lederman (2014). The tentative changing nature of science is barely recognised (13%) and there is still a reliance by these PSLs on the ‘three sciences’ idea of biology, physics and chemistry. The idea that science is cumulative, creative and developed through groups...
of people is not mentioned. There is still need to improve the teaching of NOS in schools, despite this topic now forming part of Initial Teacher Training (Ofsted, 2016).

5.4 Nested epistemologies

In order to identify his nested epistemologies, Tsai had devised a framework for categorising the participants’ responses, assigning the statements on each questionnaire to traditional, process or constructivist categories using key words identified by Tsai to classify beliefs presented in Figure 5.1.

Figure 5.1 Descriptor phrases used by Tsai (taken from Tsai, 2002)

<table>
<thead>
<tr>
<th>Category</th>
<th>Descriptor phrases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>Transfer of knowledge; scientific truths; clear definitions; firm answers; accuracy</td>
</tr>
<tr>
<td>Process</td>
<td>Scientific method; following problem-solving procedures; verification procedures; experiencing self-discovery</td>
</tr>
<tr>
<td>Constructivist</td>
<td>Making interpretations; providing authentic experiences; interacting; discussing; using prior knowledge and misconceptions</td>
</tr>
</tbody>
</table>

The descriptors Tsai used for ‘process’ do not match well with the English idea of ‘progressive’ teaching. Progressive teaching in England offers some guidance and scaffolding but is not as restrictive as Tsai’s ‘process’ category (Loxley et al., 2014). Teachers in England regard constructivist teaching as allowing children to develop their own ideas without restricting them in any way. At primary level and with a group of 30 children in a class with diverse ideas, it is not feasible to allow them to work completely in their own way; lack of time and resources are inhibitors. However, Tsai’s descriptors have been used to categorise the responses from my questionnaires.

When analysing individual PSLs’ responses to the three questionnaires, a wide variety is seen, as Table 5.12 shows. However, even within each individual questionnaires, PSLs showed differences in their replies to each question; for example, in questionnaire 1 a response to subquestion (i) might be classified as traditional, whilst responses to subquestions (ii) and (iii) might be seen as process. An example of this was a teacher who responded that successful science teaching was delivering known facts, then in subquestions ii) and iii) responded that children needed to explain their thinking and query facts, a more process-orientated response. In each case, a considered judgement was made to enable the overall response to be categorised.
Table 5.12 All the combinations of the PSLs’ beliefs of teaching, learning and nature of science, n=60

<table>
<thead>
<tr>
<th>Teaching Science</th>
<th>Learning Science</th>
<th>Nature of Science</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>Traditional</td>
<td>Traditional</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Traditional</td>
<td>Process</td>
<td>Process</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Traditional</td>
<td>Constructivist</td>
<td>Constructivist</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Traditional</td>
<td>Process</td>
<td>Traditional</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Traditional</td>
<td>Constructivist</td>
<td>Traditional</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Traditional</td>
<td>Process</td>
<td>Constructivist</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Traditional</td>
<td>Constructivist</td>
<td>Process</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Process</td>
<td>Process</td>
<td>Process</td>
<td>8</td>
<td>13</td>
</tr>
<tr>
<td>Process</td>
<td>Process</td>
<td>Constructivist</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Process</td>
<td>Process</td>
<td>Traditional</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Process</td>
<td>Constructivist</td>
<td>Process</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Process</td>
<td>Constructivist</td>
<td>Traditional</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Process</td>
<td>Constructivist</td>
<td>Constructivist</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Constructivist</td>
<td>Constructivist</td>
<td>Constructivist</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>Constructivist</td>
<td>Constructivist</td>
<td>Process</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Constructivist</td>
<td>Constructivist</td>
<td>Traditional</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Constructivist</td>
<td>Traditional</td>
<td>Traditional</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Constructivist</td>
<td>Process</td>
<td>Constructivist</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

From the 27 possible combinations of the three styles of preferred teaching and learning, the PSLs in my study fell into 19 categories, a very wide range of choices showing their individual beliefs of how teaching and learning can best be delivered. In Tsai’s analysis only 13 of the possible combinations were chosen with 41% believing ‘traditional, traditional, traditional’ was best, consistent with Taiwanese practice. Figure 5.2 presents the data in Table 5.12 in graphic form which is perhaps easier to interpret.

Figure 5.2 PSLs’ overall beliefs
My sample shows a wide range of beliefs in teaching and learning science and in the teachers’ beliefs about the Nature of Science. More teachers held beliefs that teaching should be process-orientated, rather than traditional; a low percentage held the belief that traditional didactic teaching and learning of science was the most effective method. The teachers’ stated beliefs showed that they felt science was best learnt in a constructivist way. but lesson time constraints and the diversity of ability of the pupils may have influenced the PSLs’ beliefs about teaching in a constructivist way, even though the questions asked for PSLs’ preferences in teaching and learning approaches. Whilst the questions specifically requested responses about the teachers’ beliefs, almost inevitably the older teachers’ replies will have been influenced by their experience of current class sizes, available resources and the time available for teaching a large science curriculum.

In order to compare my findings with those of Tsai I have graphed the percentage of beliefs in each group (Figure 5.3).

**Figure 5.3 Comparison of congruencies in the Tsai sample and the sample in this study**

My study shows that only 22 of the 60 PSLs (37%) were congruent across the three beliefs whilst Tsai’s study showed that 21 of his 37 participants (57%) held congruent ideas across all three. However, only 3% (2) were congruent in respect of traditional beliefs in my study, compared with 41% in Tsai’s study, showing that intentions in English primary science teaching were very different from those in Taiwan. Tsai’s study found that it was rare for teachers’ beliefs to be totally different across the areas of teaching, learning and science. Just three teachers (5%) had totally divergent beliefs in Tsai’s study whilst I found that six (10%) showed totally divergent beliefs across the three questionnaires. The PSLs from my sample may be still trying to identify their own beliefs about teaching strategies and might not be as experienced as some of the others in the sample although, unfortunately, I do not have any data about their length of teaching experience.

Just over half the PSLs (32, 52%) in my study held the same belief for two areas. Four (7%) of the PSLs who held traditional views about teaching science felt that learning could take place best in ways other than traditional. These four also had either process or constructivist views on the nature of science. Two other PSLs with traditional views
about teaching felt that children *learn* best in non-traditional ways but the PSLs’ own ideas about science were still traditional.

The numbers and percentages of PSLs’ beliefs across the three questionnaires (Q1, Q2 and Q3) are shown in Table 5.13 and are derived from Table 5.10.

**Table 5.13 Primary Science Leaders’ overall beliefs about teaching and learning science and the nature of science, n=60**

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>Process</th>
<th>Constructivist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching science</td>
<td>8</td>
<td>31</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>13%</td>
<td>52%</td>
<td>35%</td>
</tr>
<tr>
<td>Learning science</td>
<td>4</td>
<td>24</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>7%</td>
<td>40%</td>
<td>70%</td>
</tr>
<tr>
<td>Nature of Science</td>
<td>15</td>
<td>19</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>32%</td>
<td>43%</td>
</tr>
</tbody>
</table>

The first questionnaire was designed to identify the PSLs’ beliefs about teaching science overall. Table 5.13 shows just that half the PSLs felt that primary science should be taught in a process-orientated way, that is (according to Tsai) that children should follow problem-solving methods to 'discover' facts about science. However, 13% felt that traditional didactic methods were best. This might be because they lack confidence in teaching via investigative science and prefer to use non-questioning techniques, for example textbooks and worksheets. The importance of teacher confidence was mentioned by three PSLs in their comments. Many of the old science SATs questions relied upon the children knowing facts (Murphy et al., 2007), which can be learnt from texts, and although these SATs are no longer being used, current national sampling is requiring children to memorise knowledge (DfE, 2013). 35% of PSLs believed that teaching in a constructivist manner would be the best way to teach. Interestingly, only one of these PSLs believed that science would be best learnt in a traditional manner; the remaining 20 believed a process (n=3) or constructivist (n=17) approach would be the best way to learn science.

The second questionnaire asked the PSLs about their beliefs on how science is best learnt. Table 5.13 shows that just over half (53%) believe science is best learnt through constructivist approaches, that is, by letting children investigate their own ideas. It is notable though, that whilst just over half of the PSLs felt that children would *learn* best in a constructivist way, not as many felt that this way was the most effective way to *teach*. This could be due to practicalities: the restrictions imposed by classes of 30 or more children; the short amount of time for science (HMI, 2016); and the need to cover a large range of topics which would make it very difficult to allow children to explore numerous options individually. However, 40% of PSLs believed the process approach to be most successful for learning. This is possibly because the PSLs understand that children of primary age need some guidance in formulating their ideas. Whilst it is good to let children investigate their own ideas, for a number of reasons including time restraints, lack of resources and space, teachers may feel it best to steer children’s ideas in an appropriate direction. Few PSLs (7%) thought traditional methods enabled children to learn best.

The third questionnaire asked about PSLs’ understanding of what science is, and produced interesting replies. The individual questions in this questionnaire had shown that many PSLs (23%) still linked the word ‘science’ to the three school subjects of mathematics, science and technology (MST).
biology, chemistry and physics, stating that these were the main characteristics of scientific knowledge, a very traditional stance. Whilst the English National Curriculum for Primary Science suggests that developing an understanding of the nature of science is an aim, it is apparent from the PSLs' responses that many of them are not sure what is meant.

Another way of displaying the findings across the three questionnaires is provided in Figure 5.2, which is derived from Table 5.12 and shows all the combinations of the PSLs' beliefs over the three questionnaires.

**Figure 5.4 The relationship between primary science leaders' beliefs of teaching, learning and nature of science – Tsai’s nested epistemologies**

<table>
<thead>
<tr>
<th>Teaching Science</th>
<th>Learning Science</th>
<th>Nature of Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nested</td>
<td></td>
<td>37%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teaching Science</th>
<th>Learning Science</th>
<th>Nature of Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Related</td>
<td></td>
<td>25%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teaching Science</th>
<th>Learning Science</th>
<th>Nature of Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divergent</td>
<td>Learning Science</td>
<td>10%</td>
</tr>
</tbody>
</table>

Skamp and Preston (2015) stated that teachers teach and learn in ways which reflect their own attitudes and beliefs, especially if their beliefs are consistent across science teaching and learning. Bryan also showed that teachers transmit their beliefs through their teaching (2011). Amongst those PSLs in my study, who are the teachers charged with providing primary science guidance in their primary schools, only just over one-third (37%) had congruent beliefs about teaching, learning and the nature of science. Their feelings about the best way to teach and learn science were compatible with their own feelings about science itself. In Tsai’s terminology these matching beliefs are termed ‘nested epistemologies’ and he suggests this can influence the way science is taught. Just over half of my study participants (52%) showed ‘related’ beliefs, i.e. congruent responses for two of the three areas, and their comments showed how their views were linked to their own classroom situations. They typically believed that the best ways to teach and learn science were not available to them because of the lack of classroom space, time or their own knowledge. A further 10% of the participants’ beliefs were divergent, meaning that the overall responses for all three areas differed, possibly showing the teachers’ lack of knowledge and confidence in teaching science.

Tsai suggested that the more experienced the teacher, the more likely it was that their beliefs would be congruent across the three beliefs. This was borne out by studies of
secondary teachers in Australia (Boulton-Lewis, 2001). Bryan (2011), however, when looking at secondary science teachers suggested that if beliefs and practice were incongruent, then the reasons were generally very complex. She quoted Cheung and Ng (2000) who had studied science teachers in Hong Kong, and identified a hierarchy of issues surrounding curricula which involved cognitive processes, society-centred ideals and technological issues. Waters-Adams (2006) identified complex associations within sets of beliefs influencing English primary teachers’ practices. His study of four teachers showed the nested nature of espoused beliefs, particularly about NOS, and teaching and learning practices.

In my study group were some experienced, older primary teachers but very few had specific science backgrounds. Of the 120 who were attending the networking group only 8% had a science degree, with several of these being psychology. The advantage of having a science degree in primary teaching is partly that it proves a better grounding in scientific knowledge and partly that it enables the teacher to better understand the processes involved in the methodology of science, the skills required to undertake scientific investigation. If primary teachers’ beliefs about science are congruent and are coupled with a sound understanding of scientific skills, then it is more likely that their pupils will develop a better understanding and appreciation of science in their formative years.

Bruner (1996) found that teachers held beliefs about the way learners learnt and thus taught on these assumptions. Bryan (2011) suggests that teacher beliefs are so important that science teacher educators should focus on addressing systems of beliefs, rather than individual beliefs through intertwining science knowledge, the nature of science and science processes. She goes on to say that research shows that trainee teachers form their beliefs about science over a long period of time, starting when they are learners, then watching teachers and finally as participants in science education courses themselves. All these experiences gradually come together to shape individuals beliefs which are then very difficult to change (Hann et al., 1992).

The wide variation in the beliefs of the PSLs in my study is of concern because they are the teachers who are hopefully providing science support to their peers and their conceptions have a significant influence on pupils (Skamp & Preston, 2015). Many of the teachers given the PSL role in my study were in their first year of teaching. Informal conversations revealed that the role was allocated by the head teacher and frequently passed to another teacher every year as being the PSL was not the favourite or most desired role for teachers. This accounted for the relatively few PSLs who regularly attended the networking meetings. The teachers I talked with wanted help in the form of science CPD, but whilst the Surrey networking meetings had been set up to provide a forum for exchange of best practice in science and short CPD sessions, these sessions were mainly being used to provide requested help about the assessment of primary science for Ofsted purposes and updating on new policy requirements. The assessment process was dominating the work being carried out in the schools, and, it seemed to me, was considered to be more important than the science being taught. Currently (2017), specific science investigations being carried out by primary children have to be moderated by their own teachers across each year group and with work from pupils of the same age in other schools. Whilst moderation has long been carried out in secondary schools, it is relatively new to primary teachers and is sometimes a cause of concern. Some schools are devising science investigations to fit these year 6
moderation requirements rather than allowing children to develop their own investigations (Spielman, 2018).

It is important that children see science as an overarching subject linking their everyday lives with the environment and material world they live in. The Wellcome Trust Report (2015) suggests that good PSLs should develop children’s understanding of ‘big ideas’ (Harlen et al., 2015) and teach them scientific skills. PSLs need to be enabled to interpret their beliefs and feelings about teaching and learning. They need to be congruent in their own ideas about science. Whilst they are teaching what they feel they have to teach they are less likely to be able to convey the subject confidence which is so important when working with children. It seems we still are a long way off this goal, and need to ensure our PSLs and other teachers of science are happy, confident and knowledgeable about science and science pedagogy.
6 Data collection and findings from the intervention lessons

6.1 Introduction

My overall aim for using intervention lessons was to collect evidence from classroom conversations, observations and interviews to aid the investigation of my research, which is ‘the potential of earth science for the development of primary school science’. The specific objectives of the intervention lessons were:

- To show the potential of teaching earth science in primary schools
- To help develop primary teachers’ science self-efficacy
- To show the potential of earth science to increase science knowledge and understanding in primary children
- To show that earth science investigations can develop scientific skills in primary children.

The intervention lessons were devised to address all four of my research questions but specifically Research Questions 3 and 4:

- RQ3 Can earth science help primary teachers to be more confident about teaching science?
- RQ4 Can earth science enrich primary children’s science understanding?

The intervention was designed to encompass many pedagogical techniques currently recommended as good teaching practice (James & Pollard, 2011). The intervention was composed of six sections: an initial CPD training section with the teachers, analysed by audio-recorded discussion; the bubble diagram exercise carried out before and after the soil day, and analysed using SOLO (Biggs & Collis, 1982) and Bloom’s taxonomies (Anderson et al., 2001); the soil story theoretical input by teachers, analysed through my devised TALIA form (6.3.1 p112) and from audio-recording; observations of the practical investigations, reported and discussed from observation notes; audio-recording and analysis of discussion with children before and after the intervention.

Both schools A and B had the same CPD twilight and planning sessions delivered to them by me but the pilot was only trialled in school A. I anticipated that the data I collected would show whether a well-planned and delivered earth science topic could increase teacher confidence, enrich the primary children’s understanding and motivation and be an effective lesson providing suitable assessment information.

I decided to ask a school with which I was familiar if they would work with me on an earth science topic of their choice. As I had worked with my local village school (school A) previously by organising science days, I decided to ask if they would be happy to collaborate with me on work that I could monitor for my PhD thesis. I therefore discussed my ideas with the headmistress and her year 3 teacher, who were happy to co-operate in a pilot in 2015, and then for the main study in 2016. A second local primary school (school B) was approached in autumn 2015 to see if they would like to participate in 2016, and they enthusiastically agreed.

All names have been changed to prevent identification.

6.1.1 Background to School A: its demography and previous Ofsted report

I needed to work with teachers and pupils in order to collect my data. I live in a village on the edge of a commuting town in Surrey, with most housing privately owned in this
school’s catchment area. Here, 74% of the population is economically active with 13% retired people, some of whom are grandparents who look after children whilst their parents work (Census 2011). In this ward the population is 83% white British with about 1% each of a range of ethnic minorities. Many parents work in London and in the local universities.

School A is a Church of England Junior School situated in the village. It has a reputation as a caring school providing a positive learning experience and places are much sought after by parents so it was a surprise to many when the school was put into special measures in 2011. Science was one of the identified problem areas and I worked with the school in 2012 on a whole day whole school earth science investigation (Balmer, 2015), intended to enthuse children and staff about science, and get everyone to think scientifically. The day was a success, as judged by the evaluation and feedback received from staff and children, so when I returned to ask if the school would be willing to help me by participating in some science investigations the year 3 teachers were happy to be involved. (The school has come out of special measures and is now deemed satisfactory by Ofsted although continuing to aim for a higher standard.)

In 2015/16 the school had about 350 children in a three form entry, with an interesting blend of nationalities. Overall, 21% of the pupils use English as a foreign language. In this year 3 group, 24% use English as a foreign language and have a wide range of cultural backgrounds including those from the Far East, Indian subcontinent, Middle East and mainland Europe. Interestingly, no Caribbean or African children attend this school, despite it being Church of England Maintained.

6.1.2 The year 3 teachers
The three teachers working with year 3 had very different backgrounds. Ashleigh came into teaching with a B.Ed. background with specialisms in Art and RE. She had been teaching for 23 years, initially in secondary education, followed by some time in nursery classes, but for the past ten years she had had experience in junior schools. She has held managerial roles in the school for the past 15 years, and enjoys teaching geography, history and science, in fact, any subjects that lend themselves to cross-curricular learning, and is passionate about promoting and supporting independent learning. I had worked with Ashleigh on previous science projects in her current school and knew she was always willing to learn about areas of the science curriculum that were unfamiliar to her. We discussed my earth science project. Following this she was more than happy to be involved, especially when it involved soil, which she did not feel confident to teach. We agreed on a programme to run across year 3 that would enable both teachers and pupils to benefit from outside support. We both hoped this would be of value to the children’s learning as well as incorporating new practical skills, and would provide support for the teachers in a previously untaught topic.

Joachim had been teaching for ten years. His route to teaching was through a degree in American Studies followed by ten years in marketing, then training through the Graduate Training Programme at the school in which he now teaches. He had taught in KS2: years 3, 4 and 5, and had a Sports Co-ordinator role. Although Joachim had no formal science background, he was always enthusiastic and willing to take on board new ideas to improve his science subject and pedagogical knowledge. Joachim

15 Special measures are imposed by school inspectors when an inspection reveals the school is not achieving the required overall standards
participated in the pilot in 2015 and was very keen for me to observe his teaching in 2016.

The third teacher in the pilot scheme, Helen, had a B.Ed. background, and again had only limited science experience, although her father was an engineer with an interest in geology. Helen worked with this year group on the pilot programme but moved year groups in September 2015.

The teacher replacing Helen after the pilot session, Elmer, was the only teacher in the school with a science background, having a Bachelor’s degree in zoology. She had trained as a teacher through a primary PGCE course and had been teaching in primary schools for sixteen years. School A was her second school and she was working on a job share, two days each week. She had taught at all levels in KS2, really preferring year 4 but said she was very much enjoying year 3. Despite her science background, she had never taught soil, or indeed much earth science before. This was her first year teaching year 3 and she was a little dubious about the soil lessons until we met, when she recognised me from a project I had organised in her previous school. From then on she was much happier about these lessons.

6.2 The pilot intervention lessons

6.2.1 Initial discussion about intervention lessons
Parts of my methodology draws on a grounded theory approach (Gibson and Brown, 2009), in particular the analysis of the findings from intervention lessons. Intervention lessons can be used as a way of introducing a particular topic that is often misunderstood by the learners (Jimerson et al., 2007). Initial discussions with the year 3 programme leader in September 2014 had identified that soils, she suggested, were a “boring” subject area where the teachers felt less confident. The pupils needed to be able to explore ideas and ask questions in order to investigate, but this really required the teachers to have confidence in their own knowledge and understanding of the topic. The intervention lessons were planned to be in two stages, over two years, and would be with year 3. In the first year (pilot), I would teach the teachers, help in the lessons and have some time for observation and recording data. In the second year, the teachers would be wholly responsible for all the activities and I could observe. In the end, I observed and audio-recorded the soil story lesson in March 2018.

An outline pilot programme was discussed with the three teachers about ten weeks prior to the pilot intervention lessons. The three original teachers I worked with stated that although none had a science background, they were interested in science generally. However, they all found most parts of the science curriculum difficult to teach (cf. Harlen and Holroyd, 1995) as they did not really understand the physics or chemistry involved; the only areas they felt confident teaching were biology-related topics, a point raised by Sharp and Hopkin (2007). Soil was not identified as being related to biology! I suggested soil or rocks as possible subjects. They agreed on the topic of soil and all of them stated that soils were “boring”, mainly because they did not understand how soils formed and the nature of their importance in the ecological cycle. They would normally try to avoid teaching them. Rocks, they said, could be dealt with from textbooks, although they agreed this was difficult without samples. In previous years, the one long-standing teacher had never taught the topic ‘soil’, and none knew how it could be taught to stimulate children. Consequently, all that had been done was
that a worksheet had been produced which the children completed and stuck in their folders as evidence that the topic had been covered.

6.2.2 Preparation for the pilot intervention lessons and pedagogical input
In this school, recording and assessment had high priority because of the imposition of special measures so it was decided to ensure that both recording and assessment were part of the intervention lessons. Hence, both formative and summative assessment strategies would be included in the lesson planning (Serret et al., 2018). Normally, none of the teachers assessed the children’s background knowledge before starting a new science topic, so we discussed how this could be done. The teachers decided to use the ‘bubble diagram’ (Figure 6.1) method of assessing the children’s knowledge and understanding about soil before and after the lessons, in order to see if the lessons were effective. Using this method, each child completes a bubble diagram by writing all they know about the subject, in this case soil, before they have any intervention lessons, and then completes their diagram after the intervention lessons by writing in a different coloured pen. By looking at the children’s before and after statements, the teacher can assess whether any knowledge and or understanding has been gained by the child, and thus the effectiveness of the lesson.

Figure 6.1 A bubble diagram for soil

As none of the teachers had any content knowledge or understanding of soil, I taught them the basics about soil during two 1½ hour long twilight CPD sessions and showed them ways they could teach it in a stimulating manner. A third twilight was used for planning, organising and discussing how to teach soil to this year group. These three twilight sessions in 2015 included: factual input from me about soil to dispel misconceptions and identify the scientific vocabulary we would use; ways of introducing ‘soil’ to the children through a concept cartoon (Figure 6.2) and an interactive story (Appendix 3); planning a practical session including sieving and permeability exercises; and follow-up links to types of soil to use when growing plants.

We discussed ways of introducing new topics through the use of concept cartoons, a frequently used pedagogical technique (Keogh & Naylor, 1991), and I provided a suitable soil concept cartoon which I had drawn. The purpose of a concept cartoon is to offer children some ideas for discussion about the identified topic. The year 3 teachers

16 CPD - continuing professional development
in this school used the cartoon to get the children to identify their own thoughts about soil and discuss them with each other and with the class teacher. The cartoon was used after the children had written their ideas on the bubble diagram.

**Figure 6.2 A concept cartoon about soil (Balmer 2014)**

![Concept Cartoon](image)

The teachers and I discussed practical activities that would allow the children some ownership of the soil investigations that they would undertake and which would incorporate a number of science skills. In these twilight sessions, the teachers tried out the investigations we had planned and decided on how much information to give the children in order for the children to be able to work successfully. I spent a short meeting with the year 3 leader planning timing, resources and follow-up materials, including connections with numeracy, literacy and creative activities. Simple resources were collected and it was agreed that three different soils would be brought in by teachers, plus some clay from a local building site. We also talked about my role in the classroom, which would be to watch the children’s involvement and interaction with each other and the teacher, and help the teacher when necessary. It was hoped to have two classroom assistants with each teacher. The proposal was that the teachers would work for a morning with their classes, introducing soil, and then the children would spend the afternoon working on three investigations.

The pilot lessons were held just before half term in spring 2015. The time spent teaching these lessons amounted to most of the ‘science’ time scheduled for that half term. I interviewed the teachers about their feelings before and after the lessons, and made a few written observations during the lessons which might be useful when we repeated them.

The pilot lessons followed the proposed pattern identified in the twilight sessions. The soil story was followed by a circus of practical investigations, with six children working in each group, carrying out three exercises. The children would investigate the characteristics of three different soils through sieving, determine the permeability and pH of each of the three soils, and solve a jigsaw puzzle portraying a soil profile. I would audio-record discussions during the practical lessons and take notes as the children...
worked, and the teachers would assess their pupils’ knowledge for me using bubble diagrams.

6.2.3 Review of the pilot intervention lessons
The pilot lessons in spring 2015 were enjoyed by teachers and children alike; the staff stated that they felt quite comfortable with the subject and, with my help, they felt the practical investigations had been very successful. The children had been interested, excited and on task for most of the practical time. Follow-up lessons to ascertain understanding had shown an increase in the children’s understanding and knowledge, and plenty of evidence for assessment had been accrued. We now knew which areas needed some revising, but generally the pattern of the programme had worked well. However, the teachers had needed more support in the lessons that had been predicted, and I was not able to spend my time observing and recording what the children were doing. Furthermore, the attempt to audio-record children discussing their work during the practical investigations was not successful, due to too much background noise. It was agreed with the teachers that I could observe the sessions in the following year 2016 to gather my data.

6.3 The intervention lessons 2016

6.3.1 Organisation of lessons
I met with Ashleigh in January 2016 in order to arrange my observation of the soil lessons. We reviewed the pilot day from the previous year and decided that the only real issue had been the lack of time allowed for the practical investigations (Ofsted, 2013). The school had decided that the science lesson time made available would be almost double the normal teaching time for science for the term. The children would complete their soil bubble diagrams on the previous day, and then discuss the concept cartoon. A whole day would be given to the interactive soil story and investigations and the maths hour on the following day would be used to complete bar graphs so that follow-up work could take place immediately. This extra time given was in response to one of the points highlighted in the Maintaining Curiosity report (Ofsted, 2013), that frequently schools did not plan for enough time after actual investigation work to discuss concepts and enable a deeper understanding of work done. Literacy time was also available for writing up the children’s WALT17 diaries, to ensure everyone had time to reflect on their work (Holman, 2017).

One of the year 3 teachers had now moved to another class, so there were only two classes (A and O) which would be observed, and it was suggested to me that the new teacher (Elmer) would require help. I outlined the soil story to her prior to the lesson, but decided it would not be appropriate to observe her lesson that year.

A few days before the proposed intervention lessons, a small focus group of six children participated in a preliminary discussion of the topic with me. This discussion was audio-recorded and later compared with another audio-recording taken two weeks after the intervention lessons. The year 3 teachers allocated the children to give me a range of abilities. The audio-recorded interviews with the children took place outside the classroom with only the children and me present. I talked with them, two from each class, and we discussed what was meant by the word ‘science’ and whether the children thought they ‘did’ science at home. We then deliberated over items I had

17 We All Learnt Today diaries completed by the children
brought with me (four small bags containing leaf litter, humus, soil and small gravel – all components of soil). The audio-tape was transcribed and the results of the conversation are presented later in this chapter. Two weeks after the Soil Science Day, I returned to audio-record a discussion about soil with the group of children I had originally chatted with. This discussion too is analysed in the results.

The initial knowledge of soil of the three teachers was noted through discussion prior to the intervention lessons, and interviews with the teachers were audio-recorded after the lessons as well as responses from any teaching assistants who had helped with the teachers. The questions asked of each of the teachers and teaching assistants in the interviews were the same, and I transcribed the interviews for later discussion. The teachers assessed their pupils’ knowledge for me from the bubble diagrams and gave me access to one class’ group of diagrams. I was advised that the two classes A and O were very different in aptitude; class O had a number of children for whom English was not their first language and so were sometimes slower to comprehend ideas than children in class A. There therefore needed to be a slower approach with possibly more time allowed for questions in class O to enable the children to understand the concepts being taught.

In order to record my observations during the lesson, I devised a Teaching and Learning in Action (TALIA) form which enabled me to count the number of times certain actions occurred during five minute periods whilst I was observing. I chose a list of actions to be recorded from previous classroom observations I had undertaken during my Master’s degree and teacher appraisal programmes from the early 1990s (Gunter, 2002). A year later I audio-taped the initial story input of one class to observe some of the pedagogical strategies being used by the teacher.

Immediately before the lessons, I discussed the topic again with the teachers to ensure they felt confident enough about the topic to answer any questions posed by the children. The teachers had agreed to incorporate science into their maths lessons the following day to draw bar graphs from the data collected and into their literacy lesson the next morning to write up the soil story and other records of the day, and to use creative activities time to draw litter bugs. The data gathered by the children were to be used by them later to plan where they could successfully grow specific crops in the school garden.

6.3.2 The soil science intervention lessons
On the day before Soil Science Day, all three teachers spent their literacy hour discussing ‘soil’ to ascertain any alternative concepts. The children wrote down what they knew about soil on bubble diagrams in pencil, to be completed after the lessons with more comments in pen (see compilation of comments in Appendix 5). When the teachers later read these ‘before and after’ comments, they were able to assess what the children had learned from the lessons. I have analysed these comments in 6.4.1 pp113-4 to ascertain the effectiveness of the intervention, by using SOLO taxonomy techniques, as described in the methodology 3.2.3 p75-76, and Bloom’s revised taxonomy also described in the same methodology Section. The reasoning behind my devised TALIA form for recording the soil story telling is given above. After the children had written their initial comments, the soil concept cartoon was used as a starting point for discussion during this lesson.
I observed the start of two science lessons, when Joachim and Ashleigh used the interactive Soil Story to explain the formation of soil. I recorded my observations on my devised TALIA form and audio-recorded one class session. The remainder of the day was spent on practical investigations. I managed to observe, discuss parts of the investigations with the children and make notes of some permeability and sieving exercises before the teaching assistants left and extra help was needed by the teachers, which I provided. The results are discussed later in this chapter.

Both teachers decided to have a specific focus for these science lessons. Ashleigh focussed on skills and Joachim had decided to use the investigations to embed the idea of ‘fair testing’. Holman (2017) has stated that teachers frequently used the ‘fair testing’ idea as a skill rather than incorporating it within the investigation, so I was surprised that this was the only outcome Joachim required. I was interested in all science skills that were being developed by the children.

6.4 Results from the intervention lessons in School A

6.4.1 Assessing the lessons through the bubble diagrams
In keeping with ideas about constructivism (Hollins & Whitby, 1998) and assessment needs, the three year 3 class teachers asked all the children to complete a bubble diagram about soil, on the day before the soil science lessons. Approximately five minutes of time was given for this exercise, a period just long enough for the children to write down their immediate thoughts. The children wrote their comments in pencil onto their own diagrams. The purpose of this exercise was to enable the teachers to understand the children’s prior ideas about soil and to identify any misconception so these could be discussed during the lesson. After the lesson the children again wrote down their understanding about soil formation and these statements were used to assess the effectiveness of the learning that took place during the day. Firstly, changes in the assessment levels of class A using SOLO taxonomy from the bubble diagrams were identified. Thirty four bubble diagrams were assessed, as shown in Table 6.1. I initially analysed these before and after statements, assigning them to SOLO taxonomy levels as seen in Table 6.1. (All the statements analysed can be seen in Figure 6.2, p 115.)

<table>
<thead>
<tr>
<th>Initial SOLO assessment level</th>
<th>Final SOLO assessment level</th>
<th>Number of children</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

From the initial assessment where 15 of the 34 children were at or below surface knowledge level as determined by the SOLO taxonomy (levels 1 and 2), all the class exhibited connected ideas after the intervention and 15 (43%) of the children had
reached conceptual level. This suggests that the soil formation lesson had achieved its desired outcome to enable the children to construct knowledge by taking related ideas and extending them. An example of a change (from SOLO 1 to level 4) a child’s conception of soil from their bubble diagram, is seen in the two following phrases: “soil is made of compost (SOLO 1) and “I learnt there are different soils and different soils let water through at different rates, and I know how soil is made” (explained verbally) SOLO level 4.

I compared the bubble diagram statements before and after the lessons from the same class by looking at all the statements on the bubble diagrams using SOLO taxonomy and Bloom’s revised taxonomy ideas, as shown in Table 6.2. This time I used all the statements made by the children rather than assigning a level to each child’s diagram, but again the progression of the children’s learning is apparent, as visible in Table 6.2.

Table 6.2 Statements from the soil bubble diagrams before intervention

<table>
<thead>
<tr>
<th>Statement about soil made before intervention lesson</th>
<th>SOLO Taxonomy level</th>
<th>Bloom Taxonomy level revised 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without soil, some people wouldn’t survive because with soil we can grow food to help to help the environment</td>
<td>5</td>
<td>apply-analyse</td>
</tr>
<tr>
<td>Soil is in the garden (x2)</td>
<td>1 (2 statements)</td>
<td>fact (2 statements)</td>
</tr>
<tr>
<td>Soil is compost left to rot (x2)</td>
<td>4 (2 statements)</td>
<td>understand (2 statements)</td>
</tr>
<tr>
<td>Soil is earth (x2), mud (x2), muck (x2), ground (x3), mud (x4)</td>
<td>2 (13 statements)</td>
<td>factual knowledge (13 statements)</td>
</tr>
<tr>
<td>Soil is wet mud – dry mud and water = soil</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>Soil is a very dirty thing to use</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>Soil makes plants grow</td>
<td>3</td>
<td>understand</td>
</tr>
<tr>
<td>Soil is rough and has minibeasts (as given) in it. It is dark grey/black/brown (x2) colour</td>
<td>3 (2 statements)</td>
<td>factual knowledge (2 statements)</td>
</tr>
<tr>
<td>Soil is underground, under grass</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>Soil is under our feet</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Soil is dirt and you grow things in it (x6)</td>
<td>3 (6 statements)</td>
<td>factual knowledge (6 statements)</td>
</tr>
<tr>
<td>You use soil to grow flowers, bushes, trees, shrubs. Put a plant or flower in soil to make it grow</td>
<td>4</td>
<td>understand</td>
</tr>
<tr>
<td>Soil helps plants grow but needs water</td>
<td>4</td>
<td>apply</td>
</tr>
<tr>
<td>Soil grows on the earth</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Soil makes flowers</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Soil can be used for lots of things like trees</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Soil is for playing games on</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Soil is curious</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Soil is something you put in a plant</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>You can dig it up</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Worms make compost into soil</td>
<td>4</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>Soil is plastic</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Soil is garden waste</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>Soil is a substance that can be used for many things like planting or making dens or moulding things</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>Soil is a comfy place to live</td>
<td>1</td>
<td>fact</td>
</tr>
</tbody>
</table>
Using SOLO taxonomy, ten statements were at level 1 with very little idea about soil other than where it can be found; these equate to the comments identified as ‘fact’ in the Bloom’s taxonomy column, and don’t really reach a level or qualify as ‘knowledge’ in Bloom’s taxonomy. There were seven children who knew a little more about soil and identified one relevant idea under the SOLO taxonomy. Eleven statements had ‘factual’ knowledge as identified by Bloom, the term ‘factual knowledge’ being one of Bloom’s knowledge dimensions. Four statements were at SOLO level 3 with several relevant ideas; Bloom does not differentiate here between having one or more than one idea. Four statements related an idea or integrated ideas (SOLO 4) and one has further extended the idea (SOLO 5). These comments are seen as reaching understanding, then moving to applying and further analysing by Bloom.

When the statements written down after the intervention were analysed, definite changes could be seen in the children’s knowledge and understanding, Table 6.3 shows the new set of statements and how they were classified by SOLO and Bloom’s taxonomies, and Table 6.4 compares the results of both taxonomies before and after the intervention, showing percentage changes which can be compared more easily.

**Table 6.3 Statements from the soil bubble diagrams after the intervention**

<table>
<thead>
<tr>
<th>Statement about soil made after intervention lesson</th>
<th>SOLO Taxonomy level</th>
<th>Bloom Taxonomy level revised 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil is made out of weathered rock, humus, leaf litter, roots and dead nettles</td>
<td>3</td>
<td>understand</td>
</tr>
<tr>
<td>Soil is made from litter, humus and weathered rock (x11)</td>
<td>3 (11 statements)</td>
<td>understand (11 statements)</td>
</tr>
<tr>
<td>Soil is made out of humus (x2)</td>
<td>2 (2 statements)</td>
<td>factual knowledge (2 statements)</td>
</tr>
<tr>
<td>Different soils let water through faster</td>
<td>4</td>
<td>apply</td>
</tr>
<tr>
<td>Different soils let different amounts of water through</td>
<td>5</td>
<td>analyse</td>
</tr>
<tr>
<td>Soil can let water through</td>
<td>3</td>
<td>understand</td>
</tr>
<tr>
<td>Soil is brown or black</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>You find soil under grass</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>Soil is better at growing than stones</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>There are different types of soil, soft, sandy (x5)</td>
<td>3 (5 statements)</td>
<td>factual knowledge (5)</td>
</tr>
<tr>
<td>Soil has sand in it</td>
<td>2</td>
<td>factual knowledge</td>
</tr>
<tr>
<td>Soil is very useful</td>
<td>1</td>
<td>fact</td>
</tr>
<tr>
<td>There are three/four layers to soil and the bottom one is bed rock</td>
<td>4</td>
<td>apply</td>
</tr>
<tr>
<td>I learnt how soil forms (x4) (and explained verbally)</td>
<td>4-5 (4 statements)</td>
<td>apply (4 statements)</td>
</tr>
</tbody>
</table>
### Table 6.4 Comparing changes before and after intervention using two taxonomies

<table>
<thead>
<tr>
<th>Levels before and after intervention</th>
<th>SOLO before</th>
<th>%</th>
<th>SOLO after</th>
<th>%</th>
<th>Bloom before</th>
<th>%</th>
<th>Bloom after</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fact</td>
<td>11</td>
<td>24</td>
<td>2</td>
<td>6</td>
<td>11</td>
<td>24</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>SOLO 1</td>
<td>11</td>
<td>24</td>
<td>2</td>
<td>6</td>
<td>11</td>
<td>24</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>SOLO 2 / Bloom Factual Knowledge</td>
<td>19</td>
<td>42</td>
<td>5</td>
<td>16</td>
<td>28</td>
<td>62</td>
<td>10</td>
<td>31</td>
</tr>
<tr>
<td>SOLO 3 / Bloom Understanding</td>
<td>9</td>
<td>20</td>
<td>18</td>
<td>56</td>
<td>4</td>
<td>9</td>
<td>13</td>
<td>41</td>
</tr>
<tr>
<td>SOLO 4 / Bloom Apply</td>
<td>5</td>
<td>11</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>SOLO 5 / Bloom Analyse</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>16</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

### 6.4.2 Assessing the lessons through the WALT diaries

The children wrote up their WALT diaries the day after the intervention and were given more time to write down statements. However, it is not so easy to assess these statements using either of the previously used taxonomies, so they are compared with the before and immediately after lesson statements from Table 6.4 using a classification that I devised which would enable me to compare changes. Twenty six WALT diaries were analysed. Two children were not able to write diaries but told the teacher about the soil story in accurate detail, clearly having retained the knowledge about soil formation.

A comparison of the statements made by the children before and after the intervention using information from the bubble diagrams shows that whichever taxonomy is used a movement up the scale can be seen, i.e. an improvement. In both cases 24% of the children’ statements were at the lowest level before the intervention but only 6% after the intervention. Bloom’s Taxonomy (Anderson & Krathwold, 2001) now shows more statements in his category of factual knowledge, whilst the SOLO taxonomy identifies more movement upwards from level 1 to level 3; in other words the children now have more than one relevant idea about soil. SOLO level 3 indicates that the children have a number of relevant ideas, whilst Bloom suggests that there is ‘understanding’. SOLO level 4 suggests integration of ideas, which Bloom calls ‘apply’ in his hierarchy. The analysis using Bloom’s taxonomy shows that more children are able to apply ideas than before about soil development. SOLO level 5 shows more children are developing their concepts about soil. Bloom’s taxonomy suggests that one child is actually analysing these concepts.

The exercise clearly shows improvement after the intervention, suggesting effective teaching through using this earth science lesson and providing a method of assessment. When these statements are tabled the amount of learning that has been embedded overnight can be ascertained (Table 6.5).
Table 6.5 Class A bubble diagram statements, before and after the intervention lessons, and WALT statement

<table>
<thead>
<tr>
<th>Statements made by class A, n = 31</th>
<th>Before intervention</th>
<th>After intervention</th>
<th>We All Learnt Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of statements on bubble diagrams or WALT sheet</td>
<td>45</td>
<td>32</td>
<td>143</td>
</tr>
<tr>
<td>Accurate knowledge</td>
<td>8</td>
<td>13</td>
<td>44</td>
</tr>
<tr>
<td>Descriptive</td>
<td>32</td>
<td>3</td>
<td>36</td>
</tr>
<tr>
<td>Valid understanding / explanatory</td>
<td>3</td>
<td>16</td>
<td>35</td>
</tr>
<tr>
<td>Alternative conception</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Data</td>
<td>-</td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td>New Vocabulary</td>
<td>-</td>
<td>-</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 6.5 shows that these 26 children have retained a certain amount of information and have more knowledge and understanding about soil than before the intervention. The writing shows that the children had remembered specific knowledge points, particularly the definition of permeability (many of them quoted my words “permeability is a horrible word which means…”). Their knowledge statements about soil were now meaningful, with good descriptions suggesting what soil was made from. The descriptive statements were also very specific about soil content, how humus was formed, and the fact that the water collected from the permeability investigation showed different colours (pH tests). There were 35 explanatory/understanding statements explaining either why sieves had different sized holes and why that was important or why the water went through one soil more quickly than through another. A number of children wrote down the data they had recorded and tied these data in with the different layers of the soil profile. Six children mentioned the new vocabulary they had learnt, and placed it in context. Altogether, the children had achieved a great deal of learning, showing how effective the overall intervention had been.

Unfortunately, it was not possible to return to the school several weeks later to see if this knowledge and understanding had been retained by all the pupils because of the school holidays, but Ashleigh felt that her class, from whom the bubble data had been collected, had absorbed considerable understanding about soil from work that was written up later. Furthermore, the focus group of six children seemed to verify her view as can be shown later (pp141-142).

6.4.2 Observation and discussion of the interactive story sessions in Classes A and O

For two teachers, Ashleigh and Joachim, and one teaching assistant, Tasha, this was the second time they had taught the soil programme. The teachers had identified their specific objectives for the lesson, namely: to learn about soil; to enable better understanding of soil characteristics and soil forming processes; and, using the investigation, to instil the idea of fair testing. I was keen to see if an earth science lesson based around soil, where the teachers had been given subject matter knowledge (Kind, 2012) by me as well some specific CPD and pedagogic training (albeit brief) could help the teachers teach the topic more confidently (Berry, 2013). Moreover, I hoped that the children would be intrigued with such a basic yet vital, everyday substance, and would learn something that might stay with them as they grew older. All three classes had seen the soil concept cartoon (Figure 6.2) on the previous day, and this viewing had caused plenty of discussion and comment from the children. Ashleigh had additionally given her class some key words to take home and talk about for homework.
Whilst observing the interactive story sessions, I wanted to be as unobtrusive as possible to both the teacher and the children, although they were quite used to seeing me around the school. I sat at the back of each class so I could view the teacher and the children. In order to facilitate my observing both interactive story sessions, the start of class O was delayed, with class A commencing their story at 0850, and class O at 0930.

Prepared photographs and samples of soil, leaf litter and gravel were available on the table for each group of children which helped illustrate points during the story that the teachers were telling about soil formation, and the children investigated these whilst waiting for the lesson to start. Initially, I noted an atmosphere of excited anticipation within both the classes, as everyone was settling into their science groups ready to start the day. Hattie (2009) has pointed out that a good classroom climate is a powerful contribution to learning. The children sat in small groups of five or six, each with their science buddy. All the children were expecting something different from their normal routine as they had been told this would be a ‘science day’. Using my TALIA form described previously, I noted the number of times when each salient point occurred within five minute blocks, making extra notes of items not on my form for later use (see Table 6.6, p120). The whole lesson lasted 35 minutes, with the teacher input of the story taking about twenty minutes in total (not noted on the TALIA form).

Both teachers began by summarising their lesson discussing the soil concept cartoon the children had viewed the previous afternoon, and answered questions arising from the cartoon that the children had thought of overnight. The ‘learning focus’ for the lesson was identified (i.e. the objectives). Both teachers used the whiteboard to draw each part of the soil story in short stages, thus giving the children time to digest the information, ask questions and discuss points. Kyriacou (2007) states that experienced teachers divide a lesson into small periods of time, allowing children to grasp salient points, and both teachers did exactly this, reinforcing and repeating as the lesson progressed. One child in class A was able to identify the weathering processes involved in the breakdown of surface rocks, having discussed this with his mother – a secondary geography teacher – the previous evening. As the story unfolded, the children drew their own descriptive pictures and wrote down notable words, using the new vocabulary. The teachers felt confident enough to make the lesson very interactive by enabling much discussion in both classes as to the role of bacteria in the breakdown of litter to form humus. Another point much talked about was the role of worms, with some children recalling a wormery they had made in their infant classes. They remembered the worms mixing up the different layers in the wormery and were able to relate this to soil formation. The TALIA form is seen in Table 6.6.

---

18 Each child has a ‘science buddy’ – a fellow pupil with whom they can discuss their work. Sometimes a more able child is paired with a less able one, but not usually. The idea is to promote thinking, discussion and listening.
Both teachers clearly outlined the topic before starting on the soil story, then continually reinforced the points they were making by asking questions, answering questions and listening to views offered by the children, in line with Chin (2007) and Alexander's (2015) suggestions. My TALIA observations show how similarly, yet differently, the teachers worked. Interestingly, the number of points (eighteen introduction points; five/six points initiating ideas and six/five points assessing understanding) noted in all sections during the first five minutes are almost exactly the same in both classes with the teachers striving to ensure that the objectives were clearly stated, so there were no misunderstandings. In both classes, pupils participated fully, asking questions and answering those put by the teachers (Rowe et al., 2014). With the teaching assistants’ support, all children kept up with their work adequately, although some would need to complete it later, using images and minimal text available if necessary on the

![Table 6.6 Cumulative TALIA form to compare class A and class O lesson observations](image)

<table>
<thead>
<tr>
<th>Time into lesson (minutes)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class</strong></td>
<td>A</td>
<td>O</td>
<td>A</td>
<td>O</td>
<td>A</td>
<td>O</td>
<td>A</td>
<td>O</td>
</tr>
<tr>
<td><strong>TEACHER: INTRODUCTION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear outline of objective(s)</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enthusiastic/motivating attitude</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Asking for pupils’ ideas</td>
<td>4</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Noting pupils’ ideas</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Discussing pupils’ ideas</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Answering initial questions</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Totals)</td>
<td>18</td>
<td>18</td>
<td>4</td>
<td>10</td>
<td>14</td>
<td>9</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td><strong>INITIATING IDEAS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear topic presentation/reinforcing</td>
<td>3</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Using props</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Demonstrating</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(Totals)</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>-</td>
<td>8</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td><strong>FOSTERING KNOWLEDGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asking open questions</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Listening to comments</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Noting down comments</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Answering questions</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>(Totals)</td>
<td>9</td>
<td>8</td>
<td>5</td>
<td>12</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td><strong>ASSESSING UNDERSTANDING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Returning to objective(s)</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Provoking discussion</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Reinforcing ideas</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>3</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Ensuring understanding</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>1+</td>
</tr>
<tr>
<td>(Totals)</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>8</td>
<td>7</td>
<td>3+</td>
</tr>
<tr>
<td><strong>CLASSROOM MANAGEMENT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving around classroom</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>(Totals)</td>
<td>4+</td>
<td>3+</td>
<td>3+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><strong>ACTIVITIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thinking by asking questions</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Answering questions</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Reading</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>+</td>
<td>3</td>
<td>+</td>
<td>2+</td>
<td>+</td>
</tr>
<tr>
<td>Writing</td>
<td>+</td>
<td>1</td>
<td>+</td>
<td>3</td>
<td>+</td>
<td>3</td>
<td>+</td>
<td>2+</td>
</tr>
<tr>
<td>Creative/imaginative ideas</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Discussing in groups</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Whole class discussing</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Analyzing</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Prior understanding</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(Totals)</td>
<td>7+</td>
<td>7</td>
<td>6+</td>
<td>17</td>
<td>4+</td>
<td>14</td>
<td>4+</td>
<td>8+</td>
</tr>
</tbody>
</table>

119
whiteboard. Repetition of the important processes turned the story into a ‘game’, so by the end of the story every child knew the different layers of soil and their correct order. I had been insistent that the teachers reinforced ideas about soil as they went through the story. The pedagogical practices the teachers used during this lesson might have been typical of their normal teaching, or could have been initiated by my working with them during the training sessions. The content of the story engaged the children, particularly when they were responding to the recapitulation of the new vocabulary, as they were allowed to shout out the words. The range of pedagogical strategies used in the intervention lesson by the teachers are shown in Table 6.7.

Table 6.7 Pedagogical strategies used in the intervention lesson

<table>
<thead>
<tr>
<th>PEDAGOGICAL STRATEGY</th>
<th>IMPLEMENTATION</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seating arrangements</td>
<td>Children seated in groups of six, next to a science buddy/friend (response</td>
<td>Ofsted (2016)</td>
</tr>
<tr>
<td></td>
<td>partner) – not of differentiated ability</td>
<td></td>
</tr>
<tr>
<td>Class atmosphere</td>
<td>Anticipation, excitement, eager to find out</td>
<td>Ofsted (2016), Seeley &amp; Allen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2018)</td>
</tr>
<tr>
<td>Wall displays</td>
<td>Plenty of Information plus science vocabulary</td>
<td>Rowe et al., (2014)</td>
</tr>
<tr>
<td>Stating lesson objectives</td>
<td>Teacher identified objectives of lesson – to learn about soil formation and</td>
<td>Marzano &amp; Hattie (2015),</td>
</tr>
<tr>
<td></td>
<td>characteristics</td>
<td>Beasley (2014)</td>
</tr>
<tr>
<td>Concept cartoon</td>
<td>Engaging, inviting discussion, asking questions</td>
<td>Driver (1994), Smith (2016),</td>
</tr>
<tr>
<td>Instructions</td>
<td>Children told to use pencil initially and shown how to fold paper into squares</td>
<td>Devine, Phie &amp; McGillicuddy</td>
</tr>
<tr>
<td>Resources distributed</td>
<td>Envelope of pictures, texts, worms placed on each table within reach of all</td>
<td>Ofsted (2016)</td>
</tr>
<tr>
<td></td>
<td>children</td>
<td></td>
</tr>
<tr>
<td>Starting soil story</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reiterating objectives</td>
<td>Teacher began by explaining story was about soil formation</td>
<td>Harlen &amp; Qualter (2016)</td>
</tr>
<tr>
<td>Delivery</td>
<td>Interaction with pupils, discussion asking questions</td>
<td>Wilson &amp; Holligan (2012)</td>
</tr>
<tr>
<td>Giving facts through drawing and</td>
<td>Discussion, answering questions, asking questions, critical thinking</td>
<td>Wyse &amp; Rogers (2016)</td>
</tr>
<tr>
<td>talking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing</td>
<td>Making notes in own words (comprehension)</td>
<td>Bloom (2001)</td>
</tr>
<tr>
<td>Differentiation</td>
<td>Written phrases ready for use by less able writers</td>
<td>Ofsted (2016)</td>
</tr>
<tr>
<td>Well-paced session</td>
<td>Time allowed for all children to complete task</td>
<td>Rowe et al., (2014), Ofsted</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2016)</td>
</tr>
<tr>
<td>Practical permeability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concept cartoon</td>
<td>Engagement, critical thinking, discussion</td>
<td>Fisher (2013)</td>
</tr>
<tr>
<td>Solving problems</td>
<td>Critical thinking</td>
<td>Nottingham (2016)</td>
</tr>
<tr>
<td>Scaffolding</td>
<td>Discussion with TA</td>
<td>James &amp; Pollard (2011)</td>
</tr>
<tr>
<td>Testing</td>
<td>All working scientifically skills plus organising /teamwork</td>
<td>Fibonacci project (2014)</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Discussion, critical thinking</td>
<td>Harlen &amp; Qualter (2016), Smith</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2016), Abrahams &amp; Reiss (2012)</td>
</tr>
<tr>
<td>Practical sieving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review issue/resources</td>
<td>Discussion, identifying method</td>
<td>Skamp &amp; Preston (2015)</td>
</tr>
<tr>
<td>Planning</td>
<td>Asking/answering questions</td>
<td>Skamp &amp; Preston (2015)</td>
</tr>
<tr>
<td>Fair testing</td>
<td>All working scientifically skills</td>
<td>Fibonacci project (2014)</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Thinking critically, discussion</td>
<td>McCrory &amp; Worthington (2018)</td>
</tr>
<tr>
<td>Recording data</td>
<td>Skills development</td>
<td>Smith (2016)</td>
</tr>
<tr>
<td>Analysing</td>
<td>Skills development</td>
<td>Smith (2016)</td>
</tr>
<tr>
<td>Concluding</td>
<td>Skills development</td>
<td>Turner et al (2011)</td>
</tr>
<tr>
<td>Data representation</td>
<td>Skills development</td>
<td>Smith (2016)</td>
</tr>
<tr>
<td>Discussion of findings</td>
<td>Presentation, analysis, looking forward how to use information</td>
<td>Beasley (2014), Nottingham</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2016)</td>
</tr>
<tr>
<td>Concluding</td>
<td>Reiterating objectives, stating outcomes</td>
<td>Skamp &amp; Preston (2015)</td>
</tr>
</tbody>
</table>

Ensuring understanding, and assessing that understanding, are presently important parts of a primary teacher’s role, and both teachers paid great attention to this by
repeatedly returning to the objectives of the lesson, provoking discussion through asking questions, and reinforcing the story through repetition. Griffin and Burns (2013) comment on the importance of ensuring clear objectives and understanding throughout a lesson. Howe et al (2006) emphasise the value of questioning and discussion during input sessions.

The two classes were not streamed but had very different groups of children. As mentioned above, Class A were more able and all fluent English speakers, whilst Class O had many children for whom English was a second language. Class O children frequently needed more reassurance and, to support this, Joachim regularly returned to the objectives and reinforced ideas much further into the lesson than did Ashleigh, whose children seemed to understand the concepts more quickly. Ashleigh asked more open questions and received more responses. Generally, Joachim’s class asked more questions relating specifically to soil. Ashleigh’s class were all better able to write and read than Joachim’s, but her class had fewer ethnic minority children than did Joachim’s class. The majority of the children had completed their own stories by the end of the 35 minute period that I was observing, although two children in Class O were still working with the Teaching Assistant.

Overall, the children were involved, motivated, fully engaged and enthused during this part of the science day and, surprisingly to me and their teachers, we noticed that many of them returned to their versions of the soil story to corroborate their own work later in the day. The soil story, despite being theoretical, had been delivered in an effective manner which held the children’s attention and engaged them for over half an hour, a long time for a child of this age to concentrate.

6.4.3. Analysis of the audio-recording of the soil story
This audio recording was made with a different class in March 2018. Ashleigh had not delivered the soil topic as she had been on sick leave, but soil and the practical investigations had been taught by a supply teacher in January 2018. As already described, the soil story was an interactive session designed to initiate and reinforce concepts about soil formation. The children participated by making their own cartoon drawings of the formation of soil as the teacher told the story and illustrated it on a whiteboard. During the compilation of the story, Ashleigh gave information and examples of the processes, and discussed these with the children through questioning, often calling upon their prior knowledge. She also gave instructions as to what the children were to do. Ashleigh often recapitulated points as she went along to reinforce the story of soil formation. Analysis of the transcript is shown in Figure 6.3.

The audio-recording of the soil story was transcribed and analysed under the following headings:

- Information given by the teacher: instructions, examples, processes, explanations, clues
- Class management: reprimands, engagement of children, praise given, differentiation
- Questioning: open questions, closed questions
- Recapitulation of points already made
- Children’s verbal responses: inaccurate or inappropriate answer, correct answer, correct answer with explanation, answer applying knowledge, answer analysing knowledge.
The information given by the teacher has been divided into five sections. Initially, the teacher outlined what the class would be doing, making their own cartoon strip of soil formation on a large sheet of paper folded into nine squares. Each square would show a different stage in the soil formation story. There were a number of instructions given to the class during the story telling, so the children knew what to draw and where. They were also asked to examine the resources on their tables for ideas and answers to questions. The teacher explained the story, giving examples of the processes involved...
and occasionally giving clues in order that the children think along appropriate lines to answer questions. For example, “if you look at the pictures on the desk, you will find one with lots of trees and their leaves on the floor, lots of leaves on top of the weathered rock ...” and “Just check in your boxes, that you have weather (processes) in the first one, weathering in the second, weathered rock in the third ...”.

Class management points identified from the transcript are: reprimands, perhaps where a child was requested to listen; praise when a child answered correctly, by saying “that’s a good answer”; and responses of the class through laughter, discussion between themselves and comments made to the teacher. The teacher identified a method of differentiation to the class by offering those children who were slower at writing the opportunity to cut out some given sentences to stick onto their cartoon strips. This still required the child to read the sentence and some children were given help by the teaching assistants.

During the story telling, the teacher frequently asked open questions to get the children to think about the processes; an example of this is: “how does the snow affect that crack in the road?” A child responded “because it (snow) has water in it, and it gets in the crack and turns into ice, and freezes and makes the crack bigger and bits come off and it freezes again and pushes against the sides and makes the hole bigger and then we have a big hole in the road”. The closed questions were asked when referring to the soil cartoon as the session began when getting the children to identify the different ideas suggested.

The teacher frequently went over the concepts she had identified, going back over the story to reiterate the process of soil formation and getting the children to identify parts of her illustration.

The children’s responses were categorised as shown in Figure 6.3 Sometimes a child gave a totally inappropriate answer, e.g. in response to the teacher question “what does the sunshine do to the rocks?” one child answered “it makes the rock all sticky”. The teacher responded “well there is a problem with heat but not quite like that”, showing a positive response to an inaccurate answer, so not making the child feel inadequate. Other answers were explanatory for example: “spades can’t grow because we don’t have seeds for them” and “the roots will break the rock”. Some answers show application of ideas: “the worms digest the soil to make it better and then mix it all up”. Some show analysis as in the example above about the ice expanding in a crack to make a larger hole.

Overall, the soil story implanted a series of ideas which were discussed and drawn to augment the concepts in the memory, so hopefully the children would remember some of the points made when they were working with soils practically later in the day. The soil story offered many opportunities for the use of sound pedagogical techniques: for questioning and discussion between the children as well as with the teacher; the option to bring in relevant prior knowledge and examples which relate to the local environment; the possibility of applying and analysing concepts. Earth science in the form of a lesson on soil opened a number of cross-curricular possibilities for future discussion – the idea of bacteria being useful in breaking down leaf litter, the inhabitants of a proper soil, weathering processes and different types of weather to name but a few associated concepts. As a theoretical start to some practical investigations about soil, the story gave useful knowledge that children could use.
6.4.4 Observation of the practical session: permeability investigation

I sat near the children in class A as they were undertaking their soil investigations and observed two separate groups, X and Y, as they worked on the permeability and sieving investigations. In the permeability investigation the children were asked to investigate differences between the permeabilities of three soils, using the resources given: three different soils, three funnels and beakers, distilled water, a stopwatch, measuring cylinders, and paper and pencils.

Each permeability group began by talking with their teacher about a second concept cartoon shown on the whiteboard. This depicted a house and garden which had beautiful plants in the back garden and dying plants in the front garden, which seemed to be flooded. The children pointed out the various differences in the cartoon’s pictures and this led to them discussing differences between the soils and how the soils coped with rainwater. The word permeable was used and explained in ways that all the children could understand.

The children were shown the equipment available and asked how they could find the permeability of each of the three soils available for testing. The teacher explained that they were to use ‘special water’ (distilled water) and explained why. Group X decided on a plan, openly discussing the idea of ‘fair testing’ by using the same weight of soil and same volume of water for each of the three soils and timing how long it took for the water to travel through the soil (Figure 6.4).

There was some argument over who should do the timing (this was seen as the most prestigious task) but eventually one child organised the group. One child in each group recorded their results on a sheet of paper writing down the time for the water to drain through each sample. These results were not tabulated but just noted as the times were recorded. The children were intrigued at how quickly the water drained through soil A, telling me that “it would not be good for the plants as it was too dry”. Soils B and C initially had ‘puddles’ of water sitting on top, and this was related to “the soil in the front garden in the cartoon where the flowers were dying in the flood”. Soil B stopped dripping water after about 15 minutes, but soil C continued to drip water through breaktime, over 30 minutes. One child suggested to me that soil C must be a “mix of A and B and more like the back garden of the cartoon, and would be best for the plants as they would have water all the time”. The children noted that some of the water being caught in the beakers was coloured, stating that the water in beaker A was “sandy coloured so the soil must be sandy”. This group were happy to discuss why there were differences between the permeabilities of the soils, and had begun to think about reasons for this in a way congruent with their understanding of each soil’s formation.
The second group, Y, started their investigation as soon as they had seen the cartoon, and without any planning. They tipped some soil into one of the filters and poured water in before thinking about starting the stopwatch. One of the children suddenly realised that they had not timed the episode and so they began the investigation again, but with the teacher asking them to think about fair testing as well. This time they planned their investigation; they divided the tasks of collecting the soils, ensured they used the same volume in each filter (a small cupful) and measured the volume of water in the measuring cylinder provided. The exciting tasks of pouring the water and using the stopwatch were again delegated after much argument. Soil A was found to be very permeable and the water drained through quickly, within 3-5 minutes, while soil B took around ten minutes. As group Y watched their investigation, the water drained quickly through soil C, as fast as through soil A, and there was some argument amongst the children as to whether they had used the correct soil. Eventually, one child decided to redo the test for soil C and ensured the soil in the filter was from bucket C; this produced a very different result. He was pleased that he had solved what he considered to be a problem and obviously had begun to think critically about what he was doing (Figure 6.5).
Children in both groups X and Y were intrigued by the volume of water being caught in the beakers; several children observed “there is more water in beaker A than in B or C”, but none thought to measure its volume. One child meticulously recorded the time data in his notebook, wanting to time to hundredths of a second (some of the stop watches had been borrowed from the sports department!) The children were all happy to talk about what they were doing and how they had organised themselves. They told me about their results and generally related them to the cartoon they had seen.

These children were thinking critically about what was happening in relation to the soil concept cartoons they had been shown and discussed at the start of the investigation. One child at least had recognised that the permeability of C was in between that of A and B. Another child had appreciated that there was an error in one of the samples – applying logical thinking about what was being investigated. Children were observing the colour of the permeated water, although they did not record this, but were extending the investigation themselves. I was surprised that no-one thought to measure the amount of water permeating through the soils, although the children did comment on the different volumes. This would be something that could be discussed later.

Enough filtered water was saved to be able to test the pH of the three soils at the end of the day, using universal indicator. I explained the testing process and what the different colours would mean when growing different plants. One of the soils tested had been from the Year 3 garden, and the teacher explained that they would look at this result to decide which vegetables to plant after Easter.

After thirty minutes the children were asked to clean up the area to get it ready for the next group.

6.4.5 Observation of the practical session: sieving investigation
The sieving investigation was designed to separate out the different sized particles in the soil samples, the leaf litter and roots, small weathered rock particles and two levels of soil, one with finer particles than the other. The equipment available was three ‘sieves’ of different sizes and a base pan, scales (not very child-friendly) and measuring beakers.
I observed the first sieving investigation supervised by a teaching assistant. She began
the session with each group by getting the children to think about the purpose of using
sieves and the order the sieves should be used in. The children were shown three
sieves and a base and discussed how they could be used. Both groups being observed
(X and Y) eventually managed to order the sieve sizes so that four different sized
samples could be collected for each soil.

The children listened to the teaching assistant who explained that this investigation was
to try to discover what the soil had in it, and invited them to think about the soil story
and plan their investigation. The children could choose how much soil to use and
initially Group X decided on 100 g, but after putting this through the sieves and
discovering the amounts were too small to be weighed accurately, they started again
with 400 g. There was some discussion over whether to press the soil through the
sieves rather than just shake them, as the soil was fairly damp, but it was decided just
to shake as it would be “fairer”. This time there were plenty of different tasks in the
investigation. The children took turns in organising the sieves, weighing the material
caught in each and recording the data. Some children were reluctant to read the scales
on the weighing machines, but were persuaded to ‘have a go’, and were checked by
their buddies. In the end the children in groups X and Y were all quite adept at reading
these scales. The residue in each sieve was examined (Figure 6.6).

The children quickly related the residues in the sieves to the soil story, correlating the
leaves and roots to the litter in the upper part of the soil horizon, large stones to the
weathered rock horizon, true soil to one of the middle sieves, and being amazed at the
‘fines’ in the base holder, describing them as “silky” in one case. The children were
particularly intrigued by the number of worms and mini-beasts caught in the middle
sieve. These were carefully extracted and taken outside to the garden.

The children I was observing were eager to weigh the different amounts of material in
the sieves. When recording the weights in each sieve for each soil, a few remarked
about the differences between Soil A, which had most material caught in the third
sieve, and soil C, which had most in the base. They were obviously thinking about what
they were doing but did not give any reasons why they thought this was occurring.
Neither did they relate this to the previous permeability investigation.

Once all the soils had been sieved, the data were plotted onto a bar graph (although
most groups did this the following day, as time for this exercise ran out). When the bar
graphs were drawn, it was difficult to find an appropriate name for the horizontal axis as
sometimes the top sieve contained roots as well as stones and litter. This caused more
discussion as initially the children wanted to label this axis as ‘soil’, but when we talked
through the soil story, they decided on ‘components of soil’.
Once again, the children were animated at doing a practical investigation and talked amongst themselves about the differences, at one point one child thought “we had weighed one sieve wrongly” but when he added up the total weight of the soil from all the sieves he discovered that it was about right. He didn’t say why he thought it was wrong, just that it was “too much”. The exercise itself was fun and some children appreciated that the soil was being separated out into its components during the investigation but more realised this when they drew up the bar graphs later. Everyone learnt some science skills, be it timing, observing, weighing or recording, and mostly each child had the opportunity to attempt them all.

It was interesting watching the children work. All were very involved and enjoyed the different kind of lesson from their normal routine. Some, boys and girls, were initially very pernickety over touching the soil and getting their hands dirty – they needed reassurance that the soil was ‘clean’ – while others were fastidious about wiping up soil that had fallen on to the tables. All the children discussed what they were doing within their groups, correcting each other over reading the scales, and helping one other if they saw a child in difficulty, e.g. sorting the sieve sizes.

Again some children were thinking critically about what they were doing, an example is the child who thought the amounts of soil weighed in the sieves was incorrect. The teamwork involved in this investigation ensured everyone had a role which was changed with each new soil sieving. Most of the children quickly related the residue in each sieve to part of the soil story, and were surprised at the amount of root material caught. The differences between the volumes of residue in each sieve for the three soils were observed by verbal comments, and some children handled the residues identifying different textures. These observations were not suggested by the teacher but were thought of by the children themselves, thus extending the investigation and adding a new dimension to what they were doing which could be discussed later.

6.4.6 Other investigations not fully observed: clay investigation
A further exercise completed the practical session: examining clay, which consisted of two small investigations. In this area, clay is the underlying rock on which the soil is forming. First, the children put a small piece of clay from a local garden into a small
receptacle and added water to see if any air bubbles emerged. They did the same with a small soil sample. The children were surprised to find bubbles coming out of the soil but not from the clay. Several children began to relate this to the earlier garden concept map, where the garden was flooded, and there was some discussion about the three soils used in the permeability exercise, linking the slowest draining soil to the one containing most clay.

Secondly, in order to judge how pure the clay was in sample, they attempted to make doughnut shapes, an activity which was very much enjoyed. The children knew that if they could make the clay sample into a doughnut, then it was nearly pure clay. All the children relished using the sticky substance and in discussion began to appreciate that if this was in the garden it would not be very good for growing plants as it did not contain any air.

6.4.7 Making a soil cocktail
This little exercise reinforced the idea of soil composition, the children being asked to draw a soil cocktail in the provided outline of a cocktail glass Figure 6.6. This activity seemed to catch the imagination of all, and many draped ‘worms’ over the side of the glass. Interestingly, a number of children returned to their soil story sheet to check on the components of a soil, reinforcing their learning.

Figure 6.7 A soil cocktail

The picture shows the vegetation on top, with a humus layer below, soil further down on top of a dark layer of rock. There is water in the stem of the glass and worms around the edge. All the children produced a variation of the cocktail shown above and they were displayed on a wall panel in the school corridor, along with other pictures of the ‘science day’.

At the end of the afternoon, the children tidied the classroom, and we sat down to recap the investigations for a few minutes. The children were told they would have time
on the following day to write up and discuss what they had learnt (WALT sheet) and complete their diagrams and stories.

6.5 Discussion

6.5.1 Teachers' observations at the end of day from the audio transcripts
Ashleigh commented at the end of the practical day that she felt “the day was much more interactive than last time” (the pilot session). She stated that her main objective was “to get some better understanding of soil, what it was made of, and what you could find out about it”. She added that “a lot of children made the link that if water passes straight to the roots it might not be the best, or if water sits on the top it doesn’t work, so you need a mixture of both of these to get healthy plants”. Ashleigh explained that this cohort of children were “particularly visual”; “they needed something visible, something to feel, and something they could go back to and read over again, the soil story”. She was impressed by their knowledge of how soil formed after participating in the story. This year she had been interested to see if the children “could carry out an experiment and get results from it, which was an objective. I thought the sieving might be the harder of the two with the whole weighing thing. They set up the experiment, carried out the experiment and drew conclusions” she said. "They were able to tell me about it and they had exceeded my expectations!” Ashleigh went on to comment about how important it was to use material the children could handle. “I think soil is good, it’s hands-on and practical and they can actually touch it. They were able to manipulate and make mini-pots with the (local) clay you brought in, others were just squeezing it. How often can you show them that?” When asked if she thought using earth science was a useful way to get children interested in science she replied “Oh yes, I think anything you can touch and handle, find out more about gives children the opportunity to think about what is going on around them”. She stated that the lesson “was exhausting, but good fun and relevant” and “it worked well for the less academic children who even managed to record their work and were talking about it at the end of the day. They can talk about it because its hands-on even if they can’t read or write about it. It shows all children can be excited”.

Elmer agreed that the soil intervention had kept “the children engaged” and “there was a lovely balance between the practical content and the paperwork and creative elements”. About earth science she said “the soils related to everyday life; we have an allotment here and they now know about nutrients and what plants need to grow”. She went on to say “I’d feel much more confident about teaching soils again”.

All the teachers agreed that soils were no longer a boring topic and that the time spent investigating soils had provided new science skills, experiences and an understanding of soil and its characteristics – which would be utilised in the gardening project to be undertaken the next term. There was also written material available for assessing the effectiveness of learning through the bubble diagrams.

6.5.2 Reflections on the intervention day
After the intervention lessons, I audio-recorded the teachers and teaching assistants on the overall impact of the science day and its effectiveness. I asked them questions, all of which were designed to be very open and invited their reflections without trying to steer their responses at all. This way I hoped to get unbiased comments about the lessons. I have collected all comments from the audio-recorded interviews with the
teachers and teaching assistants and combined them in Figure 6.8, which clarifies their opinions.

**Figure 6.8 Teachers’ and Teaching Assistants’ reflections at end of intervention**

The teaching assistants agreed to give their views about the parts of the lessons they had helped in and their comments are presented in Table 6.8.
Table 6.8 Cumulative feedback from the year 3 teaching assistants

<table>
<thead>
<tr>
<th>COMMENTS (by teaching assistants)</th>
<th>Thelma</th>
<th>Tasha</th>
<th>Toakey</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Is earth science a useful medium to work with?</strong></td>
<td>Concrete materials, able to feel (mentioned four times). Practical.</td>
<td>Useful material to work with.</td>
<td>Able to feel it (mentioned four times). Very good subject, interesting, cross curricula (two points made).</td>
</tr>
<tr>
<td><strong>Soil story</strong></td>
<td>Children recording story for reference.</td>
<td>Useful helpful reference (mentioned twice).</td>
<td></td>
</tr>
<tr>
<td><strong>Did any learning take place?</strong></td>
<td>Mathematics skills.</td>
<td>Children interpreting/recalling from words/picture (mentioned twice). Children didn’t realise they were learning.</td>
<td>Children enjoyed a different way of learning.</td>
</tr>
<tr>
<td><strong>Assistant more confident?</strong></td>
<td>More confident.</td>
<td>More confident.</td>
<td>More confident and learnt how to zero scales.</td>
</tr>
</tbody>
</table>

The teaching assistants agreed with the teachers’ comments that the children had enjoyed the soil story and had been engaged and motivated throughout the lessons. They found that the children became adept at weighing, measuring and recording data, and they, the teaching assistants, even learnt some skills themselves. They stated that they found soil a good medium to work with; it was relevant, all the children knew what it was, and it provided good cross-curricular learning material. The assistants all felt confident they could contribute to future soil sessions, and one remarked that the “children were learning without realising”, whilst another stated that the children enjoyed the “different ways of learning” (presumably meaning through the practical investigation).
6.5.3 Summary of the Intervention lessons
All three teachers found that the children were engaged and excited by the initial soil story, Joachim stating that his class were motivated and enjoyed the interactive approach. It had been a good idea to get the children to draw their own versions of the story as these had been frequently used for reference throughout the rest of the day. They could also be posted into the children’s record books as an example of an integrated science with literacy lesson. Class A had used a homework session to get familiar with some new soil vocabulary, and this provoked questions during the soil story which the teacher felt confident to answer this year. Two teachers remarked on the number of skills the children had acquired, and how surprised they were at the way the children had tackled the investigations; “they had exceeded my expectations” was one comment. It had been successful to have a teacher or a teaching assistant on hand during the planning of the two main investigations (permeability and sieving).

Whilst the adults had not given clues or specific ideas about how to go about the tasks, they had been a calming influence on the proceedings, enabling the children to think before embarking on the investigation. The concept cartoon about the flooded garden had also proved a good starting point. When asked about the use of earth science, and specifically soil, as a way of teaching science, all three teachers agreed that soil was relevant (and fun!), and that having a resource that the children recognised and could handle was very effective. Many children were overheard discussing soil in relation to their gardens later in the day, particularly at playtime and when going home. The two teachers who undertook the pilot in 2015 now felt very happy, comfortable and confident that soil could be a useful topic and the work would provide much needed evidence for assessment, as well as being cross-curricular. The day had been a long one, with a lot of continuous concentration for the children and all three teachers felt the children were very tired by its end. Ashleigh stated that she wouldn’t extend the learning period for this topic; “it was better to finish something while it’s fresh in their minds rather than to go back when the evidence was gone”.

When asked about the use of earth science, and specifically soil, as a way of teaching science, all three teachers agreed that soil was relevant (and fun!), and that having a resource that the children recognised and could handle was very effective. Many children were overheard discussing soil in relation to their gardens later in the day, particularly at playtime and when going home. The two teachers who undertook the pilot in 2015 now felt very happy, comfortable and confident that soil could be a useful topic and the work would provide much needed evidence for assessment, as well as being cross-curricular. The day had been a long one, with a lot of continuous concentration for the children and all three teachers felt the children were very tired by its end. Ashleigh stated that she wouldn’t extend the learning period for this topic; “it was better to finish something while it’s fresh in their minds rather than to go back when the evidence was gone”. The cumulative feedback from all staff is shown in Figure 6.9 and shows the effectiveness of this earth science intervention on soil.
6.5.4 Feedback from the children’s audio-recorded interviews
I conducted two short audio-recorded interviews at school A with a group of six children before and after the soil science day, two drawn from each class by their teachers to give me a wide spread of abilities. I had composed a list of basic questions that I could ask on the first day as I wanted to find out what the children thought about science, what they thought science was and if they remembered any science form their lessons in school. I was interested in whether the children thought about science outside school, and whether they discussed science within their families. I took with me four
bags of samples for discussion after my initial questions. The children chose names so that I could address them during the interviews without their actual names being revealed to any reader. After both sessions I transcribed the interviews and analysed each child’s contribution to the discussion under eleven categories:

- Knowledge
- Description
- Explanation
- Observation/investigation
- Remembering
- Analysing
- Skills
- Recording
- Misconceptions
- Asking questions
- Discussion.

These headings are the result of grounded analysis as I identified them from the children’s statements. To some extent my categories extend Bloom’s taxonomy which was not detailed enough to record the changes in the children’s responses during the interviews. I was interested in the explanations and descriptions of science given by the children which not did not fit Bloom’s knowledge dimensions, for example the children told me that ‘science was magic stuff, did not fit any category. Neither is there a category for discussion about points the children made – the taxonomy is not suited to analyse conversations the way I wanted.

I recorded the number of statements each child made to me, some children were more talkative than others but I tried to draw them all into the conversation. The analysis of the first group of statements is shown in Table 6.9 from the discussion of the first transcript.

**Table 6.9 Children’s statements about science and soil before the intervention lessons**

<table>
<thead>
<tr>
<th>Categories</th>
<th>Bob</th>
<th>Charlotte</th>
<th>Emma</th>
<th>Grace</th>
<th>Jack</th>
<th>Lily</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Description</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Explanation</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discussion</td>
<td>2</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asking questions</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remembering</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investigating</td>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysing</td>
<td>2</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observing</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total no. of statements</td>
<td>23</td>
<td>7</td>
<td>16</td>
<td>6</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

My initial question to the children was whether they would all be happy for me to record our conversation, and they all agreed. At the end of the session the children asked me to play back what they had said, and they were amused at their answers.
I then asked them what they thought was science and although all the children had some ideas, Grace was initially somewhat shy and reluctant to talk. On the other hand, Bob could have dominated the conversation at times. Jack started by telling me “science was like, wizards and stuff, but not magic, finding out new stuff”. Emma joined in with “investigating and finding out …”. Bob’s initial idea was “science is something where you investigate with chemicals”, whilst Charlotte’s contribution was more hesitant “umm, like finding out things”. The children’s level of knowledge about science was low, with their not really understanding what science was overall. Perhaps because the conversation took place in the school environment, on the whole their idea of science was very traditional: experiments, working with acids, inventing (more technology than science), finding out ‘stuff’, and investigating. These ideas about science are common, as Ridley (2014) found; children in her school only identified ‘science’ as what had been taught in school lessons. Both the boys had specific views about scientists, influenced by television plays (Frankenstein) and Harry Potter. The girls did not state any opinions about scientists. However, the children all affirmed that they didn’t talk about science at home unless they had some science homework, which apparently was rare, and they could not agree on this possibly because they were all from different classes. Then the conversation changed slightly as Charlotte said she helped her older brother with “his science activities”, “with chemicals and things” (her brother was at secondary school). Emma then recalled that she had done “a sciency thing at home, with a volcano set”, and Bob stated “I let off a rocket”. The group had identified some science outside school science. Generally however, science was seen as a lesson in school, not something you talk about at home. I was hoping the children might mention current news items, for example, about climate change, space travel, energy saving or the environment, but nothing of that kind seemed to feature in their view of science.

The children remembered some school science from the previous autumn term and were able to describe investigations they had carried out, in some cases in detail (Bob, Emma and Lily). The first was an investigation leading to an explosion: Bob said “I have a favourite, when we made an explosion using a vitamin C tablet”. Emma and Lily described how they carried out the experiment. However, only Lily was able to give an explanation of what happened in the experiment, with changes in the volume of water, or amount of vitamin C tablet used, causing differences in the time waited before an explosion, saying “we put in (a container) half a tablet, then a quarter of a tablet, then a whole tablet to see if it would blow across a line or not”. Bob said “if we put in less water it took less time (to explode); if we put in more it took longer”. The children had partly remembered the process of the investigation and had some recall of the reasons why the explosion occurred but had nothing else to relate the investigation to, other than it was fun and they all enjoyed it.

Grace spoke at last – “My favourite experiment was making toothpaste” – and the other children added “oh, yes, I remember, and it tasted awful”. I subsequently discovered that the toothpaste making was linked to how the Romans used herbs which was an interesting cross-curricular use of a science investigation.

I then showed the children the four bags containing leaf litter, gravel, humus and soil. The children discussed the samples but did not appreciate the relationship between the samples. Bob said “I think this one is fertiliser”. I asked him why and he replied “it’s like brown fur, but it doesn’t have a smell”, so he decided he was not correct. I suggested
he was thinking of manure, and said there were other kinds of fertiliser which could be purchased that were not smelly. I pointed at the gravel, and asked where they would find it. The children all replied “on a beach” and Emma expanded on this by saying “a stony beach”. Grace suggested they “would find the leaves in the playground or the woods”. Emma then looked in the soil bag more closely and said “there’s a stone in here” and went to take it to put in the gravel bag. I stopped her by saying “this belongs in here. Look at what else is in the bag”. When we examined the fourth bag closely, Emma found small stones in the soil, and we also found fragments of leaf litter, which was helpful in verifying the true soil components. Eventually, I explained that three of the bags together made up a proper soil – which was what was in the fourth bag. Emma was the only child to show real questioning curiosity about the contents of the fourth bag.

All the children had some knowledge about science and what they had learnt at school. They were able to describe to some degree a previous investigation but were not necessarily aware of the reason for executing it. Two children were more inquisitive than the rest about the bags of soil they were shown. At the end of the interview I played the recording back to the children as promised.

The second conversation took place two weeks after the soil science day, with the intention of finding out if the children had learnt and could recall anything from the intervention lessons and if they could relate to information they had discovered. I analysed the transcripts in the same way as I had analysed the initial transcript, as Table 6.10 shows.

Table 6.10 Children’s statements about soil after the soil science day

<table>
<thead>
<tr>
<th>Categories</th>
<th>Bob</th>
<th>Charlotte</th>
<th>Emma</th>
<th>Grace</th>
<th>Jack</th>
<th>Lily</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Description</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Understanding</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Explanation</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Observation</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Remembering</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Analysing</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Skills</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Recording</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total no. of comments</td>
<td>18</td>
<td>17</td>
<td>21</td>
<td>13</td>
<td>11</td>
<td>19</td>
</tr>
</tbody>
</table>

The children were all very excited and had brought some of their soil work to show me. They were enthusiastic and motivated about the work they had participated in on soil. We started by compiling a concept map of what the children knew about soil. All the children began talking at once keen to add points to the diagram. Each child could tell me how soil had formed, so the concept cartoon and soil story sessions had enabled them to learn something about soil formation

Grace offered “soil is leaves and weathered rock”; Jack suggested “hard rock and humus”; Bob said “worms and insects eat the leaves and make ‘poo’”. When I asked for the scientific name for poo, he replied “humous” and was immediately corrected by Emma. We completed the diagram with all six children adding points about soil formation. We then talked about the investigations that the children had carried out. Charlotte described one experiment as “pouring water through different soils” and
Grace added “to find the permeability”. I asked if they could remember what they had found out. Lily and Bob both recalled that the water went through A very quickly and C very slowly. Emma remarked “I think B was the best” and when asked why Bob explained “because the water in B went through quickly then slowly. A let the water go through very quickly and C the water through very slowly. If you had plants in A they would get flooded then dry out very quickly, with C you would have puddles but B would be just right”. All the children agreed with him. Charlotte then said “the water in the beaker B was yellow, like a sandy colour, so perhaps there was sand in the soil”. Emma suddenly said “soil A was the best quality because it had a good mix”. Lily stated that “soil B would be best for the plants, because soil C looked very thin when we did the sieving experiment”. She went on to explain how they did the sieving and said “we got the big bits in the top sieve and the real soil in the bottom one”. Grace described the soil in the bottom sieve (of four) as being “very silky with no rock in it”. The other children described their findings of roots, leaves and rocks in various sieves as well as beetles, insects and worms which they rescued and returned to the garden.

I then asked if the children thought they were doing science. Emma said “we were finding things out, investigating”. Charlotte felt “we were trying to work some things out”. Grace remembered that we had tested the pH of the water giving different colours. Jack described the mini-investigation to see if there was air in clay. I asked if the children thought they had learnt any new skills, and they described putting the sieves in the correct order, weighing the soil in each sieve and recording the weights, later making a bar chart to show rock and humus and soil. They suggested they were separating out the soil again. The children identified other new skills as measuring liquids, observing, recording data and working in teams. I asked if they all felt they worked as a team and Emma said they worked “with their learning partners”.

The children described the formation of soil accurately, illustrating their remarks with the concepts from the soil story, each child adding something to the explanation, clearly showing that they had remembered the lesson. Lily explained “that the plants died and their leaves became litter” which Emma said “were broken down into humus by bacteria and worms”. Bob remarked that you also need “air and water for plants to grow as well as soil”. We ended our discussion by talking about how they would use the information they had discovered when they were gardening in the summer term.

When the before and after knowledge statements are graphed, it can be seen that there is considerable knowledge prior to the intervention (Figure 6.10).
Figure 6.10 Knowledge statements before and after intervention (Series 1 is before intervention; Series 2 is after intervention)

However, a graph showing knowledge reveals an increase by all the children except Bob who had showed considerable knowledge initially.

A graph showing understanding before and after intervention Figure 6.11 shows considerable increase in understanding statements made by the children.

Figure 6.11 Graph showing the children’s understanding of soil formation before and after the intervention. (Series 1 is before; series 2 after intervention)

Charlotte, Grace and Jack now showed understanding and were able to explain their findings at a modest level, e.g. identifying which parts of the soil profile were caught in each sieve, with some simple analysis of the results. The concept cartoon they had been shown, revealing a flooded garden – where the soil was ‘impermeable’ – had been effective, as everyone related this to the more impermeable soil they had tested, showing a level of analysis as seen in Figure 6.12.
Figure 6.12 shows how much the children’s analysis of soil formation had improved. They now understood the processes of soil formation and could explain what happened in some of their investigations because of their conceptual knowledge. All the children were now able to discuss and analyse their findings and could apply this new understanding to plant growth.

It seems that the initial concept cartoon, used to stimulate discussion and thoughts about soil, the soil story and the practical lessons had influenced the children’s learning. They had enjoyed themselves, acquired some knowledge and skills, were able to explain the processes of soil formation and linked these to practical investigations through soil sieving. They had discovered that some soils were impermeable and how that would affect a garden and plant growth. Earth science, in this case using soil as the topic, had interested them and proved to be a relevant and useful subject.

6.5.5 Summary of intervention lessons in school A
The earth science lesson, using a material known to the children, had provided an interesting and enjoyable experience in which the children had participated by investigating and discovering what made this material and the processes which formed it. They could relate the characteristics of the material to plant growth and soil permeability; hopefully, because of the way they had discovered this information, the lesson will form a lasting impression and be useful to them subsequently. Certainly, the children I interviewed two weeks after the soil lessons had increased knowledge and understanding about what soil was, its formation and use and could apply the knowledge learnt to the processes they were investigating, talking about flooding in gardens and why this had occurred, water requirements by plants and how soil could provide water, and the components of and differences between soils.

My objectives for the intervention lessons as stated at the start of this chapter were:

- To show the potential of using earth science in primary school teaching
- To help develop primary teachers’ science self-efficacy
To show the potential of earth science to enrich science knowledge and understanding in primary children

To show that earth science investigations can develop scientific skills in primary children.

I feel that these objectives were achieved. The evidence collected showed that earth science, in this case ‘soil’, the topic described as ‘boring’ by staff prior to the intervention, had been shown to be an interesting, relevant, engaging and motivating subject. Teachers and teaching assistants now felt confident and comfortable with teaching about soil. Children had learnt new scientific skills, knowledge, understanding and application of one of the materials commonly around them. The lesson had been effective providing suitable evidence for assessment as seen from the analysis using SOLO and Bloom’s taxonomies. There is therefore plenty of potential to come from teaching about soil, and the teachers were discussing the application of this work to the gardening project in the coming summer term.

This kind of intervention shows the potential for using earth science in a classroom exercise. True, there needs to be some input into teacher training through professional expertise but if the exercise is well planned and specific (Beasley, 2014), the training time is not onerous and can be fitted into short, twilight sessions. The resources are minimal. However, what is needed is the support of senior managers in the school (Wellcome Trust, 2014, 2015) to enable timetabling to be re-scheduled and fixed lesson time used more effectively, allowing extra time for science. This school had support from its senior management team, albeit initially to improve their Ofsted status, but the senior management team maintained its encouragement and support for the year 3 science days.

The soil science day has become an annual science day for this school, and was repeated in 2017 and 2018. Feedback from the school indicates that it is an effective use of time for pupils to gain valuable science skills as well as knowledge and understanding about soil. The short time spent on teaching the teachers has proved to be time well spent as the original teachers cascade their skills to new colleagues in year 3.

6.6 Intervention lessons in school B

6.6.1 Background to school B: its demography and previous Ofsted report

School B is in the same commuter village as School A and became part of an Academy group of five primary schools in 2015. The school draws from two wards and the demography is very different from that of School A. Here again, the economically active population is high, around 79%, with some 9% retired people. However, there is a larger Asian population than on the other side of the village of 16%, and a higher percentage of ‘White other’, mainly East European peoples, who make up a further 10%. The census shows 66% are White British. The Ofsted report for the school in 2012 showed a considerable number of children with special needs, and many (mainly Pakistani children) with English as a second language. From my visits to the school I have noted a wide range of ethnicities, but have not been given access to their demographic data.

In September 2015 I approached the school and offered them the same programme that I had worked on in School A. The year 3 teachers and headmistress were very
keen to participate in the summer of 2016 as the current PSL was about to go on maternity leave. One of the year 3 classes had two teachers sharing the work; one worked two days, the other teacher taught on the remaining three days. None of these teachers had any science background, neither did the PSL. I discussed the idea for some earth science input with the three year 3 teachers and as in School A they decided that soils was a subject they would normally try to avoid teaching as they did not understand it. The school had a programme dedicated to ‘outdoors’ which ran in the summer term, and the teachers felt that the soil topic would fit well into this programme. We arranged four twilight sessions in March 2016 to develop the soil lessons.

6.6.2 The year 3 teachers
Robyn had been teaching for four years, having come into teaching through GTP\textsuperscript{19} with a background in Learning Support. She had spent many years as a branch ordering specialist for a large supermarket before having children, then worked as a teaching assistant which she enjoyed so much that she decided to train as a primary teacher. She is currently Lower KS2 phase leader with computing and ICT specialisms and has taught in KS1 and Year 3.

Wendy had been teaching for eighteen years, coming into the profession from school, encouraged by her family’s interest in education and nursery provision. She took a B.A. in Education at Brighton University, followed by a QTS\textsuperscript{20} year. In the past she has taught mainly KS1 but is now part-time; job sharing and teaching Year 3. Wendy has responsibility for co-ordinating art throughout the school and this includes organising and monitoring displays.

6.6.3 Initial discussion about the intervention lessons
Four twilight sessions of about one hour each took place at the school in March 2016. As at school A, I taught the two teachers who would be participating about soil and introduced some ideas on how soils could be taught. We organised resources, planned the sessions and linked them to the out-door programme offered in the summer term. We discussed how the outdoor programme could link to the soil lessons. The outdoor programme in this school is not exactly a Forest School programme but has links with the Forest School ideals identified in the Literature Review on page 57. The soil lessons would follow on from this with a day similar to that in school A, starting with the bubble diagram, then a concept cartoon, the soil story and practical investigations. The two teachers involved stated that they would have extra helpers from teaching assistants and parents, so there would be plenty of adults to help and observe in case of any behavioural issues.

The intention was that the children would spend one day a week for four weeks exploring local heath and woodland, then have the soil lesson day and later spend time in the school garden. I would participate in one morning’s activities in the woodland, showing the children the woodland soil profile. On the day I spent outdoors with them, the children were given small projects to undertake and were asked to find and identify a number of invertebrates and plants. They were to record and draw or photograph each creature or plant found. I worked with a small group of five children, and I lifted leaves and pieces of bark under which we found many small beetles, spiders and millipedes, to name but a few creatures. Most of the children had never been in these

\textsuperscript{19} Graduate Teacher Programme, a one-year training programme whilst the trainee is working in a school.
\textsuperscript{20} Qualified Teacher Status.
woods before, despite the area being very close to their homes. They were fascinated with the creatures, and happily spent two hours looking for them.

Just before lunchtime, Robyn divided the children into small groups. I chatted with each group of ten children and showed them the different layers in the soil (the soil profile). My short talk was videoed on a mobile phone for later use in the classroom. I moved the vegetation apart and showed the children leaf litter and humus with many invertebrates in it, with the true soil and underlying rock below. I discussed the different layers with the children and answered questions about soil formation. In this area the underlying rock was sometimes sand, and sometimes clay. Nearby, both sand and clay were exposed and the children were encouraged to feel both and try to make clay into doughnuts, sausages, rings and balls. This test indicates the purity of the clay, and can also be used to determine the amount of clay in a clayey soil, as being able to form fine rings indicates the highest clay content. The children found the clay to be very pure as it could be made into rings which did not crack.

6.7 The intervention lessons in school B

6.7.1 Organisation of lessons
I discussed the running of the soil day with the two teachers who would be involved. The soil day was plan was similar to the day at school A, as that had worked well. I would be able to interview and audio-record before and after discussions with the teachers and also interview and audio-record a small group of children earlier in the designated week. The children would complete a soil bubble, this time as a class not individually, followed by the interactive soil story and then the practical sessions. The day before the soil lessons, I talked with four children, two from each class (as in School A) and audio-recorded the conversation.

6.7.2 The intervention lessons
At the start of the day of the soil lessons, I went to observe class R. The children were excited as they realised the day would be different from normal. Robyn invited the children to compile a whole class soil bubble (on a large piece of paper on the floor) and listed all the points they made. I had expected that a concept cartoon would be used next as a discussion point to introduce the concept of soil, so the children could recall some of the ideas from the woodland morning. Unfortunately, neither teacher used the soil story we had practised previously in the twilight session to introduce soil to the children. Instead, Robyn used a short video from a US source. She apologised to me that the terms being used were different from the words we had discussed, which meant we needed to use these different terms later in the day when talking about soil formation. The children watched the video quietly, which lasted for about five minutes, but were not asked any follow up questions and there was no discussion after the video had finished. The children did not repeat any of the soil vocabulary, which were not really explained. Robyn next asked the children if they remembered what I had talked to them about in the woods, and showed them the short video of my explanation about the soil layers she had recorded on her phone at that time. The children did not volunteer any information recalling my showing them the soil layers. Once again, there was no discussion, and the children watched the mini-video in silence.

These changes in the programme meant that I was not able to observe the teacher telling the interactive soil story about formation of soil, and so could not use my observation form. However, I noted the children’s attitudes and involvement.
Both the year 3 classes were then assembled together. They were divided into five groups of twelve, each to start work on a different task: sieving, permeability, making a soil cocktail, drawing a picture from different soils and devising a formation of soil story on the computer. After about half an hour, each group would move on to the next task. No real explanation was given for each task, nor any reasons for undertaking them at this point.

I had expected that there would be some extra adult help, as well as teaching assistants during the soil lessons, as this had been agreed previously, but no extra adults were on hand. It was therefore not possible for me to observe any of the practical sessions as I was required to supervise!

I was asked to supervise the soil sieving investigation. Initially, twelve children came to me and I tried to get the children to work on their own in groups of three. However, they did not understand what the investigation was about and it became obvious that these children had never participated in practical exercises before, and so found it difficult to organise themselves. I brought the whole group together and explained what the investigation was about. We considered the problem and the children decided how they could find the components of the soil by sieving. After some discussion about how to do this, eventually the children began to organise themselves in their small groups of three. By the time they had worked through sieving the three soil samples they were beginning to understand the process, although still not sure about what they were finding in each sieve.

After 30 minutes all the children moved on to a new task, and I had a new group of twelve children to work with. This time I explained at the start what we were trying to do and why. We discussed how this could be achieved and the children managed to organise their investigations although they were not efficient at recording data. Eventually, all five groups of children had attempted to sieve the soils.

I was able to observe most tasks throughout the day from a distance. At the end of the afternoon the children returned to their own classrooms and completed the whole class soil bubble.

6.8 Results from the soil science intervention lessons in school B

6.8.1 Assessing the lesson through the soil bubble diagram
As in School A, the teachers both started the soil lessons by getting the children to contribute to a soil bubble diagram. The children were all excited and keen to participate with their comments. In class R the teacher used a large piece of paper on the floor and wrote down all the children's comments in one colour pen, and another colour after the lessons. A photograph of the floor diagram is provided as Figure 6.13 and the children's statements are shown in Table 6.11. Figure 6.13 shows the floor bubble diagram for class R shows the children’s statements before and after the intervention lessons. The before statements are in purple with the after intervention statements in green.
Figure 6.13 The floor soil bubble diagram for class R

Table 6.11 Before and after statements from class R’s bubble diagram

<table>
<thead>
<tr>
<th></th>
<th>Before intervention</th>
<th>After intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of statements on bubble diagrams</td>
<td>24</td>
<td>11</td>
</tr>
<tr>
<td>Descriptive statements</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Simple knowledge statements</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Understanding statements</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Explanatory statements</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Good understanding and knowledge statements</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Statements showing knowledge, understanding and explanation</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The number of statements recorded after the intervention were fewer than those recorded before the intervention. This is because the teacher did not record the number of times a statement was repeated, only writing down new comments, so the table is not really an accurate reflection of the learning achieved by the intervention. Table 6.12 shows the statements from the bubble diagram and their achievement as shown by SOLO and Bloom’s taxonomies.
Prior to the intervention the children were describing soil in terms of its feel or colour; the three knowledge statements used soil terminology with one suggesting uses for soil. After the intervention, the children used vocabulary learnt during the soil lessons (logged as knowledge statements), but still only one recorded explanatory statement, explaining the word permeable. The points made are shown in Table 6.13.

When these points are analysed using SOLO and Bloom’s taxonomies it can be seen that there is some change in the children’s responses. They have begun to use scientific vocabulary and one children has reached level 4 (SOLO) and ‘understand’ in Bloom’s taxonomy. But overall, this result was disappointing, although the children were now using correct terminology. Another time I would try to record the number of repeated comments made by the children, at the same time as the teacher was writing.
The bubble diagram was completed quickly at the end of the soil day, and not enough time was given to completing it.

The number of improvements can be more clearly seen through the percentage changes seen in Table 6.14 which shows that half the class are now at SOLO 2 level, that is have some relevant ideas concerning soil. On Bloom’s scale the children have remembered some information.

Table 6.14 Comparison of taxonomy levels before and after intervention.

<table>
<thead>
<tr>
<th>Levels before and after intervention</th>
<th>SOLO before %</th>
<th>SOLO after</th>
<th>Bloom before %</th>
<th>Bloom after %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fact</td>
<td>1</td>
<td>0</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>SOLO 1</td>
<td>22</td>
<td>92</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SOLO 2 /Bloom Factual Knowledge</td>
<td>1</td>
<td>4</td>
<td>65</td>
<td>55</td>
</tr>
<tr>
<td>SOLO 3 /Bloom Understanding</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SOLO 4 /Bloom Apply</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SOLO 5 /Bloom Analyse</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>11</td>
<td>24</td>
<td>11</td>
</tr>
</tbody>
</table>

6.8.2 Observation of the interactive story in both classes
The soil concept cartoon was not used by either teacher to introduce the topic of soil to their classes, despite the fact that both teachers had thought it a useful starting point when we discussed the programme for the day. Both year 3 classes were all together in one large classroom after drawing up the soil bubble. There was no introduction to the programme for the rest of the day except “we are going to do something different today, so I expect you all to be on your best behaviour”. No objectives were stated, or an outline given of what the children would be doing. The soil story was not used either; instead, a video clip was switched on with the teacher saying “this tells you how soil forms, so I want you to watch it carefully”. The scientific terms used in the video were American, slightly different from the ones used in England when talking about soil, and the teacher apologised to me that they were different. After the video, the teacher showed the children the short mobile phone video taken on one of the woodland days to try to get the children to recall the short talk I had given looking at the soil. Although the teacher tried, the children did not remember much of what had been discussed at that time.

6.8.3 Observation of the practical investigations: permeability investigation
The two classes were split into five groups: one group with Wendy, investigating permeability; another with the IT teacher in the IT lab, where the children were to write up the soil story; two groups with Robyn, making soil cocktails and the other doing soil paintings; and the fifth group with me working outside on soil sieving. Each group comprised twelve children.

I subsequently discovered that Wendy was actually demonstrating the permeability test and only a few children were allowed to participate, whether by measuring out the soil samples, pouring water or timing the test. Wendy herself kept the record of the time taken by the water to permeate the soil. The children were merely observers, not active participants. There did not seem to be any discussion about what was going on, but I was not able to watch a complete session.
6.8.4 Observation of the soil sieving investigation
As there had not been any prior explanation about what the children were expected to find out from their investigations, I explained to my first group what they were going to do and why: to try to find differences between the three soils available, one from the local heathland, another from the woodland and the third from the school garden. Since the Google video on soil formation had not explained about the formation of soil, I presumed the children would not understand the reason for sieving the soils. I explained that we wanted to identify the different materials in each layer of the soil by sieving, so we discussed the different layers we might find. The children needed a great deal of prompting, but eventually were happy that we might be able to find litter, rock particles or larger pieces of rock and soil. After letting them try to organise themselves for five minutes, I brought the group of twelve children together. We then discussed how to use the sieves, and the need to write a record of the volume of material in each sieve so the soils could be compared. Since we did not have any scales to weigh the amount of soil to be tested, the children decided (after some prompting from me) to use two tubs full of soil for each soil test, and measure the amount of material caught in each sieve as a quantity relative to the measuring tub, e.g. one quarter of a tub, or one half of a tub. Eventually, the group split into four subgroups of three children each, and the investigation began. This first group of twelve children became quite committed to the task and produced some documented data of their findings. After fifteen minutes, we all discussed what they were finding in the sieves, and managed to identify the litter layer, rock particles and two layers of soil – one finer than the other.

I repeated the same exercise with four other groups of twelve children, starting with an explanation of what we wanted to do and why, but it was noticeable as the day progressed that their attention span was waning, and although each group managed to sieve at least one soil, few groups managed to work through all three. It was obvious that the children were not used to being allowed to carry out investigations on their own, particularly outside the classroom. I ensured that we kept a record of whichever soil had been used, so over the course of the day, we had several readings of the sieving for each soil.

These children did not know how to organise themselves to be able to carry out an investigation. It was apparent therefore that these children had not previously been allowed to carry out their own practical investigations and hence found it new and difficult. However, with some practice they were able to organise themselves to collect the required data, although they had to be supported with planning and the recording of information. If nothing else, the exercise in sieving gave the children an opportunity to work in small teams towards a defined task. Some children took the opportunity to feel the soil textures in the sieves but nothing was recorded.

6.8.5 Other investigations
By mid-afternoon, all the children had participated in each exercise and returned to their classrooms and their own teachers for the final discussion and bubble diagram completion. The children were all very animated, and some rather unruly. I did not feel that the children had achieved very much learning as they had not really understood the objectives for the day, since these had not been properly identified.

The children also worked on producing their own soil formation story using their IT skills and made soil paintings and a soil cocktail. This soil cocktail used breakfast
cereals for each different soil layer and liquorice sticks for worms, and the activity was very much enjoyed.

6.9 Discussion of the soil day in school B

6.9.1 Teacher comments from the transcript of the audio recording
I interviewed Robyn at the end of the day after the intervention lessons and she was very positive about what had been achieved; “the children had enjoyed it, and more importantly they learned a lot” she said. I observed that “there didn’t seem to be any misconceptions about what was soil”. Robyn thought “that the children had a real understanding of what soil was from the visits to the woods” and showing the little video recorded there “helped to make connections, and took the children back to what they had seen”. We discussed the different activities that the children had participated in during the day. The soil painting and soil cocktail making filler activities had been much enjoyed: “it was great to see the way the children realised the soil samples gave them different colours, and that some soils painted better than others”. Robyn surmised that the children who had made the soil cocktail were better able to explain the soil-forming process and write their stories in the IT suite than those children who started off the carousel of activities by writing the story. She felt that “they used the soil cocktail activity as a visual aid” which made the children recall the soil formation process video, thereby making it easier to write the soil story. When talking about the permeability investigation, she recounted what Wendy had told her about the children’s ideas of fair testing – “all children ‘having a go’ at measuring out the soil” – a common misconception (Turner, 2012). The children had not specifically mentioned the sieving exercise to her except to say that “it was fun”. She said ”they did get the idea of how to use the sieves”.

Wendy was not available for comment after the soil lessons despite having previously said she would be happy to give some feedback.

6.9.2 Teaching assistants’ comments
There was no help given to these classes by teaching assistants during the day. The only extra help was in the IT suite and I was not able to meet that member of staff as she had gone home by the time the children were dismissed.

6.9.3 Feedback from the children’s audio-recorded interviews
I carried out two sessions of audio-recorded interviews with the children from School B, asking the same questions as in School A and showing them the same samples in the first interview. I recorded their answers in the same way. The results can be seen in Table 6.15.
Table 6.15 Feedback from the children's audio-recordings before intervention

<table>
<thead>
<tr>
<th>Categories</th>
<th>Darcey</th>
<th>Jack</th>
<th>Michelle</th>
<th>Vason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Description</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Explanation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Discussion</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Asking questions</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Remembering</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Investigating</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Analysing</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Observing</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total no. of comments</strong></td>
<td><strong>8</strong></td>
<td><strong>5</strong></td>
<td><strong>11</strong></td>
<td><strong>7</strong></td>
</tr>
</tbody>
</table>

At the start of the session, I asked the children to choose their own names as in school A and each child made a name label so I could talk to them individually. Initially the children were more interested in my recording device than in talking about science, though eventually Darcey decided that science was about “making potions” and Michelle added “and explosions”. Jack suggested “you could make, like, anything out of science, like potions”. Vason came up with “I think science is like trying out something” but did not explain any more.

We talked about whether the children thought they did science at school. Michelle remembered that “in year 2 we did papermaking”. Vason recalled that “we looked at waterproof things”, though not what they actually did, in the previous year. They could not tell me how they had done this, only that “it was fun”. Michelle also remembered “we learnt about how petrol was made and about the heart”. When I asked whether they talked about science at home, Darcey and Jack had used a volcano kit, and Darcey had also made a lava lamp. Vason said that he could have used the work they did on waterproofing, in his Year 2 class, to make a new roof if his had been leaking.

I showed them my four sample bags which again evoked great interest and the children were keen to feel the samples of soil, leaf litter, humus and gravel. We talked about what each sample was and they identified the leaves, though not as litter, despite the fact that we had seen this in the woods previously. Michelle pointed to the bag containing soil and identified it as “soil”. Darcey quickly said “no, that one’s sand it’s gravelly, this is soil” (pointing at the humus). I said “that’s interesting”. What if I tell you that these three bags (humus, leaves and pebbles) make up the fourth bag – soil. So Michelle was right”. Darcey asked “so what is that one?” (pointing at the humus). I explained “that one is called humus, and it is broken leaves. When the insects and worms eat it, it is their waste”. The children recoiled a bit at this saying “saying that is, ugh, so we were touching animal poo”. I remarked that the humus made lovely soil. Darcey said “we had a lot of it in the woods”.

We finished talking at that point as the children were getting very fidgety, after fifteen minutes.
My second interview with the same children took place three weeks after the soil intervention lessons and the analysis of their comments is shown in Table 6.16.

Table 6.16 Feedback of children’s comments after the intervention lessons

<table>
<thead>
<tr>
<th>Categories</th>
<th>Darcey</th>
<th>Jack</th>
<th>Michelle</th>
<th>Vason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Description</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Understanding</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Explanation</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Observation</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Remembering</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Analysing</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Skills</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Recording</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total no. of comments</td>
<td>9</td>
<td>17</td>
<td>9</td>
<td>9</td>
</tr>
</tbody>
</table>

After initial pleasantries, I asked the children to tell me individually about the soil intervention lessons and what they had learnt. At first, there was no response from any of the children, so I asked more specific questions, the first being what the soil was made up of. Darcey responded with “compost”. I asked more probing questions to see if the children could remember the scientific word, and eventually, Michelle recalled the word “humus”, and Darcey and Vason added “bedrock and compost mixed together”. Vason said “there were beetles and things in the soil” (we had found beetles in the woods). I asked what the “beetles and things did?”. Jack replied that “the beetles eat the rock, and stamped on it to break it up”. Michelle said “the beetles ate the animal poo”. I explained how the invertebrates (minibeasts as the children call them), bacteria and fungi break down the litter to make humus. I asked if they remembered looking at the layers in the wood. Michelle recalled “there were dead leaves and things like worms”. I explained the process of humus formation, and that soil was a mixture of humus and rock, which the children all repeated “soil is a mixture of humus and broken down rock from the bedrock” (American term that had been on the video).

As an educator, the findings of this interview were very disappointing as I felt the children had not really recalled much about soil formation. However, they remembered the day as “brilliant”. When the before and after statements are graphed, it can be seen that there is some change to the children’s learning, as shown in Figures 6.14 and 6.15.
Figure 6.14 Statements before intervention in school B (series 1 = knowledge; series 2 = understanding; series 3 = analysis)

Figure 6.15 Statements after intervention in school B (series 1 = knowledge; series 2 = understanding; series 3 = analysis)

Figure 6.14 shows from their responses during the audio-recorded interview that the children have some knowledge about soil. Michelle, in particular, had remembered quite a number of points from the woods. Darcy showed some analysis of soil formation. However, Figure 6.15 shows that after the intervention whilst two of the children had better understanding of the soil process, the other two had not learnt, or were not able to recall anything new. There was no analysis seen in the interview. The conversations may not have revealed the true effectiveness of the intervention, but if these graphs are analysed alongside those from School A, then distinct differences can be seen. These will be discussed in the analysis (8.4.1 p193).

6.9.4 Summary of intervention lessons in school B
My specific objectives for the intervention lessons were the same for School B as previously stated for School A:
- To show the potential of using earth science in primary school teaching
- To help develop primary teachers’ science self-efficacy
- To show the potential of earth science to enrich science knowledge and understanding in primary children
- To show that earth science investigations can develop scientific skills in primary children.

The intervention lessons were devised to address all four of my research questions but specifically Research Questions 3 and 4

- RQ3 Can earth science help primary teachers to be more confident about teaching science?
- RQ4 Can earth science enrich primary children’s science understanding?

From my perspective as a teacher – someone who wants children to learn earth science – rather than as a researcher, I was extremely disappointed with this soil day as it had not worked very well, and I felt that very little if anything had been learnt, or would be remembered. The children were a very different cohort from that in School A, but that was expected. However, I am sure they would have benefited from the initial soil concept cartoon discussion and from the soil story itself, with its repetitive method. For some reason the teachers had decided not to use the programme we had worked on in the CPD sessions, and the lack of helpers exacerbated the issues. The teachers made no comment about why they had not used the teaching methods we had decided on. Perhaps I should have treated this session as a second pilot but the teachers themselves had professed confidence to take the lesson. Another disappointment was that I was not shown any of the follow-up work done by the children, so I can only hope that it has been recorded in some way. I appreciate the difference in that this is a school within an Academy group and so can choose how it teaches (in the sense that it is not subject to the National Curriculum) but feel that the opportunity to achieve some real learning was lost on this occasion. Robyn had stated that the use of earth science in the classroom had added to their ‘woodland’ experience, and there had been a slight increase in the knowledge and understanding of the children who had talked to me in the audio-recording. The children I worked with had learnt several skills: measuring, sieving, observing and weighing as well as working in a team and planning an investigation, albeit on a small scale. Robyn’s final comment below suggests that the intervention was more effective than I had concluded. The children in school B were very different from those in school A, less mature in their focus particularly when working in groups. It seemed that School B had not enabled children in year 3 to carry out investigations on their own.

6.10. Summary of intervention lessons in both schools

The intervention lessons had very different outcomes in the two schools with whom I worked. School A had really incorporated all the CPD materials and ideas, and both the staff and children had benefitted by acquiring new knowledge and skills. The staff also had evidence for assessing the work learnt. This school had been in Ofsted’s ‘special measures’ until 2015, and had worked very hard to improve their science status which had been heavily criticised. The latest Ofsted inspection had removed the ‘special measures’ status but the school still felt the need to improve. I had worked on several earth science projects with the staff to upgrade science in KS2 and the soil project was one specifically identified for my thesis. School B had not felt able to integrate the ideas
from the CPD programme, although they had been very positive about the implementation before the day. The work in the woodland had been useful to the teacher who had used it in class. The feedback from one teacher had been positive, although I felt she was over optimistic; the children had missed out on learning skills, and staff on collecting much written evidence for assessment as in school A. Some children had composed their own soil stories in the IT room, which were evidence of participation in the soil day. There may also have been internal issues of which I was not made aware, which resulted in no extra adult help in the classroom. It was obvious too, that these children were not used to carrying out their own investigations from the way they were unable to organise the sieving investigation. This school recently became an Academy linked with seven other schools in the local area and has not had a full Ofsted since 2011. A short Ofsted inspection in 2016 only looked at learning in English and mathematics which were given the ranking ‘good’. This intervention could have provided some suitable evidence of an effective science lesson had the children’s work been documented. However, In April 2017, I met Robyn and she thanked me profusely for teaching her about soil. She had just run a soil day in her school again, and she said “I used all the things you taught us last year”. She went on to say that the day had been very successful and the children had learnt a lot about soil. This was very pleasing, and I hope their day will develop into a more effective learning experience over time.

Both schools have an Outdoor programme. School A participates in a county run Forest School programme where each class has a half-day session for 6 weeks each year with a qualified Forest School practitioner. School B has its own ‘Outdoor’ programme where each class has a full day for 6 weeks during a year. However, these sessions are organised by the class teacher, who has had a short CPD session on ideas for working in the environment. Earth science in both schools is therefore seen as being an integrated topic, in these programmes it is identified as ‘environmental studies, and recommended as a beneficial teaching approach by the ASE (Hoath & Spring, 2018).

To summarise, in both schools, earth science had been shown to provide an enriching science day for the children. School A now had specific evidence to prove the effectiveness of the intervention lesson. The children in School B had experienced an investigative day in which they were partly able to control their practical data collection.
7 Data collection and findings from secondary data

7.1 Introduction

Secondary data to answer research questions 3 and 4 were collected in the form of evaluation forms devised by the two organisations concerned, the Earth Science Education Unit (ESEU) based at Keele University from 1998-2016 and SATRO based in Guildford, Surrey. Both organisations had given me permission to use these forms and indeed were keen to see the findings. The two research questions using these data being investigated were:

- RQ3: Can earth science help primary teachers to be more confident about teaching science?
- RQ4: Can earth science enrich primary children’s science?

7.1.1 Method of ESEU data collection from CPD primary workshops 2009-2015

The ESEU data were collected during trainee teacher workshops over the period 2009-2015. The workshops were run in a wide range of primary teacher training institutions by their local ESEU-trained facilitator. These various training institutions throughout England had requested a free primary earth science workshop through Keele University. All workshop facilitators had been trained by the ESEU and completed annual updating training, to keep them in touch with new concepts in earth science and curriculum changes, particularly with the introduction of the new primary science curriculum in 2013.

The primary trainee teachers participating in the ESEU workshops were from a range of training institutions across England and were on Teach First, PGCE or BAEd. courses or were in SCITT. The trainees’ backgrounds and ages varied greatly, some were British nationals, others were from overseas, these data do not show the differences. These workshops comprise a series of low-cost, practical investigations and simulations which can take place in any classroom and are each about 90 minutes long. In the workshops, the participants were encouraged to work on as many of the investigations or simulations as they could, in order to gain as much experience as possible during the time available. The facilitator worked with the trainees, responding to theoretical and practical questions as they arose. The participants were asked to evaluate the workshop sessions after they had participated in them and the data and comments from these evaluations, collected by the ESEU, have been made available for analysis in this thesis. The evaluation form (Appendix 6) requested background information about the trainee teacher’s science and earth science training since taking GCSEs and whether the trainee teacher felt confident teaching earth science before the workshop input. Given the large sample size, the evaluation forms used were the first 25% of forms completed for each year, taken from the archive in the order they had been collected at Keele. This is not necessarily the order in which the workshops were taught.

After completing the workshop, each participant was given the resource lists, risk assessments and workshop instructions for the three primary workshops taught, so they could use the materials in their schools immediately and pass the workshop information to their peers. The photograph shown in Figure 7.1 shows trainee teachers investigating soil.
For my pilot study, I gathered data from 125 ESEU evaluation forms for each of the years 2009-2014, this figure was based on 25% of the completed forms for 2009. This provided enough data for the pilot (750 forms) but was not a true sample as the number of forms completed in each year was not the same. I therefore increased the collected data to 25% of the evaluation forms for each year the programme was taught, 2009 to 2015 (1395 forms). The ESEU data are partly in Likert scale form, but the part of the evaluation of most interest to me was the 'comments section' written immediately after the workshop. The ESEU evaluation form requested data in several formats:

- Background information on trainee teachers (these data have been used for the purposes of this thesis)
- Eleven questions to be answered on a Likert scale referring to amount of earth science that trainees may be teaching (most of these data were not used for the purpose of this thesis)
- Participants’ comments about their workshop experience (these data have been used for the purpose of this thesis).

When analysing these data, I transcribed all the comments on the sampled evaluation sheets for determining themes in order to be able to analyse them using thematic analysis (Braun & Clarke, 2006).

7.2 Results of the ESEU data collection

7.2.1 The data
The background information data were extracted from the evaluation forms and tabulated so that different years could be compared as seen in table 7.1.
From Table 7.1 it can be seen that the number of female trainees participating in the workshops is much greater than the number of male participants, who are barely one-fifth of the overall total, in line with Government statistics for 2015 which show that 85% of primary teachers are female (DfE, 2015 p7).

Table 7.1 Compilation background data of primary trainee teachers taken from the data on the ESEU evaluation forms 2009-2015.

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Totals</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of trainees in workshops in year</td>
<td>424</td>
<td>452</td>
<td>688</td>
<td>1252</td>
<td>1196</td>
<td>1164</td>
<td>1144</td>
<td>424</td>
<td>5580</td>
</tr>
<tr>
<td>No. of evaluation forms used in study</td>
<td>106</td>
<td>113</td>
<td>172</td>
<td>313</td>
<td>299</td>
<td>286</td>
<td>106</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>No. of females in study</td>
<td>84</td>
<td>101</td>
<td>189</td>
<td>253</td>
<td>217</td>
<td>233</td>
<td>78</td>
<td>78%</td>
<td></td>
</tr>
<tr>
<td>No. of males in study</td>
<td>22</td>
<td>12</td>
<td>43</td>
<td>60</td>
<td>82</td>
<td>53</td>
<td>28</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>Earth Science studied to 16</td>
<td>13</td>
<td>9</td>
<td>15</td>
<td>29</td>
<td>21</td>
<td>26</td>
<td>8</td>
<td>121</td>
<td>8.70%</td>
</tr>
<tr>
<td>Earth Science studied to 16+</td>
<td>62</td>
<td>73</td>
<td>108</td>
<td>163</td>
<td>149</td>
<td>207</td>
<td>61</td>
<td>823</td>
<td>59%</td>
</tr>
<tr>
<td>Earth science as minor part of degree</td>
<td>17</td>
<td>8</td>
<td>15</td>
<td>39</td>
<td>26</td>
<td>26</td>
<td>3</td>
<td>134</td>
<td>9.70%</td>
</tr>
<tr>
<td>Earth Science as major part of degree</td>
<td>9</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>13</td>
<td>2</td>
<td>1</td>
<td>39</td>
<td>2.80%</td>
</tr>
</tbody>
</table>

The number of trainees who stated they had learnt any earth science or geology during GCSE was 59%. A small amount of earth science was included in GCSE physics/chemistry up to 2014, but the respondents may not have appreciated earth science as a specific topic within the curriculum. These workshops mostly took place before the 2014 changes in the National Curriculum which have now virtually removed earth science from the secondary science curriculum, placing it in geography with a more social emphasis, which means that the next generation of teacher trainee recruits will probably have studied even less earth science, from a science perspective, up to the age of 16. There is, however, more earth science in the primary curriculum from 2014. About 10% of trainees said they had studied earth science / geology after GCSE with some stating it was a minor part of a degree course (approximately 10%) whilst others had studied earth science as a larger part of their degree (2.8%). But overall, few primary trainee teachers in my sample have science degrees (Table 7.2), although it is not necessarily the case that those who do are able to teach science better than their colleagues as they sometimes cannot relate their science studies to the level required in primary school (PSST, 2016).

Table 7.2 Number of trainee teachers with science degrees in workshop

<table>
<thead>
<tr>
<th>Number of trainees participating:</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Totals</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree in biology</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>25</td>
<td>1.8%</td>
</tr>
<tr>
<td>Degree in chemistry</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>0.40%</td>
</tr>
<tr>
<td>Degree in physics</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>0.43%</td>
</tr>
<tr>
<td>Degree in earth science</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0.72%</td>
</tr>
<tr>
<td>Degree in geology</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>
Further data from the evaluation form is shown in Table 7.3 which shows trainees’ confidence in teaching primary science. (Note some teachers were confident in more than one subject.

**Table 7.3 Actual numbers of primary trainee teachers who are confident in teaching primary science**

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Total</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trainees</td>
<td>106</td>
<td>113</td>
<td>172</td>
<td>313</td>
<td>299</td>
<td>286</td>
<td>106</td>
<td>1395</td>
<td></td>
</tr>
<tr>
<td>participating:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching confidence in biology</td>
<td>63</td>
<td>72</td>
<td>114</td>
<td>210</td>
<td>186</td>
<td>233</td>
<td>57</td>
<td>935</td>
<td>67%</td>
</tr>
<tr>
<td>Teaching confidence in chemistry</td>
<td>16</td>
<td>16</td>
<td>20</td>
<td>25</td>
<td>32</td>
<td>36</td>
<td>30</td>
<td>175</td>
<td>13%</td>
</tr>
<tr>
<td>Teaching confidence in physics</td>
<td>21</td>
<td>18</td>
<td>27</td>
<td>46</td>
<td>40</td>
<td>33</td>
<td>22</td>
<td>207</td>
<td>15%</td>
</tr>
<tr>
<td>Teaching confidence in earth science</td>
<td>3</td>
<td>2</td>
<td>10</td>
<td>17</td>
<td>18</td>
<td>12</td>
<td>6</td>
<td>68</td>
<td>4.9%</td>
</tr>
<tr>
<td>Teaching confidence in geology</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>0.40%</td>
<td></td>
</tr>
<tr>
<td>Teaching confidence in all</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>13</td>
<td>0.93%</td>
</tr>
<tr>
<td>No confidence</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>18</td>
<td>10</td>
<td>27</td>
<td>68</td>
<td>4.9%</td>
</tr>
</tbody>
</table>

Since it is difficult to compare the raw data, Table 7.4 shows the same data transposed into percentages.

**Table 7.4 Percentage of trainee teachers who are confident at teaching particular science subjects**

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Average %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of trainees</td>
<td>106</td>
<td>113</td>
<td>172</td>
<td>313</td>
<td>299</td>
<td>286</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>participating:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching confidence in biology</td>
<td>59</td>
<td>64</td>
<td>66</td>
<td>67</td>
<td>62</td>
<td>81</td>
<td>54</td>
<td>65%</td>
</tr>
<tr>
<td>Teaching confidence in chemistry</td>
<td>15</td>
<td>14</td>
<td>12</td>
<td>8</td>
<td>11</td>
<td>13</td>
<td>28</td>
<td>14%</td>
</tr>
<tr>
<td>Teaching confidence in physics</td>
<td>20</td>
<td>16</td>
<td>16</td>
<td>15</td>
<td>13</td>
<td>12</td>
<td>21</td>
<td>16%</td>
</tr>
<tr>
<td>Teaching confidence in earth science</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>4.6%</td>
</tr>
<tr>
<td>Teaching confidence in geology</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0.85%</td>
<td></td>
</tr>
<tr>
<td>Teaching confidence in all</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1.1%</td>
</tr>
<tr>
<td>No confidence</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>18</td>
<td>10</td>
<td>27</td>
<td>5.9%</td>
</tr>
</tbody>
</table>

The data in Table 7.4 show that between 2009 and 2015, 65% of the participants stated they were confident in teaching primary biology, but confidence in teaching chemistry, physics, earth science and geology (the other sciences in the primary science curriculum) was much lower at 14%, 16%, 4.6% and 0.85% respectively. In 2015, however, confidence in teaching biology within the sample, had fallen from a high the previous year, to its lowest level, whilst the same year, 2015, showed an increase in confidence in teaching chemistry and physics. This difference between chemistry and physics, on the one hand, and biology, on the other, may relate to the 2014 changes to the primary curriculum, which reduced the amount of chemistry and physics in the curriculum. Overall, though, a much higher percentage of teachers had
no confidence in teaching primary science in 2015 (25%), a huge increase on previous years, as seen in Figure 7.2.

**Figure 7.2 Bar graph showing overall trainee teacher confidence in teaching primary science from 2009-2015**

If teachers are not confident in their ability to teach a subject, this can often affect their enthusiasm and ability to enthuse their pupils (Aalderen-Smeets et al., 2013). Across the 2009-2015 period, only 1.1% of the trainees stated that they were confident at teaching all of primary science.

Confidence in teaching geology/earth science was low (averaging 5.7% across the 2009-2015 period) before the workshop, as stated by the trainees on the evaluation form (Figure 7.3).

**Figure 7.3 Percentage of teacher trainee participants at ESEU workshops stating they had no confidence in teaching primary science prior to participating in the workshop.**
One worrying feature is that the graph suggests an increasing percentage of primary trainees who state they have no confidence in teaching primary science (Figure 7.3). Since the major increase occurs after the implementation of the new National Curriculum it may be that trainees feel less confident with the new programmes and their assessment procedures.

A Likert scale was used in the CPD evaluation form to ascertain whether the respondents felt the workshop had increased their confidence. All participants indicated that their confidence had increased and many of the comments used in the later analysis stated that their knowledge and understanding had improved.

7.2.2 Trainee comments on the ESEU evaluation forms
The trainees were asked to comment about their workshop experience on the evaluation form. There were 2365 comments from the 1395 participants; these were transcribed and classified into six themes in the following manner, as described by Braun and Clarke (2006). A list was made of all the comments and these were initially grouped under headings (Table 7.5) which were then categorised to form themes. These themes were identified as the main benefits the trainees had identified from the workshop: the practical nature of the investigations and simulations; the engaging nature of the workshops; the usefulness for their own future teaching; the simplicity and availability of the resources used in the investigations and simulations; other positive points; and negative points. The numbers of comments are listed by year and the themes to which they were allocated are shown Table 7.5.
Table 7.5 Composite table of comments and themes from participants about ESEU CPD workshops 2009-2015

<table>
<thead>
<tr>
<th>Comments from evaluation forms</th>
<th>Theme</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pratical / Hands-on</td>
<td>1</td>
<td>46</td>
<td>38</td>
<td>67</td>
<td>81</td>
<td>77</td>
<td>87</td>
<td>24</td>
<td>420</td>
</tr>
<tr>
<td>Models</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Good experiments</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>20</td>
<td>19</td>
<td>14</td>
<td>20</td>
<td>83</td>
</tr>
<tr>
<td>Interactive/investigative</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>17</td>
<td>15</td>
<td>10</td>
<td>2</td>
<td>57</td>
</tr>
<tr>
<td>Useful/valuable/effective</td>
<td>1</td>
<td>10</td>
<td>0</td>
<td>18</td>
<td>40</td>
<td>20</td>
<td>50</td>
<td>1</td>
<td>139</td>
</tr>
<tr>
<td>Interesting/good background</td>
<td>2</td>
<td>15</td>
<td>4</td>
<td>12</td>
<td>40</td>
<td>16</td>
<td>0</td>
<td>18</td>
<td>105</td>
</tr>
<tr>
<td>Engaging/enjoyable/fun</td>
<td>2</td>
<td>23</td>
<td>12</td>
<td>36</td>
<td>39</td>
<td>42</td>
<td>27</td>
<td>9</td>
<td>188</td>
</tr>
<tr>
<td>Fantastic/brilliant/excellent</td>
<td>2</td>
<td>13</td>
<td>17</td>
<td>9</td>
<td>11</td>
<td>23</td>
<td>0</td>
<td>18</td>
<td>91</td>
</tr>
<tr>
<td>Creative/inspiring</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>Presentation/ambience</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Presenter’s knowledge</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>14</td>
<td>33</td>
<td>30</td>
<td>10</td>
<td>92</td>
</tr>
<tr>
<td>Discussion /informal/experiences</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Enthusiasm/passion for ES</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>8</td>
<td>14</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>42</td>
</tr>
<tr>
<td>Answered participants’ questions</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Great teaching ideas</td>
<td>3</td>
<td>16</td>
<td>19</td>
<td>29</td>
<td>62</td>
<td>36</td>
<td>65</td>
<td>20</td>
<td>297</td>
</tr>
<tr>
<td>Good information/concepts</td>
<td>3</td>
<td>17</td>
<td>8</td>
<td>13</td>
<td>30</td>
<td>24</td>
<td>23</td>
<td>14</td>
<td>124</td>
</tr>
<tr>
<td>Useful in class/lesson plans</td>
<td>3</td>
<td>0</td>
<td>19</td>
<td>5</td>
<td>26</td>
<td>35</td>
<td>32</td>
<td>18</td>
<td>135</td>
</tr>
<tr>
<td>Relevant to curriculum</td>
<td>3</td>
<td>0</td>
<td>7</td>
<td>23</td>
<td>13</td>
<td>7</td>
<td>22</td>
<td>6</td>
<td>78</td>
</tr>
<tr>
<td>Right level/easy instructions</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>12</td>
<td>4</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td>Extensions</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Adaptable</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Differentiation</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Good for SEN</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Fits own teaching</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Easy delivery</td>
<td>3</td>
<td>8</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Good vocabulary</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Gives confidence/deliverable</td>
<td>3</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td>18</td>
<td>11</td>
<td>8</td>
<td>5</td>
<td>56</td>
</tr>
<tr>
<td>Cross curricula links</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Misconceptions</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Relates to real world</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Correlates life skills</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Improves thinking skills</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Evokea curiosity/insightful</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Improves understanding</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>18</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>Improves own knowledge</td>
<td>3</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Useful resources</td>
<td>4</td>
<td>18</td>
<td>15</td>
<td>9</td>
<td>14</td>
<td>27</td>
<td>26</td>
<td>11</td>
<td>120</td>
</tr>
<tr>
<td>Good CD ROMs</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td>Clear explanations</td>
<td>4</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>Knowledge giving/good info.</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Not overloaded</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Too short</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>16</td>
<td>1</td>
<td>7</td>
<td>2</td>
<td>30</td>
</tr>
</tbody>
</table>

The themes are identified below and shown as a graph in Figure 7.4.

- **Theme 1 Practical**: 705 comments relating to effectiveness of practical activities and investigations, and the usefulness of the CPD in the classroom.
- **Theme 2 Engaging**: 578 participants’ comments about how workshops would be received by primary children and learning points which could be made.
- **Theme 3 Teaching**: 856 comments about the ease of delivery, use of good vocabulary, differentiation uses, level of approach, clarity of explanations.
- **Theme 4 Resources**: 155 comments related to the simplicity, availability and inexpensive use of everyday items for the investigations and simulations.
- **Theme 5:30 positive comments including ones on length and timing of the CPD workshop, and how the participants felt towards teaching earth science after the workshops.
- **Theme 6**: 41 negative comments including those from participants who did not intend to use the exercises in their classes.
In the ‘practical’ theme, trainees’ comments stated that the workshop sessions provided effective simulations and hands-on practical investigations that were both interactive and investigative. Trainees felt these investigations would appeal to the children’s imagination and that pupils would identify with the concepts from the investigations, thus dispelling alternative conceptions, evoking curiosity and improving thinking skills and knowledge and understanding. This can be seen as effective pedagogy, enabling learning. The workshops gave ideas for making a simple water cycle model; practical activities to show how soil erosion could be curtailed by vegetation; and using a piece of guttering to replicate a river’s flow, simulating relevant experiences that children may experience in their local area.

The ‘engaging’ theme brought together the trainees’ comments about their feelings of working on the earth science investigations and how they thought these investigations and simulations would run in their primary classroom. They also commented that the investigations would provoke discussion and the asking of many questions, again invoking effective learning pedagogy as children would recall the practical side of the investigations and working together.

The ‘teaching’ theme included points about the good vocabulary, the ease of delivery, and the fact that the experiments could be differentiated for differing abilities. Using scientific language in an appropriate setting was an important point made; children could visibly see evaporation and condensation in the water cycle simulation, and permeability could be measured in the rock and soil investigations. Trainees felt that they could use the workshop materials in their own teaching and use them for cross-curricular purposes as well.

The ‘resources’ theme recognised that these investigations could be carried out using simple equipment made from everyday items, for example, lemonade bottles and coffee filters. It also acknowledged the usefulness of the CDROM which contained all the necessary investigative ideas and risk assessments.

Some of the positive points raised were the clear explanations given by facilitators, and the fact that the materials could easily be differentiated and also used for SEN work.
The subject knowledge input was appreciated as was the discussion which arose during the workshop, as all the facilitators would endeavour to explain the scientific concepts behind some of the practical investigations and simulations. Negative points that were made were on the length of the CPD (too short) and the need for more KS1/EYFS resources, despite the CPD being advertised for KS2 trainees.

Overall, the feedback was positive with few negative comments. The comments received from the trainees about the ESEU workshop were very encouraging and shows what a well-designed short CPD session can achieve. Trainee Teacher comments on how they will use their newly gained knowledge are shown in Figure 7.5.

**Figure 7.5 Comments on how the CPD will be used**

![Trainee teacher comments on how CPD will be used](image)

**7.2.3 Identifiable pedagogy within the ESEU workshops**

CPD of this nature can greatly enhance a trainee’s pedagogical content knowledge by providing ideas on how to teach concepts, increasing the trainees’ self-efficacy and hence the likelihood that they would use the material in their teaching. Various off-the-cuff comments from participants after a workshop have been “Oh good, I have to teach soils/rocks in my next teaching practice, so now I know what to do” and “I wish we had had this workshop before my last teaching practice as I had to teach about rocks and soils and really did not understand it, but I do now”.

The workshops offer opportunities for discussion and questioning, and for pupils to develop the investigative ideas offered in different ways, to answer their own queries. For example, using the investigation simulating coastal erosion, pupils can change the wave direction and strength, the size of material being moved by the waves and the cliff material composition (more clayey, sandy, gravelly). These different simulations can be linked to real life examples happening around the British coastline, making them very relevant to where the children live or their holiday experiences. Learning becomes more accessible and connected through noticing the changes in a practical manner, and children can explain the erosion concepts from their observed understanding. Children give verbal feedback from their visual experiences, and playing with sand and water has a ‘wow’ effect which may well be remembered. All the investigations offered in the ESEU CPDs enable a range of concepts to be examined and taught, which,
when investigated at a simple level, applicable to the age of the participants, provides a motivating and therefore hopefully lasting impression.

Trainees commented that providing concrete experiences using local resources would benefit their teaching, as suggested by Fitzgerald (2012). The workshops continually promoted the use of local soils, rocks and fossils and examples relating to the 'real world'. The simulations offered models to help understand concepts such as the water cycle, a difficult idea for children to grasp. The CPD provides effective teaching and learning as well as opportunities to assess children’s progress through their oral or written understanding.

The trainees identified ways that they would use their CPD session when in school. A number believed they would be able to use the material directly, during teaching practice. Some also stated that they would have liked to have had the resources and ideas earlier so they could have used them when on teaching practice. Other trainees felt they could modify the ideas to fit their teaching programmes, whilst others said they would share these ideas and use them for planning future work.

The themes categorised by the trainee teachers relate closely to those identified by Guskey (2000) as being important outcomes for an effective CPD. Guskey suggested that CPD can be evaluated at five levels of outcomes:

- level one: participant reactions
- level two: participant learning
- level three: organisational support and change
- level four: participants’ use of new knowledge and skills
- level five: student learning outcomes.

Levels one, two and four are applicable here.

Level one, participant reactions, can be identified through all the positive and negative statements made by the participants after the CPD (Table 7.5). Of the 49 different points identified, only four are negative, showing that the statements made over the 2009-2015 period indicate positive reactions.

Level two, participant learning, is indicated within the themes in a number of places, not just under ‘knowledge giving’. For example, comments such as ‘good information given’, ‘answered participants’ questions’, and ‘discussion/informal experiences' all suggest learning.

Level four, participants’ use of new knowledge and skills, has been graphed in Figure 7.5 and identifies how the participants say they will use the CPD information.

Since these were only trainee teachers participating in the CPD, they had no way of influencing their organisations (level three) or of knowing student outcomes (level five) at the present time.

At the end of the workshop, each primary trainee was given a USB stick, which held a complete set of the materials and instructions used in the workshop, linked to references in KS2 primary science curriculum. This gave rise to the following comments: that the instructions had “clear explanations”; the activities were “instantly
available to use in the classroom because of the ease of obtaining resources”; and they gave “good knowledge in a format useful for children and trainees”.

7.3 Discussion of the ESEU CPD results

The results from the analysis of the comments show that participants’ feelings towards the workshops were overwhelmingly positive with very few negative comments (1.7%). The CPD provided subject content knowledge (SCK) and the pedagogical content knowledge (PCK) for teaching earth science for trainees with little or no science background, enabling them to use scientific ideas confidently. Trainees stated that the provision of resource materials such as the CDROM, which contained all the investigations and risk assessments would be very useful when teaching this section of the primary science curriculum. Informal discussion revealed that trainees were thinking further than the given ideas, and in fact using the CPD as a starting point for other topics in the primary curriculum; for example, the simulations of coastal erosion, river processes and water cycle can be linked to geography, history, biology, design and technology. This makes the time spent on one CPD time well used.

The main themes identified by the participants – practical, engaging, teaching and resources – all relate to sound pedagogical practices as identified in the ten TLRP principles of effective pedagogy (James & Pollard, 2011). The theme ‘practical’ embraces interactive, investigative practices, which are valuable and effective. The trainee teachers were motivated and stated under the engaging theme that there was scope for questioning and discussion leading to higher thinking and critical thinking. The’ teaching’ theme entailed identifying misconception, use of appropriate vocabulary, adaptability and differentiation activities, evoking curiosity and insightfulness, as well as being suitable for planning and later assessment.

As already suggested the workshop identifies with those points identified by Guskey as being effective CPD outcome levels. The CPD is therefore seen to be an effective teaching strategy in in its design and delivery by its participants, providing an applicable short workshop when using Guskey’s criteria.

A further piece of research which looked at the impact of focused CPD on teachers’ subject and pedagogical knowledge was undertaken by Scott et al (2010). These researchers stated that where CPD was domain-specific and teachers were able to focus on learning, teachers found the CPD effective and useful. Many respondents in this survey said that they would use the pedagogical ideas in their teaching and that the CPD had provided additional subject content knowledge they could use. Scott et al (2010) looked specifically at secondary physics and chemistry short CPD provision, because of the shortage of secondary physical science teachers. King and Thomas (2012) evaluated short earth science CPD intervention workshops for secondary teachers with similar conclusions. My research suggests that these primary earth science CPD workshops were as effective as these secondary workshops in providing both pedagogical and subject content knowledge.

The ESEU primary teacher trainee evaluation forms had not previously been investigated although analysis of the CPD impact on secondary science teachers and science trainee teachers had been undertaken (Lydon & King, 2009). That analysis of the secondary CPD showed that even though some of the research literature concludes that short-term CPD is not effective, the ESEU CPD led to increases in
knowledge and understanding, at least as stated by the participants. Further, a follow-up postal survey of participating secondary teachers carried out a year after the CPD indicated that teacher practices had changed, indicating long-term benefits from these short CPD workshops (Lydon & King, 2009).

The findings from the primary evaluation forms indicate that the workshops given to primary teacher trainees were well received. Comments suggest that the trainee teachers intended to use earth science in their primary science work because they saw it as being relevant to their pupils’ everyday lives. King and Thomas (2012) calculated the impact secondary ESEU short CPD workshops had on the number of trainee teachers, teachers and, using a multiplier gauge, number of students. My research shows how the primary education sector benefitted too, with some 700 primary teachers attending workshops between 2008-2011 (ESEU data), who could influence some 18,000 primary pupils annually. The total number of trainee teachers who had attended the workshops between 2009 and 2015 was 5580 (ESEU data). The large majority of these trainees would be teaching pupils in the coming years, adding to the number benefitting from the CPD.

The trainee primary teachers said that the materials fitted in well with their approach to teaching and were relevant to the curriculum. Harlen and Elstgeest (1992) stated that it is important that teachers have their own understanding of a subject before they teach it, or explain it to their colleagues. These workshops provide that understanding at an appropriate level for primary science. Unfortunately, it was not possible to follow up with a postal survey of the trainees’ teaching practices, as was done for the secondary workshops, since the trainees completed the activities whilst not in permanent employment in schools, the time that has elapsed since the training took place is too great, and contact details are not available.

Overall, the evaluation from these workshops suggests that the trainee teachers will use the materials to the benefit of their primary pupils with confidence. This evaluation shows that the workshops are fulfilling a need, by offering relevant subject and pedagogical knowledge and do increase confidence in teaching primary science. The trainees were devising their own plans for implementing these investigations, which will surely enrich their teaching, not just in earth science but by relating the concepts they had learnt to the overall science curriculum.

7.4 Method of SATRO data collection and findings

7.4.1 Introduction
The primary science workshops on rocks and soils have been delivered by me through SATRO for around fifteen years and are still popular with schools, the workshops being requested annually by up to ten schools despite the fact that they are no longer government-funded. The newer fossils workshop was devised to assist teachers with the latest changes in the primary science curriculum and has been running for over five years. Some schools in Surrey have been fortunate enough to have sponsorship from large national companies with headquarters in the county. Many of these companies were petroleum-based, and offered to pay for primary earth science workshops delivered by SATRO. Five schools have received this sponsorship for several years. One company also paid for the development of a fossils workshop, which has since been used within and outside the county. The primary SATRO data were taken during 2013-15 from the evaluation forms (Appendix 7) completed at workshops that I taught:
‘Rocks and Soils’ and ‘Fossils’. Mostly, the workshops were delivered to year 3 and year 5 pupils aged 7-8 and 9-10, respectively. Permission to use the data was given by SATRO.

Teachers often request these workshops as they are generally not au fait with the subject and have difficulty sourcing appropriate accurate materials at the right level for years 3 and 5. As I taught the children and teachers on these workshops, my involvement here extended beyond researcher to educator as well. It is largely because of my experiences in these roles that I am so intrigued by the issues surrounding primary science teaching and learning.

7.4.2 Method
All these workshops comprised practical activities with each child having examples of rocks, soils or fossils to examine and write about. The facilitator (in all cases myself) initiated all sessions with discussion about the children’s prior knowledge. Sometimes the children completed an individual ‘bubble’ diagram but more often a composite class record was kept on the computerised class whiteboard or as a floor map (Figure 7.6). These were completed at the end of the session. The individual bubbles enabled the teacher to assess each child’s learning, whilst the composites allowed the teacher to assess the effectiveness overall of the workshop.

Figure 7.6 A composite floor map of children’s ideas about rocks before (in pink) and after (in blue) workshop.

A range of different pedagogical practices were built into the rock and soil workshops; these included questioning and discussion, the opportunity for assessment and feedback from both teachers and pupils. The workshops were designed to engage pupils as they each had their own rock samples to work with. After the initial discussion to ascertain prior knowledge, each child was given a rock sample. The workshop began with observation of the colours seen in the rock. All colours identified by the children were written on the whiteboard, and classified by me into mineral groups. I explained the difference between rocks and minerals.

The children had a sheet with nine different rock characteristics to be observed for each sample. Initially, the class worked as a whole, but after being shown how to
identify certain characteristics, the children were encouraged to record their own observations, help being at hand when needed. The children completed a chart of characteristics of the first rock, identifying the minerals they could observe in their sample from the list on the whiteboard. Once all the characteristics required had been noted, I gave the children the name of the rock and we discussed its use in everyday places, each child noting where they might have seen a similar rock used. It was emphasised that each child’s own observation was acceptable so long as they would be able to identify the same rock again from their own observations.

The children went on to describe a second rock in the same manner as before, though this time with less help from me, although we discussed various characteristics as a class. The use of each rock and where it might be found was discussed before a new sample was handed out. We identified four different common rocks in this way, and talked about their economic use. At the end of the session, I showed the class a range of minerals, linking them to the rocks we had identified. I also showed other metallic minerals and answered questions from the children about their use, where they could be found and how valuable they were.

Soil sessions revolved around the soil story and the investigations used in the intervention lessons (as discussed in Chapter 6). Because of time constraints, it was often only possible for me to tell the soil story with a simple demonstration and the investigations were carried out later by the teachers. The fossils workshops outlined fossil formation and evolutionary changes, with the children handling specimens and making models of the evolutionary changes occurring in ammonites. The workshops were designed to cover the points outlined in the year 3 and 5 primary science National Curriculum. An evaluation form devised by SATRO for the sponsoring companies was completed at the end of the workshops and can be found in Appendix 7.

7.5 Results of the SATRO workshop evaluation

7.5.1 Evaluation of prior knowledge of rock workshop
The prior knowledge about rocks of each class was obtained by children completing an individual bubble or a whole class bubble diagram. The class diagrams were compiled on the class whiteboard or on a large sheet of paper on the floor. Both class teacher and facilitator wrote the children’s comments around the bubble. At the end of the workshop, the procedure was repeated in a different coloured pen, so that the teacher would be able to see and assess all the changes as seen in table 7.6.
Table 7.6 Comments from one group about rocks before and after workshop by Year 3 (age 7-8)

<table>
<thead>
<tr>
<th>Before workshop comments</th>
<th>After workshop comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>hard</td>
<td>rough</td>
</tr>
<tr>
<td>soft</td>
<td>smooth</td>
</tr>
<tr>
<td>thin</td>
<td>weak</td>
</tr>
<tr>
<td>fat</td>
<td>grains</td>
</tr>
<tr>
<td>spiky</td>
<td>crystals</td>
</tr>
<tr>
<td>big</td>
<td>layers</td>
</tr>
<tr>
<td>small</td>
<td>granite</td>
</tr>
<tr>
<td>colours</td>
<td>slate</td>
</tr>
<tr>
<td>made of different things</td>
<td>sandstone</td>
</tr>
<tr>
<td></td>
<td>not permeable</td>
</tr>
<tr>
<td></td>
<td>minerals</td>
</tr>
</tbody>
</table>

The comments show that prior to the workshop the children used adjectives generally relating to descriptions of colour and size, descriptions that can be classified as level 1 in SOLO understanding. However, one comment was more scientific – “made of different things” – showing some understanding of a rock and its attributes (SOLO level 2). There were no real ‘misconceptions’ as such, although the children really did not state any facts about rocks, using mainly descriptive words. The comments made after this workshop are more explanatory; the children have recalled the scientific vocabulary used in identifying the characteristics of the different samples: permeability, particles, minerals and more specific descriptions of texture and composition. They have remembered some of the names of the rocks examined. Many children also remembered the uses made of different rocks, although these were not recorded by the teacher within the time available. These comments are certainly at a higher level of understanding than the pre-workshop points and effective learning could be measured using either the SOLO or Bloom’s taxonomy. This list was compiled in less than five minutes, but I would expect more points to be made if there was a longer time allowed. Lunch break curtailed more discussion. Had the children completed individual diagrams, the teacher would have been able to assess their individual learning. In this case, however, the teacher felt that the workshop had been effective in getting the children to observe, record, analyse data and use scientific vocabulary properly. The workshop had engaged the children, including some pupils normally more difficult to motivate. The teacher also identified an autistic child who became very involved in the workshop, an unusual occurrence. However, it must be stated that children often respond favourably to an outside visitor and will work more readily with them.

7.5.2 Pedagogy involved in the rock workshop
The teacher of this group of pupils had not previously tried to identify prior knowledge, and was surprised at how much the children could recall an hour after the workshop had finished. The effectiveness of the lesson could be seen through the children’s understanding of scientific terminology like texture, strength, composition, e.g. grains or crystals, and permeability. It could also be judged by what the children remembered after the workshop. It would have been interesting for me to return at a later date to each school to ask the classes what they could remember about rocks, to see how lasting the lesson effect was, but this was not possible due to the large number of workshops given and time restraints. Reports from the teachers, however, suggested that pupils recalled much of the work they had done when revisiting the topic at a later date. The workshop used materials that the children identified with, showing how
valuable earth science can be for learning scientific skills using relevant resources. A range of different questioning techniques had been used, including Socratic questioning, probing the children’s thinking as to why rocks would or would not be permeable, and why they would be suitable for specific purposes, e.g. the use of slate for roofing and granite for paths. The children had discussed points raised between themselves and with me and predicted the permeability of rocks from a critical thinking perspective. They understood why the rocks were permeable because they could observe the structure of the rock, being able to differentiate between grains and crystals. The teacher had intimated that the children would write up their experiences in their WALT diaries, so she would be able to assess their knowledge and understanding. It would have been possible to analyse the diaries using SOLO taxonomy had the children written down their individual prior knowledge, which other classes participating in these workshops occasionally did.

7.5.3. Evaluation of the prior knowledge of the fossil workshops
The children’s comments prior to the fossil workshop show some factual knowledge about fossils but those comments made after the workshop not infrequently show more knowledge and understanding of processes as seen in Table 7.7.

Table 7.7 Children’s ideas about fossils and fossilisation before and after workshops, yr 5 age 9-10

<table>
<thead>
<tr>
<th>Ideas before workshop</th>
<th>Ideas after workshop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sticks can be fossilised</td>
<td>Bodies get covered up by ash to become a fossil</td>
</tr>
<tr>
<td>Fossils come from animals</td>
<td>Bodies can be covered by: ash, sand, mud, avalanches, tar, peat bogs to become fossils</td>
</tr>
<tr>
<td>Fossils are bones in the ground that become solid</td>
<td>Traces e.g. droppings are fossils</td>
</tr>
<tr>
<td>Fossils have patterns on them</td>
<td>Not only animals but plants can be fossils</td>
</tr>
<tr>
<td>Fossils are bones encased in rocks</td>
<td>Fossils can show us changes over time</td>
</tr>
<tr>
<td>Fossils are quite rare</td>
<td>Dinosaurs did live</td>
</tr>
<tr>
<td>Skeletons can get imprinted</td>
<td>Nautilus has survived</td>
</tr>
<tr>
<td>Animals die and get carved into rocks</td>
<td>To be fossilised you need to be covered up by mud or ash</td>
</tr>
<tr>
<td>Fossils are dinosaurs squished by rocks</td>
<td>Plants can become fossilised</td>
</tr>
<tr>
<td>Fossils are bones indented in rocks</td>
<td>There were at least 62 different ammonites</td>
</tr>
<tr>
<td>Fossils are bones with cement stuff over them</td>
<td>We can tell something about the fossil animal by looking at its poo</td>
</tr>
<tr>
<td>Fossils are inside our bodies making the shape of the bones</td>
<td></td>
</tr>
<tr>
<td>Fossils can get washed up on the beach</td>
<td></td>
</tr>
<tr>
<td>Fossils are from ancient times</td>
<td></td>
</tr>
<tr>
<td>Some fossils have squirley things in the middle</td>
<td></td>
</tr>
<tr>
<td>Fossils are in statues</td>
<td></td>
</tr>
</tbody>
</table>

(NB some of the ‘before’ statements manifest misunderstandings)

These responses can be assessed through the concept of SOLO taxonomy, where the children are moving into level 2 and 3; for example, pupils are stating multiple ideas and relating these ideas to ways of becoming fossilised. They are suggesting explanations – “fossils can show us changes over time” being one example. Analysing these comments using Bloom’s Taxonomy, it can be seen that responses are moving up Bloom’s hierarchical diagram, no longer just remembering but moving through understanding into application, which is a promising development at this age. These comments suggest that the pedagogical strategies that had been put in place in the workshop enabled learning to be effective.
The outcomes of both of these workshops were seen by the teachers to have been effective because the children had more understanding and knowledge about rocks and fossils. Hardman and Luke (2017) also found that teaching about fossils and rocks in primary school really engaged children. They Hardman and Luke) suggested that discovery lessons based on rocks and fossils really did have a ‘wow’ factor, reiterating the findings from my workshops.

7.5.4 Results of the workshop evaluation forms
Evaluation forms were completed by the children after every workshop, rocks and soils or fossils. This form was a standard SATRO evaluation form, not constructed by me (see Appendix. 7). It consisted of two parts. In the first part, children were asked to respond to four questions with either a ‘yes’ or ‘no, tick or cross response or a smiley/scowling face; their responses are shown in Table 7.8. 198 children completed the forms. The four questions asked were:

- Have you learnt more about science in this workshop?
- Has it been helpful working with a partner?
- Would you like to become a scientist or engineer in the future?
- Did you enjoy working with the guest scientist facilitator?

<table>
<thead>
<tr>
<th>Questions asked</th>
<th>% replying yes</th>
<th>% replying no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you learnt more about science?</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Was it helpful to work with a partner?</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Would you like to be a scientist or engineer in the future?</td>
<td>46</td>
<td>54</td>
</tr>
<tr>
<td>Did you enjoy working with the scientist facilitator?</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

This quick evaluation gives an overview of the children’s initial thoughts about the workshop and suggests that the children found the teaching environment relaxed enough for them to be able to ask questions and not feel intimidated by me, as facilitator, or other helpers in the room.

The children were also asked to state their feelings about the workshop but were only given five minutes to write their comments, not long for children aged 7-8. These comments frequently included such phrases as “I feel more confident about science”, “good explanations”, “I understand science more now” and “I feel happy about science”. The full range of comments is shown in Table 7.9 The responses have been grouped in order to be able to analyse them thematically (Braun & Clarke, 2006)
Table 7.9 Composite response data from SATRO rock and soil workshop participants 2013-15

<table>
<thead>
<tr>
<th>FEELINGS (191/338 responses) 56%</th>
<th>LEARNT MORE ABOUT SUBJECT (65/338 responses) 19%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happy</td>
<td>Learnt a lot</td>
</tr>
<tr>
<td>Excited</td>
<td>Increased confidence in science</td>
</tr>
<tr>
<td>Fun</td>
<td>Good explanations</td>
</tr>
<tr>
<td>Very good 6</td>
<td>Enjoyed learning</td>
</tr>
<tr>
<td>Liked</td>
<td>Understood more</td>
</tr>
<tr>
<td>Loved</td>
<td></td>
</tr>
<tr>
<td>Enjoyed</td>
<td></td>
</tr>
<tr>
<td>Great</td>
<td></td>
</tr>
<tr>
<td>Comfortable</td>
<td></td>
</tr>
<tr>
<td>Amazing</td>
<td></td>
</tr>
<tr>
<td>Feel like a scientist</td>
<td></td>
</tr>
<tr>
<td>Cheerful</td>
<td></td>
</tr>
<tr>
<td>Smart</td>
<td></td>
</tr>
<tr>
<td>Enthusiastic</td>
<td></td>
</tr>
<tr>
<td>Joyful</td>
<td></td>
</tr>
<tr>
<td>Best day of life</td>
<td></td>
</tr>
<tr>
<td>Special</td>
<td></td>
</tr>
<tr>
<td>Glad</td>
<td></td>
</tr>
<tr>
<td>Tingly</td>
<td></td>
</tr>
<tr>
<td>Pleased</td>
<td></td>
</tr>
<tr>
<td>Awesome</td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>Brilliant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total number of responses 338</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROVOKED INTEREST IN SUBJECT (55/338 responses) 16%</th>
<th>CONSIDER SCIENCE AS A CAREER (26/338 responses) 8%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interested</td>
<td>Want to be a scientist</td>
</tr>
<tr>
<td>Want to find out more</td>
<td>Want to be archaeologist</td>
</tr>
<tr>
<td>Feel good</td>
<td></td>
</tr>
<tr>
<td>Felt clever</td>
<td></td>
</tr>
<tr>
<td>Liked more</td>
<td></td>
</tr>
<tr>
<td>Discovered</td>
<td></td>
</tr>
<tr>
<td>Inspired</td>
<td></td>
</tr>
<tr>
<td>Made me work</td>
<td></td>
</tr>
</tbody>
</table>

| NOT INTERESTED IN WORKSHOP (1/338 response) >1% | | |
|------------------------------------------------|------------------------------------------------|
| Not happy                                       | Total number of responses 338                     |

The responses clearly show that the children had been motivated by the workshop even if they were not very positive about a science or engineering career as shown in Table 7.8. They all felt they had found out something about rocks or fossils that they did not previously know. The workshop was interactive, enabling the children to ask questions, and included a great deal of discussion about the rocks, between the children and their learning partners and with me either at whole class or individual level. If a child raised a suitable question that I felt everyone should think about then the whole class was asked to discuss the point. The children were intrigued by using magnifiers to look at the rocks as can be seen in Figure 7.7.
7.5.5 Thematic analysis of children’s workshops on rocks and soil and fossils

The second part of the evaluation form asked the participating children to describe their feelings about science after the workshop as written comments and these as seen in Tables 7.9 and 7.10 separated into groups which allow the comments to be analysed thematically.

**Table 7.10 Composite response data from SATRO fossil workshop participants 2013-2015**

<table>
<thead>
<tr>
<th>FEELINGS (44/144 responses) 31%</th>
<th>LEARNT MORE ABOUT SCIENCE (37/144 responses) 26%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exciting</td>
<td>Learnt a lot</td>
</tr>
<tr>
<td>Fun</td>
<td>More confident about science</td>
</tr>
<tr>
<td>Enjoyed</td>
<td>Helped understanding</td>
</tr>
<tr>
<td>Liked</td>
<td>Lots more to learn</td>
</tr>
<tr>
<td>Inspired</td>
<td>Explained a lot</td>
</tr>
<tr>
<td>Great</td>
<td>Discovered ideas</td>
</tr>
<tr>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Feel old, gone back in time</td>
<td></td>
</tr>
<tr>
<td>Epic</td>
<td></td>
</tr>
<tr>
<td>Now feel enthusiastic</td>
<td></td>
</tr>
<tr>
<td>Happy</td>
<td></td>
</tr>
<tr>
<td>Amazed</td>
<td></td>
</tr>
<tr>
<td>Feel better about science</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>PROVOKED INTEREST IN SUBJECT</td>
<td>CONSIDER SCIENCE AS A CAREEER</td>
</tr>
<tr>
<td>(62/144 responses) 43%</td>
<td>(1/144 response) 0.7%</td>
</tr>
<tr>
<td>More interested in science</td>
<td>Want to be a palaeontologist</td>
</tr>
<tr>
<td>Want to collect, will look on</td>
<td></td>
</tr>
<tr>
<td>beaches</td>
<td></td>
</tr>
<tr>
<td>Want to know more</td>
<td></td>
</tr>
<tr>
<td>Like science more than before</td>
<td></td>
</tr>
<tr>
<td>Love science</td>
<td></td>
</tr>
<tr>
<td>Excited about learning science</td>
<td></td>
</tr>
<tr>
<td>More to science than had thought</td>
<td></td>
</tr>
<tr>
<td>Not boring</td>
<td></td>
</tr>
<tr>
<td>Made me curious</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>NOT INTERESTED IN WORKSHOP</td>
<td>Total number of responses 144</td>
</tr>
<tr>
<td>responses</td>
<td></td>
</tr>
</tbody>
</table>
When analysing these data, I have transcribed all the comments on the sampled evaluation sheets for determining themes, as described for the ESEU data. There were 338 written responses to the rock and soil workshops, and 144 for the fossil workshops (the full comments written by the children can be seen in Appendix 8). These responses were categorised into five themes. On reading through the responses, they fell into different clusters, some children described how they felt after the workshops, others stated they had learnt more about rocks and soils or fossils. A third group of children indicated that the workshops had provoked interest in the subject, whilst a few children said they were now interested in science as a career. Very few children had negative feelings about the workshops. These clusters of responses were allocated to themes (Braun & Clarke, 2006). The purpose of theming the data was to identify patterns so that the overall effectiveness of the workshop can be gauged. All primary teachers need to be sure that time is spent as effectively as possible and that learning outcomes are achieved. From their viewpoint, effective time is when specific parts of the science National Curriculum are being covered. From SATRO’s point of view, the purpose of delivering these workshops is to motivate children about science and encourage them to think about science as a career. The companies sponsoring the workshops in the schools have a vested interest in encouraging children to think about science careers at an early age in the hope that if they become enthused by earth science at this level they may develop into future employees.

The responses from both Figures 7.9 and 7.10 were categorised into the following themes:

- Feelings about the science and the workshop
- Whether the respondent had learnt something new
- Whether the workshop had provoked interest in science
- Negative points about the workshop
- Whether science might now be considered as a career.

The percentages for each category were calculated for both workshops to facilitate comparisons between comments, and the results are shown in Figure 7.8.

**Figure 7.8. Themed pupil comments about the rock and soil and fossil workshops**
Since there were fewer fossil than rock and soil workshops, it is more suitable to use percentages as a comparison of the workshops. The workshops gave rise to a variety of responses identified as ‘feelings’ which describe how the children said they felt immediately after the workshops. The sessions obviously stimulated and enthused the children enough for them to express their enjoyment, bearing in mind these were mainly year 3 (aged 7-8) pupils. There were 191 rock and soil ‘feelings’ responses and 44 fossil ‘feelings’ responses. Two of the pupils went as far as to state “this was the best day of my life!” (see the full list of comments are shown in Appendix 8). Words such as ‘awesome’ and ‘epic’ were used by the children to identify their feelings. A higher percentage of the children expressed their feelings about the rocks and soils workshops compared with the fossils workshops in which a greater percentage of the children commented that the fossils had provoked their interest. However, since generally the children made just one comment about the workshop overall, it is noteworthy that their interest in fossils provoked more curiosity about science than did rocks and soils.

The second theme related to comments indicating that the children felt they had learnt something new from the workshops, many stating they had learnt “a lot”. Within this theme, 6% of the comments specified that the workshops had made them feel more confident about science, perhaps because they were being encouraged to talk about their samples. By working with a partner, they were discussing what they could see and their observations were accepted by their partners and often the other children sitting on the same table. For example, if one child said they could see ‘gold’ in their sample, the other children would all look at their samples to check and discuss why some samples had ‘gold’ and others did not. This discussion often became a full class discussion, with many differing ideas arising, many of which were possibilities. All observations were debated and deliberated over before a sample was identified. Several children said “I felt like a scientist” because they were discovering concepts they had not come across before, e.g. the permeability of rocks. Again, fossils triggered more responses, some 29% against the 18% who felt they had learnt more during the rock and soil session.

The next group of comments (provoked interest: 16% for rocks and soil and 49% for fossils) showed that the workshops had inspired pupils to want to know more about science and that they had become interested in both topics. Fossils, in particular, caught the children’s interest and of the 126 children who took part in the fossil workshops half of them stated that they now had an interest in finding out more about fossils and might make their own collections. Children had not appreciated that fossils could easily be found locally in chalk and limestone rocks, in gravels and in the stone facings on many buildings.

Interestingly, more children (24) who worked on the rocks and soils workshops stated that they would consider becoming earth scientists, than they thought they might consider a career using fossils (one child). The final theme shows that very few children’s interest was not captured – fewer than one child per workshop, seven overall. At this age children are generally truthful and say whether they enjoyed something or not.

Each workshop was also evaluated by the teacher, teaching assistants, other volunteers and the children, and changes made where necessary to keep the session in line with the National Curriculum (DfE, 2014) and teaching requirements. I feel...
therefore that this was a valuable lesson, using easily available earth science resources, relevant to the age group being taught. Learning is shown to have been effective, and assessment of progress can be recorded. This workshop fulfils many pedagogical requirements.

Several teachers remarked that they too had learnt a great deal from the workshops and felt more confident about teaching this section in the future. All the notes that had been made during the sessions had been recorded on the whiteboards for later use. The teachers were very positive about having enough samples for each child to be able to use, which they felt was an excellent teaching strategy. They commented on the use of appropriate science vocabulary and the suitability of the words used to explain different concepts in understandable language, “much easier than in the textbooks” one teacher told me after the workshop.

Increasingly, teachers are taking part in these SATRO workshops, rather than just observing, completing the rock observation sheet, and saving the fossil presentation and investigation work carried out on the whiteboard for future use. A distressing point is that many schools have purchased expensive cases of individual rock samples which are of little use in a primary classroom. I believe it is important that a set of 30 plus samples of each rock is available so that each child can have a piece to handle and thus make their own individual observations. Often, a highlight of the rock workshop is my showing the children a collection of minerals, many of which are components of the rocks they have been investigating. This part of the workshop always elicits plenty of questions. At the end of the fossil workshops, too, I am able to show the children examples of fossils I have collected. Frequently, the children bring their own samples to the session and we discuss these, with each child showing their sample to their peers and describing what it is. This provokes more interest and the teachers are always surprised how knowledgeable some of their less able pupils are about their collections.

My main conclusions from the evaluation of these workshops are that both the children’s remarks and their teachers’ oral comments suggest that the workshops were effective in that the children had learnt something about rocks and soils or fossils through a range of pedagogic techniques. Moreover the children had used a number of skills during these workshops, namely observation and recording skills. Furthermore, the teachers found the workshop useful and informative and incorporated scientific language previously not used. The workshops provide evidence to contribute to the answer to Research Questions 3 and 4, showing that such earth science workshops can increase teacher confidence, enrich children’s scientific skills and enhance children’s interest in science.

7.5.6 Teacher participation in fossil workshop and critical thinking analysis
As part of an education conference held in Kharkhiv, Ukraine in March 2018, I was invited to present two workshops, the first for teachers during the conference, and a second for children and lecturers in the University. Some sixty teachers came to the first workshop making it a little difficult to run in the same way as in a normal classroom environment. One participant, an educational psychologist, had asked to be enabled to use the workshop to evaluate critical thinking, as part of her research, and I felt this would be useful to include in my work. The interactive part of the workshop went well, given the numbers and the fact that everything had to be translated. Teachers were
forthcoming with questions, to which I responded and they also discussed between themselves. The environment was relaxed and participative.

The analysis from the psychologist who used the definition of critical thinking from the APA Delphi Report (1998) looked at the interpretation, analysis, evaluation (that is, assessing credibility of statements made), inference, self-examination and self-correction of the workshop by the participants. The psychologist asked the teachers a series of questions based on the six areas mentioned and they responded with explanation and understanding which showed how they interpreted the concepts presented in the workshop, analysed the information given, evaluated and made inferences from the information and drew their own conclusions. The psychologist concluded that the workshop could and had been used to explain the idea of teaching critical thinking skills, by incorporating the concepts in the given definition, as the examples given would explain different ideas. The teachers had re-examined their own points of view. They were also asked to give feedback about the workshop itself and how they felt their pupils would react. Two answers (both from serving teachers) were recorded in the time available, the first suggesting that “the workshop would be too complicated for children to understand”. However, this respondent withdrew his statement after his children had attended the same workshop in the university, where they were engaged, motivated and understood the concepts suggested. The second comment was very positive: “My children are pupils of the secondary school. They would be delighted with such training. Our children are capable of much bigger things than we imagine it. Sometimes I learn from my children the ability to understand the many details and relationships between them”.

I feel the workshop stood up well to the discussion with a group of people unknown to me and also to my subject. Many of them stated how much they had been engaged in the session and how much they had learnt, knowing nothing about the subject at the start. The concepts offered were understood and the teaching environment permitted discussion and debate, despite the language differences. Many teachers have emailed to say they will adapt and use this workshop in their primary and secondary teaching. Others stated how much they enjoyed the participatory style and would use it in some of their future teaching.
8 Discussion of findings

This chapter returns to the research questions and associated methods of data collection, as shown in Figure 3.1 (p78), in order to bring together the findings and discuss the results. These findings are then reviewed in the light of the central issue that the thesis addresses: the potential of earth science for the development of primary science.

8.1 Discussion of findings for RQ1: To what extent does a trainee primary teacher’s own childhood experience affect their approach to teaching science?

The data collected to answer RQ1 were obtained from the questionnaire designed to identify trainee teachers’ own primary experience and interest in science; the questionnaire was completed by most of my sample of teacher trainees (75) before they embarked on their primary teacher science training. Only trainee teachers were sampled because I felt that there was a risk that experienced teachers might have been too influenced by their teaching experiences and associated knowledge of children’s views and experiences of science to be able accurately to recall their own childhood memories. My hypothesis was to identify what the trainee teachers recalled as being science without influencing their opinions. I wanted to find out if these trainees had remembered any science in general, and in particular any earth science. The questions were designed so that they did not mention the term earth science to avoid ‘planting’ ideas in the respondents’ minds.

My questionnaire results indicate that these trainees’ experiences of their primary science lessons were not memorable. An article in Primary Science by a group of seven trainee teachers just completing their training in 2017 stated that few of them could remember their primary science and those who did remembered it being repetitive (Cain et al., 2017). These seven trainee students would have studied primary science under the National Curriculum (DfE, 2000) if they were at primary school in England. Perhaps those people for whom primary science was memorable entered scientific careers or secondary teaching but not primary teaching. Bulunuz and Jarrett (2010) also found in the USA that their participants’ childhood memories of school primary science were not particularly positive.

The most remembered topics mentioned by my participants were animal and plant biology (28%), and the Earth and planets (24%). I was surprised, however, that no-one mentioned earthquakes, volcanoes, dinosaurs or fossils, as often, in my experience over more than twenty years, primary children remember these events. Possibly, these topics did not come under the trainees’ recollection of ‘science’; they might have been thought of as geography or non-school biology. People generally recall exceptional events, for example local flooding or world events such as a tsunami or space exploration. These could have been incorporated into the trainees’ primary science lessons; however, none of these topics were mentioned.

Few trainees in my survey remembered their primary schools offering a science club to their pupils. Hopefully, that would be less likely nowadays as many primary schools in England now have science clubs, although they are usually after school clubs and only those children who are interested attend. In 1991, Kingsland suggested that science clubs offered an extra dimension to primary science teaching which allowed individual
pupils to gain experiences beyond the classroom. The British Association Crest Awards endeavour to increase participation through offering certification at bronze and silver level in primary school and this can be achieved through science lessons or science clubs. This certification is for investigative studies carried out either by individuals or by small groups of children, and can be achieved through a class study. My experience of this has been that children became motivated and enthused about their own investigations, and remembered these projects long after primary school. Whilst science clubs are still run on a voluntary basis by teachers, they do stimulate interest and generally allow children more scope to investigate their own ideas (Kingsland, 1991). From experience, I know there are now more science clubs in primary schools in my county than there used to be, which is an encouraging development, although the Wellcome Trust Report (2013) stated that generally science clubs in England had been cut due to budget and staff constraints. Locally, there are Saturday science clubs for children who have a keen interest in all things scientific, which may increase the appeal of the science. These clubs are run by dedicated scientists and engineers.

Another point that became clear from the questionnaire responses was that for these trainees’ visits to science fairs were rare events and apparently were not career-focused. In my county Surrey, at least, there have been career-focused science fairs for the past ten years. However, as suggested previously, it may well be that those students interested in science were not keen on becoming primary school teachers.

After dividing the questionnaire participants’ responses into two groups, those with a high interest when learning primary science and those with a low interest, no statistically significant differences were found between these two groups of trainees’ enjoyment of primary science. However, 55% of the participants did not recall having enjoyed their primary science. This is reflected in the current Social Attitudes towards Science survey (British Association of Science, 2016) which showed 25% of those aged 16-24 in England had no interest in science.

My questionnaire also asked about the trainees’ memories of secondary school science. It seems that whilst most participants enjoyed KS3 science, in particular biology (59%), KS4 (GCSE) science was not liked as much, although again biology was the most liked (41%). Comments from the respondents were that GCSE science became a “fact learning” process, working from text books with the teacher. Earth science processes were included in science curricula but would not have been identified as such, although some schools studied environmental science which incorporates most earth science concepts. Some geography syllabuses included earth science topics but did not specify the science behind the concepts, instead looking mainly at the social issues caused by earth hazards. Students would have difficulty identifying earth science topics from science lessons unless they had a very strong understanding of terminology.

Generally, GCSE science appears to have discouraged these participants from further science studies as few of them studied science A levels and only four of the 75 went on to study science, psychology or science-related degrees. As suggested already, perhaps those who were really interested in science were not drawn to primary teaching, but it is also somewhat disheartening that science was hardly mentioned in these trainees’ current interests. The questionnaire offered the opportunity for respondents to add other science activities or interests but none were mentioned.
whereas I had hoped that issues like climate change or deforestation might have been of recent interest.

The final section of my questionnaire asked respondents to mark any interests they had as children on a given list, the importance of that interest to them as a child and also which interests were of importance to them as adults. There were some noteworthy differences between Bulunuz and Jarrett’s (2010) survey and mine. My respondents highlighted ‘playing in sand’ as their most important childhood activity, whilst Bulunuz and Jarrett’s trainees identified ‘visits to zoos or aquaria’. The majority of the interests identified by both groups were not scientific, although playing with Lego bricks (a possible engineering activity) was featured highly by both my and Bulunuz and Jarrett’s respondents. As adults, the only scientific interests identified by my respondents were watching TV nature and science documentaries and stargazing. Bulunuz and Jarrett did not list their respondents’ adult preferences.

I have only been able to find a few research articles which identify the importance of primary school science experiences in fostering a lifelong interest in science. Pell and Jarvis (2001) stated that the primary years of science schooling are significant. The Wellcome Trust (2014) report suggests that there is need for good inspirational experiences in science at primary level to encourage further study at secondary level. Roe’s (1952) study of 64 eminent scientists did not mention the importance of primary science experiences, but Joyce and Farenga (1999) recognised the significance of enabling children to explore concepts at primary level, ask questions and discuss their own ideas. Lunn and Solomon (2000) showed that positive experiences of science in primary schools could help generate a positive science self-image whilst Appleton (1995) deduced that science knowledge alone did not improve self-confidence in teachers, but using local knowledge to illustrate unfamiliar concepts helped understanding. Avraamidou (2017) found that childhood events were critical to the life identities of primary (elementary) teachers, suggesting, amongst other points, that these events would influence their feelings of self-worth and confidence. She proposes that teacher training should incorporate more information from trainees’ backgrounds which would help them understand why they feel as they do about teaching science. It is significant that whilst her study focussed on five primary teachers in the USA who felt very positive about teaching science, they all had negative feelings about the way they had been taught science in school. McCrory and Worthington (2018) ask their readers what made science special for them at school or whether they considered science difficult to understand, boring and not relevant. I can complement this with an example of my own. A local primary science teacher told me (in 2017) that her primary science experience was so bad that she vowed to work to try to make science the most enjoyed subject for her pupils, so they would have positive feelings for the subject as they matured.

Evagorou et al. (2014) felt it was important to engage trainee teachers in critical discussions about everyday scientific issues (for example earth science around them), by looking at these issues through a socio-scientific lens. She suggested that normally teachers do not make links between science and everyday life and that this is essential when teaching young children, so they can become critical citizens in later life. I would suggest that it is necessary, therefore, to ensure science is memorable for all children from pre-school through primary years, so that it is later seen as a positive part of their early schooling. Indeed, there were several notable science events during the 2016-
The 2017 school year that highlighted the way in which earth science can engage primary children, notably the option to participate in the Royal Horticultural Society’s Seed experiment (RHS Rocket Science, 2016) and talking to Commander Tim Peake in the Space Station, sending him messages and devising meals and experiments for him whilst in space. In other years, world events like major tsunamis, earthquakes and volcanic eruptions could all be included in science lessons either just through talking and discussion sessions or, with some imagination, incorporated as a cross-curricular part of the curriculum. Karvankova and Popjakova (2018) investigated noise in the environment and found that linking physical geography lessons with scientific fieldwork raised interest in science. I feel that many primary teachers do not always appreciate that science is everywhere around, all the time and can so easily be incorporated into learning.

Harlen (2011) states that the importance of learning science in the primary school is so that we are able to make sense of our world and local environment, gain valuable life skills and equip ourselves with knowledge and understanding to be informed citizens. Pre-adolescent feelings are significant in determining later impressions about science (Skamp & Preston, 2015), indicating the worth of ensuring that an interest in science is formed by the end of primary school. Recent (October 2018) informal discussions with primary trainee teachers at UCL revealed that none of the dozen students with whom I spoke recalled any science from their primary school days, so this situation may not yet have changed. The need for primary science to be memorable for everyone is extremely important, and earth science topics are crucial at an international scale at the present day.

It seems therefore that my questionnaire to answer RQ1 shows that my sample of trainee teachers generally do not bring with them positive childhood experiences of primary science. Educators and teacher trainers should surely be rectifying these school science experiences in order to improve the understanding of the relevance of everyday science events in our lives and especially when teaching science to primary children. Early Years activities can encourage children to investigate local issues, but the increasing formality of Key Stage 1 teaching precludes ongoing investigations, generally because of time restraints, despite the National Curriculum specifying the use of first-hand experiences. Primary science needs to be memorable and the inclusion of ‘wow’ factors (McCrory, 2018) is important if children are to see science as a credible subject later in their schooling. Earth science would seem to have the potential to fill the gap not generally filled by the current teaching of primary science, by linking everyday events to school science. Not only is it topical and in the news frequently, so an easily obtainable resource, but it generally has a ‘wow’ factor that children remember, examples being sink holes with houses falling into them or the discovery of a new species of dinosaur. Earth science discussions, even for just a few minutes occasionally at the start of a school day, would provide a positive image of science to every child.

8.2 Discussion of findings for RQ2: What do primary teachers think of science and how do they consider it should be taught?

The second part of my data collection considered the way primary science is taught and learnt in schools through the beliefs of primary science leaders (PSLs), using a questionnaire based on Tsai’s (2002) study. I wanted to ascertain local PSLs’ thoughts about how best they believed teaching and learning science could be taught and
whether they espoused these beliefs. Tsai's original questionnaire also asked for teachers’ ideas about the nature of science which is an important criterion in the 2013 Primary Science National Curriculum. I felt it would be useful to ask for Primary Science Leaders’ perceptions on the nature of science as there is often misunderstanding about this concept.

Most PSLs in England are classroom teachers without specific qualifications in science, so it is important that these teachers regard science highly, have confidence in their science teaching ability and also are willing to foster links with literacy and mathematics (Lawrence & Beverley, 2018). PSLs are the means whereby science should be disseminated throughout the primary school. The PSLs’ responsibilities (Ofsted, 2011) include managing, planning and organising science throughout the school, the training of their colleagues and updating these teachers in the latest requirements for assessment. The Wellcome Trust (2015) report identified the skills required by ‘good’ PSLs. This report suggested that they (PSLs) need deep understanding of the science concepts in KS1 and KS2, appropriate pedagogical content knowledge (PCK) and subject content knowledge (SCK) to be able to teach these concepts, as well as a sound understanding of the scientific language necessary at primary level. The latest Wellcome Trust report (2017) also felt that PSLs should value science, as it develops skills and ideas that can be applied across the curriculum and are useful for life. When discussing their role with the PSLs, I found that the science leader role is not popular in most primary schools and that the holder changed frequently, sometimes termly. The role is often allocated to teachers in turn, irrespective of interest in science, by the Headteacher or Senior Management Team (SMT). Such turnovers did not enable continuity of feedback as I noted from the meetings I attended, and meant that the network co-ordinator often had to repeat previous information. The lack of popularity of the PSL role may well be connected to the lack of science specialism in schools (Wellcome Trust, 2013), since where a teacher is interested and enthused by science, they tend to remain in that position for a long time. However, 60 PSLs completed my questionnaire (about half of those attending the meetings) and their thoughts and beliefs make interesting reading.

The first set of questions asked for the PSLs’ beliefs about the best way to teach primary science, to learn primary science and the ideal teaching environment for primary science. Skamp and Preston (2015) state that teaching science is influenced by the beliefs and attitudes of the teacher involved, so I was concerned by some of the responses which highlighted current teaching issues. Overall, many of my PSLs identified a shortage of time, space and resources as major barriers to the way they wished to fulfil science activities in accordance with their espoused beliefs.

It is interesting that my results show that the PSLs generally did not think it possible to teach science in the way they would have liked through a truly constructivist approach, because of time limitations. Fifty three percent of my PSLs also felt that their own content knowledge was a major restriction to the teaching of science even though Wellcome Trust (2017) argued that a PSL does not need any other qualification above the national statutory requirements for teaching. However, this and other research (Howard, 2018) suggests that PSLs need knowledge of appropriate methods for teaching science across all age groups in their school, including pedagogical strategies for out-of-classroom and practical activities. Jarvis and Pell (2007) stated that teachers with limited science content knowledge also suffered from lower confidence in teaching
science. Although science is identified as a core subject, along with English and mathematics in the primary curriculum, in many schools less time is available for science teaching than the other core subjects (Wellcome Trust, 2014). HMIs found that two-thirds of primary schools visited in 2015 had only one to two hours of science teaching per week and one-fifth had less than one hour per week (HMCI, 2016). This substantiates the PSLs’ claims that there is not enough time allowed for science teaching and that science is a poor relation to the other core subjects, English and mathematics.

A classroom environment that is conducive to discussion and allowed questioning as well as the use of investigations was seen by the PSLs as the best way for children to learn. Throughout my questionnaire responses, PSLs repeatedly mentioned the importance of ‘questioning’, including posing questions to their pupils and inviting them to ask questions and discuss between themselves. The PSLs also believed that allowing children time to investigate their own ideas was an ideal to be aimed for. However, PSLs stated that the time allowed for science lessons and resource limitations meant that they were forced into other strategies, rather than allowing children to ‘explore’ individual ideas. Some research by Kirschner et al. (2006) suggests that pupils at primary level do need support through guidance (scaffolding) rather than being allowed to explore concepts without structure. The National Curriculum for Primary Science (2013) suggests that children be enabled to ‘work scientifically’ through first hand investigations. As the PSLs mentioned, they are wholly in agreement with this but space restrictions coupled with too few resources and little time precludes many investigations. It is encouraging, however, that my data show that few PSLs believed that didactic teaching strategies were the best way to teach and learn science.

The second set of questions asked for PSLs’ thoughts about successful science learning, the responsibilities of pupils and the most important determinant for success in learning science. Hands-on activities and investigations were felt to be the most significant factor here, with 65% of responses stating so. This response is interesting as research shows that whilst practical activities are seen as being the best way to learn, in effect they all-too-often do not result in better achievement by children (Abrahams & Millar, 2008), as discussed in 2.6.8 p52, although practical activities do seem to increase motivation and enjoyment of science.

Engaging children (Fitzgerald, 2012), permitting them to ask questions and be curious were obvious responses made by the respondents which PSLs felt enabled successful learning. My results showed that having engaged children figured frequently (13-15%) in the responses from my sample of PSLs. The engagement of children in primary science is seen as essential to motivating learning by many researchers (Shaw, 2003; White, 2005) and acknowledgement of their ideas as worth taking seriously (Harlen, 2001) can be very motivating for children. Alongside this was the need for SCK confidence (Sharp et al., 2009) of the PSLs themselves in being able to respond to the children’s needs.

Many teachers do not have the confidence to admit they do not know all the answers and so find it difficult to allow classroom discussion. As long ago as 1992, Hann et al. (1992) suggested that teachers’ science confidence might be improved by watching, then discussing, science TV programmes with their peers. The discussion would, it was implied, help teachers better understand the science. It is so important that teachers
have the confidence to throw back questions to their pupils (Chin, 2007) and be prepared to learn with their pupils. Another important determinant for success was seen by the PSLs as children being able to formulate their own questions and discuss them with their peers.

Most responses (40%) by the PSLs’ about their pupils’ responsibilities when learning science centred on the need for children to adhere to health and safety rules: for example, wearing safety glasses when necessary and using equipment properly (DfE, 2014, CLEAPS, 2016). Being able to work in teams, working together and listening to each other were skills that were seen as needing to be developed by the children. Some PSLs felt that children should be able to link new ideas with earlier knowledge, though I feel this would generally be more attainable by those children at the upper part of KS2.

The third group of questions asked for the PSLs’ views about the nature of science, and produced some rather disturbing responses, given that these teachers are the conduit through whom science is taught throughout their primary schools. Most PSLs (75% of those responding) stated that the nature of science was the investigation of the world around us, but did not mention that these investigations were continually changing in the light of new evidence. The English 2013 Primary Science Curriculum specifies that children should be taught about the nature of science through different types of science enquiries that help them answer scientific questions about the world around them (DfE, 2014). Although this term ‘nature of science,’ (NOS), has been shown to have diverse meanings amongst academics, as discussed in my literature review (p28), it was disheartening to find that many replies still indicated that biology, physics and chemistry alone were seen as constituting science, and that the idea of science continually changing was not a dominant view. Since earth science is, I would maintain, the science that investigates all aspects of the world we live in, it is most apt to use earth science examples to illustrate the nature of science. In particular, human ideas about the world have changed over time, with new technologies showing the dynamism of science; an example is the idea of continental drift which was evidenced from information gained about sea-floor spreading in the 1950s.

The PSLs in my study did not appear to understand that scientific knowledge is not fixed but open to change. Although 15% of them said that scientific knowledge provided evidence of why things happen, no one suggested in their responses that changes to theories could occur. Theories were seen by 12% of the PSLs to be a major characteristic of science. However, scientific knowledge was seen by many of the PSLs to be no different from other kinds of school knowledge.

Our understanding of the NOS needs to be nurtured at a young age. Appreciating the dynamism of science; the fact that all of us could add to the store of scientific knowledge, is something that Citizen Science projects endeavour to promote. Earth science projects, often ecological in nature, are habitually identified as investigations in which we can all participate. Programmes like the BBC’s Spring Watch series invite much participation in order to identify changes in animal behaviour and are aimed at viewers of all ages.

I believe that despite our science teaching in schools being compulsory until students are aged sixteen, there are some major issues which it is necessary to resolve. Basic understanding of the nature of science, whilst part of the National Curriculum since its
first appearance in 1989, still has not been made clear. School science does not seem to have provided all our citizens with relevant knowledge and understanding about the world and nature of science (Osborne et al., 2003).

The data collected were analysed to show nested epistemologies about teacher beliefs. Overall, the data retrieved from this questionnaire showed that the main beliefs identified by my sample were in favour of using constructivist approaches to teaching. This is in line with the ideals stated by the 2013 English National Curriculum. This is in contrast to Tsai’s study, although the traditional culture he was working in was very different to the one in England which does support a constructivist approach. However, whilst my sample mainly held constructivist beliefs about teaching, whether it was possible for them to manifest their beliefs is another matter, given some of the difficulties highlighted by my PSLs of time, space and resources.

All in all, this questionnaire identified many of the issues discussed by primary teachers about their science teaching that I have overheard when working in primary schools during the past twenty years. The lack of content knowledge, pedagogical subject knowledge and confidence is not impossible to rectify. However, the role of the PSL in the primary school needs to be given more prestige (Ofsted, 2013; Wellcome Trust, 2017) and the incumbents should be enabled to perform their duties more effectively and competently by providing them with extra training in both science PCK and SCK. The data collected showed that PSLs believed that primary science should be taught through a constructivist approach but that circumstances beyond their control did not generally enable this. However, if earth science topics were used more frequently in cross-curricular learning, possibly more time would be available for discussion and analysis. Examples could include using literacy to read and write about local events geography to identify places where events were occurring, and also mathematics to show temperatures, rainfall and wind conditions.

The responses made by the PSLs when responding to the questionnaire which I used to answer RQ2 are encouraging in that the PSLs are endeavouring to promote more constructive teaching practices as they believe this encourages primary science learning. However, the status of primary science has fallen with the demise of the national SATs tests (Sharp et al., 2017) and it is extremely necessary that the Senior Management in primary schools enable science by allocating time and prominence in the primary curriculum (HMCI, 2016). Primary science should be seen as the highlight subject to teach because it has so many cross-curricular links, particularly if earth science topics are used. The role of PSLs should be elevated and sought after, rather than being seen as just a ‘job to be taken on because no one else wants to do it’.

I also found it concerning that the PSLs in my study sample have access to a primary science network which was set up to encourage the sharing of good practice between primary science teachers yet are not taking the advantage of it that they might. This is not able to happen because of the frequent changes in the role holders and continuing changes to the assessment of primary science now that the SATs are no longer in use. There is a real sense here of an opportunity of the development of a primary science community being missed.
8.3 Discussion of RQ3: Can earth science help primary teachers to be more confident about teaching science?

8.3.1 The importance of teacher confidence in the intervention lessons
On many occasions, particularly after a poor Ofsted report, I have been asked into primary schools to support science, in my role as project manager for SATRO. Discussions with teachers often highlight their fears because of lack of confidence about the teaching of science even when they themselves understand the concepts, as they not infrequently have little pedagogical subject knowledge. Hence, my idea behind the intervention lessons was in part to see whether teacher confidence could be improved through giving content knowledge and pedagogical ideas on a topic the teachers had identified as boring. In addition, I hoped to find that the children’s learning, as well as interest and motivation, could be enhanced. Since the teachers in School A themselves decided that the topic ‘soil’ was very boring and difficult to understand I was very happy to help, as soil fell within my remit of earth science. School B teachers had also intimated that soil was a topic they found difficult to teach. The intervention programme was thus planned to stimulate learning through increased motivation and interest by the teachers and children, as well as giving the teachers plenty of confidence with accurate SCK. It would include pedagogical strategies to be used and opportunities to gain evidence for assessment purposes.

During the twilight teaching sessions I was surprised that several of the teaching strategies I had thought were in common use were, in fact, new to these teachers: These were the use of bubble diagrams (Figure 6.1, p110) or some other method of assessing before and after knowledge; concept cartoons (Figure 6.2, p111) and interactive stories, all of which I had used in my teaching career many years earlier. I also discovered that most assessment at this level in each school was not based on written assessment.

During discussions with the year 3 science leader in School A, I was made aware that no extra funding would be available for equipment. The teachers felt that lack of appropriate equipment would be detrimental to this investigation and all three teachers were surprised that the necessary resources could be sourced from old kitchen equipment: sieves and colanders, empty lemonade bottles, clear plastic drinking beakers and plastic spoons. Similarly, School B had little science equipment, despite being part of an Academy chain (although in my experience such chains often have better science resources). They had no weighing scales at all, so we used cups and spoons to measure and compare volumes, an innovative idea from me they had not thought of previously. The only real expense for both schools was a bottle of Universal Indicator which would last for several years. The issue of lack of money for resources and equipment had previously been raised by my PSL respondents, but I have found that generally earth science investigations require little expensive equipment, and most investigations can be carried out at minimal cost. Assuring teachers that they did not need expensive equipment to carry out practical earth science investigations made the teachers happier and more confident about children using simple equipment, where it would not matter if it were broken. It also meant there were multiple copies of resources available for the children to use, without them having to wait in turn to use them.
The teachers' confidence in teaching about soil in School A increased greatly after the twilight teaching sessions and the pilot day, and they themselves began to have ideas about how the day could be improved. This included extending the time spent on introducing the topic through presenting new scientific words pertaining to soil, as well as allowing more time for follow-up discussion, drawing graphs and writing up science (WALT) diaries Clark, 2015) (Appendix 4). However, despite participating in the same CPD twilight sessions, the two teachers in School B did not use the teaching ideas learnt during the intervention lessons. There could be many reasons why these teachers changed their minds over the way the lesson was to be taught. One could be due to a lack of confidence (POST, 2003) in their overall knowledge about soil. Another, that the management team was unable to supply extra staff for the session, who would have provided valuable help for the investigation sessions, and would not allow parental help. A third reason could be that the teachers knew their children well and did not feel confident to allow them to carry out investigations on their own. School A teachers certainly had increased confidence after the pilot phase, so perhaps, had there been the opportunity for me to return to School B for a second year, these teachers, too, might have used the CPD materials with confidence. School B may not have seen the opportunity for recording evidence for assessment through the intervention programme, although I had mentioned this during our CPD meetings. As the school is in an Academy Group, I appreciate their different requirements for assessment.

My observations of the interactive soil story which began the soil science day in School A were recorded on my TALIA form (Table 6.6, p119) and gave some enlightening results. By observing two different teachers, I was able to compare the way they approached the topic and how they taught two very different groups of children. The children in Class A were all able English speakers, whilst Class O had a number of children who were struggling with English as a second language, and the teachers responded appropriately to these differences. Class A clearly understood the objective of the lesson and the soil forming process quite early on in the lesson, as they were able to discuss, ask questions, answer open questions and respond to each other. In Class O, the clarity with which the teacher introduced the story and his continued reinforcement of points ensured that all the class soon understood the concepts and were able to complete their own stories after the half hour introductory lesson.

During my observation of the telling of the soil story, I was surprised at the similarity of the number of actions both teachers used, despite using different teaching strategies to respond to the needs of the children. Both teachers began by giving information and then reinforced the children's understanding by asking open questions. At this point they explained any misunderstandings being raised through the responses. Both teachers clearly felt confident with the topic and were enthusiastic and motivating. The lessons changed after the first five minutes from information giving to discussion between teacher and pupils and between the pupils themselves in their small groups, again emphasising the fact that the teachers felt confident in their knowledge and understanding of the topic. In both classes, as the lesson proceeded, the children became more involved, provoking discussion and asking questions. Group discussion was animated and involved both the interactive story and the pack of photographs and other resources available on each table.
Examples of the pedagogical strategies used by the Class A teacher were noted from the audio-recording of the soil story lesson and can be seen in Table 8.1. The teacher herself did not identify the pedagogical strategies used, but I have related them to references in the literature.

### Table 8.1. The pedagogical strategies used by the teacher when telling the soil story

<table>
<thead>
<tr>
<th>Pedagogical strategy used by teacher with references</th>
<th>Example from audio-recording of intervention lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify pre-existing knowledge through open questioning and help children to formulate ideas clearly (Ofsted 2016)</td>
<td>Getting children to discuss a concept cartoon between themselves or the teacher, teaching assistant and observer.</td>
</tr>
<tr>
<td>Allow pupils time to formulate answers (Smith, 2015)</td>
<td>Children were given time to answer questions. Sometimes a volunteer was chosen to answer; at other times a specific child was asked. All responses were valued.</td>
</tr>
<tr>
<td>Use of closed questions (McMahon &amp; Eley, 2018)</td>
<td>None used.</td>
</tr>
<tr>
<td>Noting those ideas even if not directly relevant to lesson</td>
<td>Child thought Sun heating rocks makes them melt and sticky (possibly referring to the original magma base of some rocks).</td>
</tr>
<tr>
<td>Discussion of ideas with pupils, e.g. reflective questioning (Chin, 2007; Alexander, 2015)</td>
<td>Getting children to think about what happened to bottle of water in freezer. Discussing potholes in the road and how and why they get bigger.</td>
</tr>
<tr>
<td>Teacher enthusiasm (McCroy &amp; Worthington, 2018)</td>
<td>Teacher very enthusiastic and confident.</td>
</tr>
<tr>
<td>Encourage writing and drawing, using appropriate vocabulary (Ofsted, 2016; Smith, 2016)</td>
<td>All children worked on their own cartoon story using new vocabulary being introduced as story unfolded.</td>
</tr>
<tr>
<td>Use resources (Sharp et al., 2017)</td>
<td>Set of resources on tables: pictures, worms, samples introduced during story telling.</td>
</tr>
<tr>
<td>Discuss any identifiable links brought up by children.</td>
<td>Idea of potholes getting bigger when ice freezes and breaks up road.</td>
</tr>
<tr>
<td>Ensure all pupils participate by using different strategies for different levels of ability, e.g. spelling words (Sharp et al., 2017)</td>
<td>Handed out short, typed sentences to those children who were slower at writing so they could cut out and stick sentence in story—children still had to read to find appropriate sentence. Explained reasoning to whole class and asked them to help each other.</td>
</tr>
<tr>
<td>Enable/allow interactive discussion between children (Mercer &amp; Littleton, 2007)</td>
<td>Children talked to each other about concept cartoon and their own pictures and statements.</td>
</tr>
<tr>
<td>Assess understanding through open questioning/responding to pupil questioning (Pollard &amp; Pollard, 2011)</td>
<td>Asked children to recall water freezing, plants breaking up pavements visible outside window. Responded to child who asked about cliff weathering/erosion.</td>
</tr>
<tr>
<td>Reinforce ideas (Skamp &amp; Preston, 2015)</td>
<td>Continual reinforcement when drawing new cartoon section.</td>
</tr>
<tr>
<td>Relate to previous work (Skamp &amp; Preston, 2015)</td>
<td>Recalling freezing water in bottle, how bottle expanded, cracked.</td>
</tr>
<tr>
<td>Drawing lesson to a conclusion (Smith, 2016)</td>
<td>Discussion about continuous but very slow soil formation—more weathering, more plant debris, breakdown, so on-going process.</td>
</tr>
<tr>
<td>Other</td>
<td>Involvement and engagement of all children during a lesson frequently interrupted because of snowy weather conditions.</td>
</tr>
</tbody>
</table>
In School B, however, my classroom observations were very different despite the two teachers involved having worked with me through the same three twilight sessions as in School A, and having repeatedly stated that a day spent on the topic of soil would add to the children’s previous ‘woodland’ experience. At the start of the investigative day in School B, the children were not given any objectives for the work to be investigated. In addition, the teachers chose not to use the interactive soil story or a concept cartoon to introduce the soil investigations as we had practised, but rather to use an American video found via Google which used different vocabulary from that we had planned. I observed Class R as they watched the video. Few children paid much attention; others fidgeted although they were all quiet. There was no discussion about the video between the teacher and her class at the end of its showing, even though the teacher tried to get the children to recall looking at soil in the woods. She showed the children a short phone video she had made when I was indicating different soil layers in the woods, but the children did not remember this when asked.

I consider that the differences in approach of the teachers in the two schools studied show how much need there is for both SCK and PCK in the teaching of primary science. School A teachers had gained confidence through understanding the topic they were teaching and knowing that the investigations could be carried out by the children. This might have been because they had taught this topic the previous year and gained confidence, although the lesson had worked well the first time. School B teachers, however, despite their telling me they felt confident about teaching the topic, did not feel able, for some reason, to use the strategies we had practised.

Both groups of teachers had been volunteers, and their backgrounds were not dissimilar (p107 and p143). Teaching the primary science curriculum is difficult enough at all times, but if teachers still lack confidence after a concentrated CPD course (which included both SCK and PCK) and having practised the investigations themselves using a well-known material, how much more difficult will it be to teach abstract concepts like forces without adequate preparation? I can understand that researchers have found new primary teachers sometimes try to avoid science teaching and use integrated themes with little science content (Appleton, 2003).

The idea of using bubble diagrams generally and as a form of assessment was new to both schools I worked with, but is now used in School A in different forms to elicit prior knowledge as a useful starting point for science and other subjects. The use of an interactive soil story (Appendix 3), building up soil formation in stages on the whiteboard introducing new vocabulary at the same time as teaching the process of soil formation, was welcomed as an innovative method of increasing the children’s knowledge and understanding of soil by all the teachers involved during the twilight sessions. Linking the investigations to the soil story and other concept cartoons added to the teachers’ understanding and was seen by them to be something their pupils could relate to. The three teachers in School A were surprised at the range of concept cartoons that were available on the web, eventually discovering more cartoons themselves relevant to teaching soil, although initially I had created one for them. However, School B had used concept cartoons in the past, but not recently in their science programmes, though they intimated they were willing to use the one I provided. Neither school used either SOLO or Bloom’s taxonomies as ways of assessing
learning, and did not have a whole school policy on questioning techniques, although School A stated in 2018 that this was under consideration.

This intervention lesson used an earth science topic which was easy to resource, although not normally used as an investigation in either school. The intention was that the investigation conclusions were going to be further utilised in later discussions about plant growth and gardening projects and in School B as an additional activity, relating to their time spent in the local woods. The opportunity to use this earth science investigation additionally in other science projects shows the potential for developing earth science to enhance cross-curricular learning.

8.3.2 Discussion of findings from interviews with staff before and after intervention lessons

In the observation year in School A, prior to teaching the intervention lessons, the two long-standing teachers were very sure that they understood soil formation processes and would be able to answer the children’s questions with confidence. This was very different from the pilot year, when they had been dubious about their knowledge. The new teacher in 2016 was not very confident about the methodology we were going to use, and although she had been enthusiastic when discussing the soil concept cartoon with her class, she still felt nervous about a whole day to be spent on soil, despite her colleagues’ convictions. However, after the intervention lessons, she was as confident as her peers, and was ready to plan for the next year (2017).

The teaching assistants, too, commented in their interviews (6.5.2, p131-133) on the children’s concentration during the day and the number of skills that the children (and they themselves) had learned. They, too, felt more confident at answering questions and were able to sit back and allow the children to formulate their plans for their investigations without feeling that there would be major problems. The children “organised themselves well once on the right track”, one assistant told me later. They were all pleased to hear the children talking about soils on their way home from school. The comments from teachers and their assistants were audio-recorded after the intervention as shown on Figure 6.8 (p134). Teachers and teaching assistants reflected on the concepts introduced, the curriculum objectives and the pedagogical strategies used, stating the usefulness and effectiveness of the intervention lesson (Figure 6.7, p122). The teaching assistants’ comments showed that they too had increased knowledge and understanding about soil and the investigation methods used to identify soil characteristics (Table 6.8, p134). They felt better able to respond to children’s questioning with more confidence. It was also noted by the teaching assistants that the children themselves were talking, with enthusiasm, about the soil intervention lessons in the playground and on their way home.

The intervention lesson in School A was deemed to be effective at providing an experience which offered a range of teaching pedagogies, learning strategies, skills experience, assessment evidence and a wow factor. As such, the teachers stated that it would be repeated in the coming years, and the basic lesson programme would be adapted for other science topics. The topic of soil was no longer seen as boring but as an exciting and relevant lesson, offering knowledge, understanding and application, which could be linked into other science topics, for example, plant growth and the school gardening project.
The one feedback interview from School B identified the fact that the teacher was very pleased with the way that the intervention had gone. Despite my personal feelings about the lesson, she felt that the children had been engaged and would remember what they had investigated. She stated that the children who wrote up the formation of soil after investigating the soil sieving seemed better able to understand the soil formation processes, possibly because I explained this before we started the investigation. I feel that there were few pedagogical strategies utilised in this intervention and a great deal of opportunity to make the lesson effective was lost. I was disappointed with the intervention lessons in School B from the point of view of effectiveness of the teaching and learning which I feel could verify my assertion that teachers need confidence and real understanding of the science they are teaching in primary school as well as PCK strategies in order to be able to teach scientific ideas effectively.

8.3.3 Discussion of RQ3 using secondary data: Can earth science help primary teachers to be more confident about teaching science?
The Earth Science teacher programme was delivered to PGCE and BAEd students at teacher training institutions that had requested the programme. The workshops were free and institutions only paid for the facilitator’s transport. However, the workshops required at least one half day for delivery which, given the modest time allowed for science in most training programmes (ITT Report, 2017), could be seen as too long to spend on one topic area and is probably a reason why more institutions do not take up this offer. Only feedback data from trainee teachers were used, as the workshops were mainly held in training establishments. Occasionally, the workshops are run for serving teachers in their schools, but there were too few evaluation forms for a proper sample.

These trainee teacher workshops were found to be very effective at delivering specific content and pedagogical knowledge through a short CPD programme with the trainees’ confidence at teaching earth science having increased by the end of the session. Since this practical investigative programme was devised, and lately revised, to comply with the new 2013 Primary Science National Curriculum, it is perhaps not surprising that the trainees were so enthused with the training programme since it included new material on fossils and evolution required by the latest curriculum (DfE, 2013). The large majority of trainees attending these workshops were comfortable with the practical approach used in the workshops. The themes the trainees identified tallied very closely with those themes identifying positive workshop outcomes researched by Guskey (2000). The themes identified were: practical, engaging, useful for teaching, and easily available resources. Trainees stated that the CPD had increased their confidence in teaching earth science and that they now had more content and pedagogical knowledge. The workshop resources are made available to all the trainees to copy and use, resource lists are given and risk assessments attached, making the materials immediately ready for use in the classroom. My PSLs’ survey showed that there was a need for science CPD which would increase content and pedagogical knowledge. The importance of focused science CPD sessions was highlighted by Eady and Hardy (2015), Wellcome Trust (2017) and Turford and Turner (2018).

Many of the institutions which request these workshops ask for them every year for their new cohort of students. I personally teach these sessions to four groups a year in two different universities. Other ESEU facilitators have similar commitments, and presumably this is because the institutions recognise these workshops as being
successful CPD, delivering effective science teaching and learning opportunities which they would otherwise have difficulty in presenting.

It is expected that the trainees will be enabled to use these methods when they are eventually teaching in primary schools. The written comments from both the trainee teachers’ CPD sessions and the oral comments from teachers after the primary rock and soil workshops show increased understanding and knowledge coupled with learning innovative ways to teach these topics.

Interestingly, the Royal Society of Chemistry has used many of the investigations from these earth science workshops in their teaching plans in conjunction with Millgate House publications, using a thematic approach.

8.4 Discussion of RQ4: Can earth science enrich primary children’s science understanding?

8.4.1 Assessing children’s learning enrichment through bubble diagrams
In order to assess whether the children in both Schools A and B had learnt anything about soil, I returned to the bubble diagrams deployed by the teachers before and after the soil intervention lessons and analysed the responses using both SOLO and Bloom’s taxonomies. In School A, it was apparent from the bubble diagrams completed individually by the children that learning had taken place as fewer children were now at SOLO level 2 or Bloom Factual Knowledge and had moved up the scale to SOLO level 3 and Bloom Understanding. There were also more children at the higher levels of Application and Analysis identified in both taxonomies. The WALT diaries showed more in-depth knowledge and understanding of the processes of soil formation and the characteristics of soil that the children discovered during their investigations. School A allowed time for discussion of results at the end of the day, which was important for tying up ideas and firming up all the concepts introduced during the lessons (Beasley, 2014; Nottingham, 2016).

The children in School B also showed increased knowledge and some understanding of soil formation, although this was less easy to analyse as the children had made a class bubble rather than individual ones. A class bubble can be used as evidence to show overall increase in learning, but is harder to use for formative assessment, although individual teachers would remember which child had shown more understanding. Unfortunately, time was not available for discussion at the end of the day for the teachers to consolidate any learning.

8.4.2 Discussion of the investigations carries out by the children
My observations of the children undertaking the investigations also differed between the two schools. Whilst School A children planned and organised their investigations because they had been given specific objectives, the children in School B were very much at a loss, as they did not understand the objectives of the lesson. The children in School B needed considerable help (scaffolding) in order to be able to carry out the soil sieving activity, primarily because they did not understand either the task itself or the purpose of undertaking the task. It was also apparent that they had not previously had the opportunity to carry out their own investigative work. Osborne and Millar (2017) commenting on the latest (2015) PISA report suggest that investigations in secondary science in England too often do not have sufficiently clear goals and that not enough time is allowed for the discussion and evaluation of investigation outcomes. I feel that
this is also frequently the case with primary science investigations: School A is now deliberately spending more time on follow-up work and discussion as it consider this beneficial to the learning process.

The children in School A whom I observed began to relate their permeability investigations to the initial concept cartoon and their soil sieving exercise to the characteristics of a soil, based on the soil story. One child in particular was thinking through his investigation and because he was unhappy with his results, decided to repeat his investigation. This was an impressive line of thought for a year 3 pupil, who obviously was thinking critically about what he was doing. But whilst all of the children in both groups in school A commented on the different amounts of water that had permeated through the soils, I was surprised that no-one thought to measure it, although they had initially recorded how much water had been poured onto each soil. However, these are young children (age 7-8), who are just beginning to plan their investigations, and had had no hints given as to any investigations other than which soil was most permeable.

The teachers in School B had planned for the children to watch the permeability investigation whilst it was carried out by a teacher. The children did not ask questions but watched what happened without making any observations or notes. There was no real explanation by the teacher as to why there were differences between the soils’ permeabilities and the children did not have the concept cartoon to refer to. Later, when I worked with all the children in small groups to investigate the characteristics of the soil samples through sieving, the children needed considerable scaffolding in order to plan and organise their own investigation and it was obvious they had not had the opportunity to do this previously. Eventually, they began to work as teams, but had no real sense of purpose as the soil day had lacked clear objectives.

I believe the differences between the learning achieved by the groups of children I was observing were in large measure due to School A giving the children clear objectives for the topic at the beginning of the day. These children then understood what they were investigating and why and what they were hoping to find out. Because the children in School B did not have this initial understanding, they appreciated neither the investigation into soil permeability nor looking for soil characteristics through sieving. I am sure that these differences occurred because of the confidence of the teachers involved. However, undertaking investigations using an easily available resource was shown to have enriched the children’s knowledge and understanding to some degree about an everyday local earth science resource.

8.4.3 Discussion of the audio-recorded interviews with the children
The before and after interviews audio-recorded with the children in both schools produced some interesting conversations. The transcripts were analysed and comments identified as knowledge, understanding or analysis and the results graphed so that differences before and after the intervention could be identified. The second discussion took place two or three weeks after the intervention in order that there would be time for the children to assimilate, or indeed forget, what they had learnt. However, in both schools the children achieved some increase in learning, as seen in Figures 6.11 to 6.15, pp141-154. School A children discussed soil with more understanding and analysis after the intervention, though had some prior knowledge before the soil intervention day. School B children also showed changes in learning, despite the different teaching approach. Before the intervention, the children in School B all had
had some factual ideas about soil, but after the intervention they all spoke with more knowledge and understanding. The intervention had enriched the children’s learning about soil.

Both groups of children had found the soil intervention to be fun and enjoyable, although Abrahams and Reiss (2012) suggest that this alone is not a good enough reason to indulge in practical work. However, it could be that this day may be a memorable science day since it was different and enjoyable.

8.4.4 Discussion of RQ4 using secondary data: Can earth science enrich primary children’s science understanding?

As mentioned in 7.4 (p 168), I have been teaching primary science workshops on rocks and soils and on fossils for fifteen years. The evaluation comments from both workshops (rocks and soils, and fossils) showed that the sessions motivated and stimulated the children and often the teachers as well. Mostly, the workshops are attended by year 3 children but although the children are still learning to write down their feelings, they are frequently stimulated enough to write that their confidence in learning science has increased as well as their enjoyment. When these comments were thematically analysed, they showed that the children had a wide range of positive feelings towards science pp171-175 and had learnt some science. The comments suggested that the participants’ interest in science and in making collections of rocks, minerals and fossils had been evoked, and a few were enthused enough to say they might consider earth science as a career.

The children’s comments from the workshops showed their increased interest, knowledge, understanding and confidence after the workshops, leading to an enrichment of their science. Their comments were full of enthusiasm and motivation; such comments as “it has made me want to learn more about rocks”, “I used not to like science but now I feel more comfortable with it” and “I would like to find out more” showed their evident enjoyment. Hopefully, these workshops will be remembered as ‘wow’ lessons from primary school, and spark interest in science when they are older.

By collecting statements made by the children before and after these workshops using bubble diagrams, my evidence shows that changes in learning had occurred, with most children moving up levels as defined by either the SOLO or Bloom’s taxonomies. The teachers whose classes participated considered the time spent on the workshops provided effective learning because of these improvements. I consider these workshops can be memorable, as I have met participants five years later and they still remember what we talked about and worked on during the workshops. Earth science in these sessions has certainly enriched the participants’ knowledge and understanding of science. Given some simple and cheap appropriate resources, these workshops can be carried out by teachers in their classrooms to great effect.

8.4.5 Overall findings from the intervention lessons and workshops (using secondary data)

These intervention lessons show what can be achieved with only a small amount of time spent on CPD for a specific topic in earth science. The soil day in School A is now firmly established as a science day in the Spring Term, with children and staff learning and enjoying the work. The teachers are confident in both their newly acquired SCK and PCK which have given them a better understanding of soil and how to deliver a teaching programme to their pupils. The staff also found new concept cartoons which could be used in other science areas, and are frequently using bubble diagrams as a
starting point for finding out prior knowledge and as an assessment tool. Other earth science topics are being integrated into cross-curricular studies, increasing the time spent on science – rocks, fossils and weather, as well as earthquakes and volcanoes which, although part of geography, have been looked at scientifically. In School A, earth science is now being used as a basis for introducing other science concepts required to be taught in the National Curriculum, for example forces.

I had been disappointed with the intervention day in School B, but the two teachers there stated that it had been successful and they thought their pupils had learnt a great deal. My analysis of my follow-up interviews with the School B children did show evidence of some learning. Furthermore, I subsequently discovered that the school had repeated the soil day a year later, to their satisfaction, which was pleasing.

The intervention lessons gave plenty of opportunity for children to undertake investigations using easily obtainable resources, and the opportunity for questioning and discussion, all points raised by the PSLs. The lessons relate to events experienced by children and incorporate biology, chemistry and physics, linking these subject areas to everyday life.

The children in both schools had had an investigative earth science experience and all of them had enjoyed the day, hopefully making it memorable, and something they could recall later as adults. However, I feel that only in School A did the intervention really enrich the children’s science knowledge and understanding because the staff took on board all the suggested pedagogy. There is plenty of potential in using this kind of investigation, using local earth science resources to enhance understanding.

The short workshops given in schools enabled the children to investigate rocks or fossils using interactive and hands-on methods. Relating rocks to everyday use encouraged children to look at and think about their own environments. Understanding fossil-forming processes and looking at evolutionary changes in one species gave children the opportunity to question changes in other animals and think about adaptations to the environment. The evaluation showed how much their interest had been stimulated in science, thus enriching their understanding.

8.5 Potential of earth science for the development of primary science

It is interesting that in my questionnaire the only science subject many of the primary teacher trainees felt confident about teaching, before participating in the CPD workshops, was biology. My first questionnaire looked at trainee teachers’ memories of primary science and this, too, showed that biology had been the most enjoyed aspect of primary school science. The trainees’ secondary experiences also generally highlighted biology as the preferred science. Perhaps biology is as close as primary and secondary school science gets to looking at science which is relevant to young people? Everyone has some understanding of themselves, but we don’t develop the science that is around us all the time. The physics strand of the primary science curriculum is often seen as difficult by trainee teachers, who feel less confident when having to teach it (McCrorry & Worthington, 2018). Earth science can be used to introduce physics concepts such as forces, using children’s relevant experiences of wind and its effects.

Why are we not making greater use of earth science everyday materials and events in our primary science teaching, as these are available resources of which we all have experience? It is notable that many authors of primary science text books utilise earth
science as examples of enquiry and practical work (e.g. Beeley, 2012; Harlen & Qualter, 2014; Smith, 2016; Skamp & Preston, 2017 to name but a few). Earth science is a readily available, ever-changing resource that requires little specialist equipment and where enquiries can fulfil all the working scientifically requirements of the primary science National Curriculum. Earth science can contribute to many areas of the current primary science programme of study as seen in Table 8.1. Fogarty (1991) identified different curriculum models for teaching in primary school; earth science topics can be integrated throughout the curriculum, providing relevance and using learners’ own experiences.

Table 8.2 Where earth science could fit in the English primary science National Curriculum.

<table>
<thead>
<tr>
<th>PROGRAMME OF STUDY</th>
<th>Rocks</th>
<th>Fossils</th>
<th>Soil</th>
<th>Weather</th>
<th>Ecology</th>
<th>Environment</th>
<th>Seasons, day, night</th>
<th>Water</th>
<th>Shadows</th>
<th>Planets, space</th>
<th>Atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working scientifically</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Everyday materials KS1</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Seasonal changes KS1</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Living things &amp; their habitats KS1&amp;2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Animals basic needs KS1</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Uses of everyday materials KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Plants KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Rocks KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Light KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Forces and magnets KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Animals and humans KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Sound KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Electricity KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Properties/changes materials KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Earth and space KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Evolution and inheritance KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Secondary research KS1 &amp; KS2</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
</tbody>
</table>

Earth science also facilitates simple enquiry and investigation that combines learning skills in a practical way. Table 8.3 identifies the specific science skills that can be incorporated in the various topics identified in the English National Curriculum (2014).
Table 8.3 Science skills that can be developed through earth science topics.

<table>
<thead>
<tr>
<th>TOPICS IN EARTH SCIENCE</th>
<th>Soil</th>
<th>Rock</th>
<th>Weather</th>
<th>Properties of materials</th>
<th>Changes of state</th>
<th>Seasons, day, night</th>
<th>Shadow lengths</th>
<th>Earthquakes, using secondary data</th>
<th>Key Stages (1-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘WORKING SCIENTIFICALLY’ SKILLS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning/asking questions</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Observing</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>1-3</td>
</tr>
<tr>
<td>Observing over time</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Measuring</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>1-3</td>
</tr>
<tr>
<td>Recording</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Identifying</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>1-3</td>
</tr>
<tr>
<td>Grouping/classifying</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>1-3</td>
</tr>
<tr>
<td>Pattern seeking</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Fair testing</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Explaining /analysing</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Evaluating</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Predicting</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>1-3</td>
</tr>
<tr>
<td>Concluding</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Raising further questions</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
<tr>
<td>Further investigations</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>2-3</td>
</tr>
</tbody>
</table>

Fogarty (1991) suggested various curriculum models, including one which linked across a number of disciplines. Earth science is easily assimilated into cross-curricular activities as shown in Figure 8.3. Catling and Martin (2011) pointed out that children start school with knowledge of naïve or simple local geography. They identified geography as ‘powerful knowledge’ that is gradually being eroded from teaching as time for humanities lessons is reduced in favour of the ‘core’ subjects. Figure 8.3 expands on these links with geography and other subjects, pulling them together as a comprehensive whole, emanating from earth science, rather than splitting into individual disciplines at this early age. Earth science may be a better base subject for the sciences than geography, because it incorporates more science e.g., ecology. Catling and Martin stated that the primary curriculum needs to be more meaningful and relevant to children’s everyday lives by connecting and linking everyday occurrences.
Figure 8.1 Earth Science cross-curricular links

- **Science**
  - Chemistry, biology, physics, technology

- **Geography**
  - Physical geography landscape soil, rock weather

- **Literacy**
  - Readings, writing, poems

- **Mathematics**
  - Display of information, space distances

- **Planetary organisation**

- **History**
  - Volcanoes, wars, earthquakes, e.g. Lisbon

- **Social challenges**
  - Hazards, climate change, sea level rising
  - Resource sustainability water, minerals, energy

- **Environment**
  - Preservation of soil, forests, habitats (ecosystems)

- **Art**
  - Materials, minerals, landscapes

- **Religion**
  - Tsunamis, earthquakes, stars
Much of the current primary curriculum does not lend itself to moving from very simple ideas to more complex ones, as in Bruner’s spiral curriculum, until children reach secondary schooling. However, earth science is one subject where knowledge and understanding of a range of topics can be simply enhanced. For example: starting at EYFS with the idea that water in puddles can disappear, in KS1 practical investigations can look at different weather conditions to see how quickly puddles disappear, whilst at KS2 pupils would begin to think about evaporation and where the water goes, then the water cycle, and eventually at KS3 into the physics and chemistry involved. Other science topics, for example ‘forces’, can use earth science examples as a starting point, e.g. using ‘water’ as a force.

Coppard (2016) suggests that the English science curricula does not flow from the ‘Big ideas’ of primary science through to more specific science concepts at secondary level. Children begin to develop intuitive ideas from an early age (Driver, 2000), which do not always agree with accepted ideas. These ideas are challenged as they advance through school, but may not be rejected, persisting into adulthood (Coppard 2016).

8.6 Contribution to knowledge of the thesis

The rationale of this thesis was to examine the potential of earth science for the improvement of primary science. Within this ideal is the opportunity to increase the knowledge and understanding of science by primary teachers, through improving their cognitive knowledge and key activities which could enable children to acquire further conceptual understanding and scientific skills. The study was seen as a viable research project because of the author’s long association (some 30 years) with primary teachers who find teaching some of the science in the English National Curriculum difficult. My research is both about the teaching of primary science and raising the confidence of practitioners by providing a pathway of relevant primary science which they feel able to teach. It proposes using the local environment and experiences that children have and extending the concepts that children have associated with these so that by the time they reach secondary education they bring with them background knowledge to biology, chemistry and physics which can be built upon. Earth science is dynamic and ever present, so resources are easily available locally and through the media. It therefore offers adaptable, cross-curricular (Figure 8.1 p200) and flexible learning opportunities for all children at all levels from EYFS to upper primary.

This thesis contributes to knowledge in the following ways:

The introduction of more earth science into the primary curriculum can be seen to be of benefit to pupils, science education and science literacy. The thesis shows that the confidence of experienced primary teachers and of trainees in teaching science can be enhanced through short, focused CPD. It shows that primary science can be enriched through the use of earth science which uses children’s relevant experiences and relates to local issues.

The analysis of the trainee teacher earth science workshops shows that a modest amount of CPD delivered to trainee teachers and to experienced teachers can increase confidence and enthuse teacher trainees, providing accessible, flexible ideas for practical implementation of science concepts and skills as well as using beneficial
pedagogical strategies. There are opportunities for sound assessment evidence to be easily collected, identifying different levels of achievement. Evaluation of the feedback received from 1385 trainee and experienced teachers showed how they intended to incorporate earth science teaching into their future lessons where possible. The short CPD given to the teachers involved in the intervention lessons has had a lasting effect with the topic now being included annually in this format.

The analysis of the children’s workshops shows increased motivation for science and raised self-confidence in science. The topics used – rocks, soils and fossils – were identified by teachers as areas they felt uncomfortable teaching because of lack of content knowledge. Feedback from the teachers report effective use of lesson time, giving them, too, an understanding of concepts about these topics which they can use in the future.

Lastly, earth science uses children’s relevant experiences to develop science concepts in a way children can relate to, which can subsequently be linked to secondary school science. Tables 8.1 (p189) and 8.2 (p197) indicate how other primary science topics can be enhanced through using relevant earth science as a way into further biology, chemistry and physics studies later in school. Earth science can be used to introduce and give an early understanding of more difficult science concepts, which can be built upon, through using children’s own experiences.

The thesis therefore presents a principled argument as to how the introduction of more earth science to the primary science curriculum, extending the work done in the EYFS programme, would be to the benefit of pupils’ science education and their science literacy.

8.7 Summing up

Alexander (2006) reflected on the purpose of primary education, asserting that government policy, including assessment, all too often gets in the way of the aims of an appropriate education. Alexander’s contention has been reinforced by the latest HMCI report (Spielman, 2018) which states that primary science is being squeezed out by English and mathematics because these two subjects are nationally tested externally (rather than solely through teacher assessment) and schools are judged on their results. As well as suggesting that the age of commencement of formal education should be raised to 6, Alexander asserted that the curriculum should consider the notion of ‘basics’ needed by 21st century citizens who would have to manage climate change issues, sea level rising and loss of land. He felt that children should be empowered by understanding at an early age how they would need to take control of sustainability. My proposition is that developing primary science through the potential of earth science would support this endeavour as children would grow up appreciating important interconnecting relationships between themselves and their environments. It would extend the work done at EYFS by encouraging children to learn about their local environments and it would enhance community links, another of the objectives identified in the 2013 National Curriculum. Children would learn skills and the basic links between all aspects of earth science. This would then be enhanced at secondary level through studies which would further connect these issues through the other sciences.

There have been few studies undertaken recently which have looked at primary science from the children’s or teachers’ points of view. My research has started to
identify some of the issues faced by primary teachers when teaching primary science, and their pupils when learning science. The teachers I work with are experienced and trained ten or more years ago. They often find science daunting as they want their children to enjoy investigations but do need feel sufficiently competent to allow children to experiment in case the results do not conform with what is expected, and they have to explain why. Earth science does not have black and white answers, and children need to think critically about their results.

I have shown that earth science does have potential for improving primary science through motivating both teachers and pupils, and enabling scientific concepts to be understood at a level relevant to pupils’ age and experience.

The input of a modest amount of earth science CPD did increase teacher confidence in teaching science, and opened doors to other concepts required in the curriculum, for example, scientific skills, and cross-curricular links. These short twilight sessions enhanced two primary schools’ science, and offered opportunities for evidence of learning and assessment by teachers. Both schools have continued to use the intervention lesson, so the relatively brief training has had long-term effects. In one school at least, earth science has spilled over into other projects. History with volcanoes, tsunamis and earthquakes are being followed in geography more closely by reacting to media information rather than just relying on conventional teacher input. This constitutes a positive contribution to the curriculum.

Earth science workshops for children show that with few and relatively inexpensive resources, children aged 7 and 9 can be motivated. The effectiveness of the sessions has been evaluated from the children’s comments and the amount of understanding and learning can be identified through the changes shown between pre- and post-workshop discussion and debate.

In England, teachers do not have to engage in or with research (DfE, 2012), whereas in Scotland Donaldson (O’Brien, 2012) suggested this could be an ongoing requirement and Scottish initial teacher training requirements emphasise this (www.ucas.com/teachertraininginScotland). Perhaps assisting teachers who are currently experiencing difficulties in teaching primary science to undertake their own research might identify issues that could be resolved if listened to by curriculum planners. However, this would require empathetic supervision by working teachers perhaps through local forums and networking groups.

I have also shown that if we consider science to be an important part of a child’s primary schooling, then the Primary Science Leader’s role needs to be held in higher esteem in schools, with more status and time given to science teaching than at present. Whilst science retains its core status it should be given equal teaching time to the other core subjects, English and mathematics as indicated in the May monthly report (HMCI, 2016). The Wellcome Trust report of 2017 found that only 50% of PSLs believed that their Senior Managers saw science as an important part of the primary school curriculum. The necessity for teachers to have a positive science self-image, which leads to increased confidence, has also been highlighted, as this improves attitudes towards both science teaching and learning, particularly at primary level. Again, the same Wellcome Trust report (2017) highlighted the issues of lack of confidence and little CPD allowed for primary science. Developing a positive self-image and improving confidence can be achieved in part through short, specific CPD
workshops. The earth science workshops for trainee teachers and teachers add to both pedagogical and subject content knowledge (Wellcome Trust, 2017). Appropriate primary earth science workshops for children given by enthusiastic specialists can increase interest in everyday earth science.

My research questions were designed to investigate why primary science is often not seen as an interesting subject, attracting young people to forward their scientific studies into lifelong awareness. I also hoped these questions would identify the issues behind the teaching of primary science and ascertain what could be done to improve the situation in which many primary teachers find themselves, that is, not having enough knowledge or confidence to teach the subject. My findings go beyond previous research, reinforcing that teachers are frequently not confident about teaching primary science, something that is truly a sorry reflection of our present approach towards teaching science in primary schools. Surely teaching and learning should be about more than aiming at higher final assessment levels for prospectus purposes as proposed by Spielman (2018).

We need to ensure that primary science lessons are educational and memorable, promoting a lifelong interest in and understanding of science. Tyler (2017) suggests that topical science has great impact on learners, increasing engagement and adding to scientific literacy (Primary Science, 2017). Earth science is an invigorating topic to use in primary schools as a basis for understanding the physics and chemistry that will be taught later in secondary school. It has great potential for the development of primary science if used with local issues and with supporting CPD programmes.

8.8 Limitations of the thesis
My study is limited first by the size of the sample of trainee teachers and Primary Science Leaders I was able to access to complete my questionnaires, although in both cases my samples were larger than those in the studies I was emulating. It was also limited to the geographical area where I was able to collect my data. However, the data collection could be repeated in other parts of England to compare results.

I was not able to be present at all the sessions when my first questionnaire with primary trainee teachers was completed. This might have limited the responses as I believe that being there in person often motivates the respondents as they know who will be analysing their answers. The Initial Teacher Training courses used were being run in London and the SE of England, which means that one cannot be confident that the findings can be generalised nationally.

The group of Primary Science Leaders who completed my questionnaire were self selected from schools which had joined the Surrey Primary Science Network group. This limited the participants in number as only 100 PSLs from the county were able to join. Since the schools had to pay for the privilege of belonging to the group, this limited the range of participants to those coming from schools that were prepared or able to pay.

The two schools who agreed to work with me on the intervention were both in my local village which lies on the edge of a commuter town for London. I was only able to work with year 3 students for the purpose of this research. Further research with more schools and in different parts of the country might produce different results. It could be suggested that the positive impacts of the intervention lessons might be attributed to
my participation. However, the long term effect of the intervention on these local schools, is that both have incorporated a ‘soil science day’ into their annual programme, which is a positive outcome. My study was not designed to measure long term effects and it was not possible to measure the amount of knowledge recalled over time by the children, but it does seem that the teachers have benefitted in both PCK and confidence. School A is also incorporating earth science as a starting point for other topics.

Another issue to do with the generalisability of the findings is that whilst ESEU offers its trainee teacher workshops to all teacher training institutions, not all these institutions decide to apply for them, possibly because they are not seen as being important enough to justify spending the already limited amount of science training time available. Again, the long-term effects of the primary workshops are unknown as those involved were trainees on the whole, not yet established in their schools. These workshops took place in institutions across England and were taught by a number of different tutors. A follow-up study of the secondary ESEU workshops found that teachers had incorporated many aspects of the workshops into their teaching and changed the way they approached earth science topics (Lydon & King, 2009). It might be presumed that the primary workshops have a comparable impact.

The SATRO children’s workshops were limited to those schools that were linked to a company sponsoring the rock and soil and fossil workshops in Surrey, or those schools that could afford to pay for the workshops. Nevertheless, in my experience, these children were of average ability for the county.

8.9 Validity of this research and ethical considerations

I have tried to ensure objectivity throughout my research. My samples have been as homogenous as possible within the different groups I have questioned, but are geographically limited to some extent. The questionnaires were completed in as similar an environment as it was possible to obtain. In order to ensure that my results are valid, I have used at least two methods to collect data to answer each research question. The two schools where the intervention lessons were introduced were fairly typical of the county in which I reside; it would be valuable to try this approach in different areas, such as an inner city area and a more rural environment. At the same time, having taught in an inner city environment, I know that earth science can be successfully introduced there.

Ethical considerations were borne in mind throughout my research. All the data collections adhere to the BERA ethical standards. Before the questionnaires were handed out it was explained to the participants that they were volunteers and could withdraw at any time. All participants were assured that withdrawal would not in any way affect their work status. Data were anonymised after collation. The head teachers at the two primary schools were happy for intervention lessons to be introduced and both they and the teachers agreed to data being recorded and used; photographs were only taken where permission had been given by parents. As far as possible, faces were not photographed unless important to the issue being examined, in which case permission had been given. No names appeared on any of the children’s work used and the teachers’ names were also anonymised. The ESEU and SATRO evaluation forms were analysed with permission from the companies that had collected the data.
8.10 The way forward

The task of educating the next generation of scientifically literate citizens means that the present generation of adults, not just teachers, need to be educators. Earth science will become increasingly important in the decades to come, as we understand more about the need to sustain our planet in order to survive (Gray 2018). The Royal Society of Biology (Glackin & King, 2018) document on the importance of environmental education reinforces these ideas. The many important socio-scientific decisions that will have to be determined in the future are earth science allied: climate change, sea level rises, the need to feed more people with decreasing agricultural space because of increased housing demand, the use of finite water resources, other economic mineral usage and energy resources. It is vital therefore that our children are knowledgeable and understand the relationships between human activity and our planet (LePage et al., 2017). I believe that the development and growth of earth science teaching in the primary school, EYFS and even pre-school is a necessity for our future as well as improving overall motivation for learning science. My research sought to provide a starting point to determine whether there was potential for earth science to develop primary science, and thus children’s understanding of science, and I feel that I have achieved this.

My research questions generated from the literature review have been explored through questionnaires and intervention lessons in schools and analysis of CPD workshops. The results suggest that earth science can be beneficial to primary science teaching and learning. I believe that where teachers are unhappy about having to teach science in primary school, using more local and relevant earth science examples would benefit both teachers’ and children’s feelings towards learning science and better prepare children for further science education at secondary level. However, this would inevitably require discussion about the science curriculum with individual SMTs and the collaboration of the local community for participation in local projects.

Initially, when science was first introduced systematically into primary schools in 1989 because of the National Curriculum, there was a flurry of activity to provide science CPD for primary teachers because of the dearth of science specialism amongst primary teachers. This extra training, financed by government grants and with the CPD given by local authority science advisors, seems to have been effective since an improvement in primary science learning was noted by the Ofsted (1999). However, more recently, Sharp et al. (2009) looked at how well primary teachers were trained and equipped to teach science. They concluded that despite significant revisions to the KS1 and KS2 science curricula and changes to initial teacher training programmes, there were still issues with primary science teaching. After twenty years in the National Curriculum, primary science was still regarded as ‘challenging’, although the majority (61%) of teachers in their sample indicated that they ‘generally’ enjoyed teaching this subject. Delegates from across Europe and Asia at the 2017 Hands-on in Science conference in Braga 2017, considered that science was not being taught effectively in primary schools in their countries and welcomed my proposal (Balmer, 2017) that earth science could be a useful basis for introducing science prior to secondary schooling.

James Williams in an article in the TES (October 2018) identifies some of the issues within primary science today, suggesting that we don’t give children an education about science and arguing that we need to ensure understanding as well as facts. He emphasises that a lack of understanding may unintentionally be the result of a too
‘knowledge-rich’ curriculum. He suggests that we need to overhaul our school science curricula to allow teachers to teach about the way scientists reason using evidence to produce a theory – the nature of science.

I believe that there needs to be a real change in attitude to science in primary schools. Is it appropriate to use a ‘watered down’ version of the secondary curriculum? Would it not be better to devise a curriculum more suited to children’s experiences and teachers’ science knowledge? The extension of the EYFS curriculum of exploring the ‘world around us’ would be a suitable place to start early primary science. The use of earth science examples in KS2 can be allied to physics, chemistry and biology at higher levels in the primary school, and these examples will form the basis of scientific understanding in secondary school. Secondary teachers, in my experience, have suggested that they prefer to teach those year 7 children who are enthusiastic about science and have some scientific skills rather than the sometimes inaccurate knowledge with which they arrive at the start of their secondary schooling (Allen, 2014).

There is, therefore, much to be said for a total reconsideration of the primary science curriculum. In the past, valuable ideas have been suggested but lost, for example the SPACE programme (Russell et al., 1993). Can we not start again, perhaps with a different emphasis, using earth science as the base? With sections like Air, Water, Earth and Fire the majority of the current science curriculum could be covered using earth science, incorporating physics and chemistry concepts using everyday phenomena. An earth science curriculum based around these medieval elements would help to integrate local phenomena, enabling children to observe and record everyday happenings, handle local resources and investigate local issues in their environment. This would encourage understanding of small scale issues which, as the child develops, can be seen on a larger, world-wide scale and might promote understanding of such global problems as climate change and deforestation.

The New Scientist (June, 2017) ran a special report on ‘how to live with climate change’. The 35th International Geological Congress held in Cape Town in summer 2016 stated that “investigating, managing and intervening in various components of the Earth’s systems” was vital to the sustainability of the planet (Di Capua et al., 2016). The statement goes on to say that geoscience (earth science) needs to be at the heart of international debates on sustainability as it has a wider knowledge base than the natural sciences. Earth science will continue to be important in ethical and social decisions on a world scale and as such should be communicated to all peoples.

Perhaps the easiest way to do this would be to ensure earth science teaching is enshrined in primary science. Northern Ireland has introduced a revised primary science curriculum which highlights earth science projects. These projects have been shown to be instrumental in encouraging primary children’s enjoyment of science and increased enthusiasm as the children enter secondary school (McCune, 2009). The United States Next Generation Science Standards (NGSS) look to increasing earth science teaching throughout the country and, whilst not yet adopted by all its states, about one-third of the proposed new science curriculum is earth science based (NGSS, 2013). However, the latest English secondary science curriculum (DfE, 2013) has removed all earth science despite its importance economically, environmentally and socially. How much more important is it then, that we teach our young learners this vital subject, and what better way to do this than through primary science? Earth science has all the ingredients for teaching science: resources and examples are all around at
a variety of scales: local, regional, national and global. Earth science throws up questions children can identify with and investigate at home or in class. Earth science can be a discussion point at home as well as in school, no longer separating science as a subject learnt in school with no links to the real world. Earth science is *dynamic* and children can see changes. All the scientific skills and many that are going to be required in secondary school, and also in subsequent life, can be acquired through earth science in primary school. Socio-science issues too, are often of interest to children, and if they are enabled to understand the principles behind these issues at an early age, they will be better informed as they mature. I maintain that there is great potential in earth science for the development of primary school science.

### 8.11 My journey through this research

At the beginning of my research I was sceptical about my own beliefs that many people do not understand the importance of earth science, of looking after our planet, and the necessity for something to be done soon to alleviate future world problems, not just in England but on a world-wide scale. Earth science has been my life-long enthusiasm and I want others to understand and enjoy it. From my working experience, I knew that there were issues facing primary teachers about teaching science. I have learnt how widespread these issues are, particularly amongst those people who have been teaching for some time. I appreciate that none of the resources or ideas about science teaching and earth science in particular are entirely new. However, they are new and innovative to the teachers I work with who are more mature, have been teaching for many years and are struggling with ways to make science investigative and relevant. For them, earth science has opened their eyes to new ways of integrating local events into their science curricula, showing the potential of earth science.

I have learnt the need to assemble an argument and find appropriate research to ratify the argument. I appreciate now some of the education policies that were introduced whilst I was teaching, as I understand the thinking behind these policies. It would have been beneficial to me at the time had I had the time and opportunity to read some of this research, and I would suggest that important, policy-changing research is made more accessible to teachers. Teachers should also be allowed time to read and digest such research before it is implemented and becomes statutory.

When I started my research, my mission was to try to understand why science is not seen as an exciting and interesting subject by everyone. I now have some understanding of the problems and would very much like to help bring about change to improve the status of science and show how important science is to everyone. I still believe in the positive nature of primary children and that showing them how their environment works is a way to foster science into their lives for life. As one of my primary colleagues told me in 2017: “primary science is about whipping up a frenzy of enthusiasm about everything, not killing it with a list of facts or criteria!”

The great scientist Alexander Humboldt (1769-1859) identified the importance of viewing our world as a whole, with all systems integrating and being interdependent. He forecast many of the present issues which are affecting our lives because of human intervention. He stressed the need for the world’s population to understand the intricacies to sustain our planet. By teaching earth science and its values in early schooling, perhaps we will understand the need to work together to ensure a sustainable future for humankind.
References


Di Capua et al see IGE (2016)


Foundationyears.org.uk/files/2017/03/eyfs_statutory_framework.pdf


government (https://www.gov.uk › ... › GCSE subject content and requirements).


HMCI (2018) see Spielman.


http://www.forestschooltraining.co.uk accessed April 2018.


https://www.gov.uk › ... › GCSE subject content and requirements accessed August 2018.


https://www.ucas.com/ucas/teacher-training/train-teach-scotland


IGEO (2015) International geoscience syllabus www.igeoscied.org/activities/international-geoscience-syllabus...


223


Planet Earth (2003) NERC.

Planet Earth (2016-17) *Keeping back the floods*. NERC


SATRO Internal Report 2012.

Science SCOPE September 2018 42(2) NSTA. Arlington.


TERC (center for earth and space science education.) see Hoffman, M. & Barstow, D.


Turford, B. and Turner, J. (2018) Professional development and learning


Wellcome Trust (2014). *Primary Science: is it missing out?* Wellcome Trust. London.


*What is Education for?* Submission to House of Commons Education Committee Inquiry into the Purpose and Quality of Education in England. 25th January 2016.


www.gov.uk/government/collections/ofsted-annual-report-201516; what research has to say. (eds Osborne, J.& Dillon, J.)


www.SchoolsWeek.co.uk (July 10 2016).


Appendices

Appendix 1 Questionnaire to Trainee Teachers

QUESTIONNAIRE FOR TRAINEE PRIMARY TEACHERS – DRAFT

Teacher Trainees.

Dear Student,

I am currently undertaking a PhD looking into issues surrounding science teaching in primary schools and how to best support training programmes. I should be very grateful for your help in completing the following questionnaire, but I should like to make it quite clear that this is totally voluntary and you may withdraw at any time you wish to do so. Non-participation will not be held against you in any way, and all data used will be anonymous. There will be two questionnaires, one now at the start of your course and a second, a follow up at the end of the year. I am asking for your names on each so that I can link responses, but my evaluation will discard all names so that the information is totally anonymous.

Thank you

Denise Balmer

SCIENCE BACKGROUND EXPERIENCES SURVEY

Name________________________________________
Date_______________________

1 How would you describe your general primary school science experience?

I enjoyed science at primary school (please circle response)

Strongly disagree 1 2 3 4 5  Strongly agree

If you really can’t remember anything about your primary school science, tick below and skip the rest of question 1

--------------I cannot remember anything about primary school science.

How would you generally describe your best year in primary school science?

Strongly Disagree

Strongly Agree

a Not Fun 1 2 3 4 5 Fun
b Boring 1 2 3 4 5 Interesting
c Text book based 1 2 3 4 5 Hands–on
d Worksheet based 1 2 3 4 5 Hands-on
e Did not learn much 1 2 3 4 5 Learned a lot
2. Identify the science topic you liked best in year 6 of primary school, by subject name (e.g. biology, planets) Please explain why you liked this topic, was it the teacher or the subject matter?

Describe how typical of your year 6 science experience this topic was.

How I enjoyed my year 6 science lessons

Strongly disagree 1 2 3 4 5 Strongly agree

How would you generally describe these lessons?

Strongly Disagree
Strongly Agree

a Not Fun 1 2 3 4 5 Fun
b Boring 1 2 3 4 5 Interesting
c Text book based 1 2 3 4 5 Hands-on
d Worksheet based 1 2 3 4 5 Hands-on
e Did not learn much 1 2 3 4 5 Learned a lot
f Teacher dominated 1 2 3 4 5 Much pupil input
g Learning by heart 1 2 3 4 5 Emphasis on understanding

Did your primary school have a Science Club

Yes No

Please circle

Did you attend this

Yes No

If so, what did you enjoy about it?

3 Please put a tick beside each of the lower secondary school science courses you took (in year 7, 8 and 9, when you were aged 11-14). Then rank them in order with number one being the one you liked best.

Tick if you studied subject

Rank

Biology

Physics
Earth Science
Chemistry
IT
Any other science course
Please specify below:

--------------------------------------------------------------------------------------------
Referring to the
course you ranked as 1 above:

How would you generally describe this course?

**Strongly Disagree**
**Strongly Agree**
a Not Fun 1 2 3 4 5 Fun
b Boring 1 2 3 4 5 Interesting
c Text book based 1 2 3 4 5 Hands –on
d Worksheet based 1 2 3 4 5 Hands-on
e Did not learn much 1 2 3 4 5 Learned a lot
f Teacher dominated 1 2 3 4 5 Much pupil input
g Learning by heart 1 2 3 4 5 Emphasis on understanding

Describe how typical this was of your lower secondary school science experience

4 Did you attend any science fairs whilst in years 7, 8 or 9? (please tick)

______none at all       ______in one year       ______in more than one year

Describe how you felt about these fairs:

**Strongly Disagree**
**Strongly Agree**
a Not Fun 1 2 3 4 5 Fun
b Boring 1 2 3 4 5 Interesting
c Not useful 1 2 3 4 5 Useful
d Not career focused 1 2 3 4 5 Career focused
5 Please put a tick beside any GCSE or A level science courses you have taken and rank them, with number one being the one you enjoyed most

<table>
<thead>
<tr>
<th>Course</th>
<th>GCSE Rank</th>
<th>A level Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earth Science/Geology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applied Science</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How would you generally describe this course/courses

**Strongly Disagree**

**Strongly Agree**

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Not Fun</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>b</td>
<td>Boring</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>c</td>
<td>Text book based</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>d</td>
<td>Worksheet based</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>e</td>
<td>Did not learn much</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>f</td>
<td>Teacher dominated</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>g</td>
<td>Learning by heart</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Have you studied any science after A level?  Yes  No

Please describe level and subject:  ________________________________

6 I felt my parents were supportive in establishing an interest in science in (for example, by taking me to science museums, buying science kits or resources)

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Strongly disagree  1  2  3  4  5  Strongly agree

7 School field trips were an important part of my science experience

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Strongly disagree  1  2  3  4  5  Strongly agree
8 My non-school experiences stimulated my present curiosity more than my science classes (e.g. camping, gardening collecting items)

Strongly disagree 1 2 3 4 5 Strongly agree

9. The following is a list of activities and experiences. Please put a tick before ones that were part of your childhood/youth, and a second tick if it was an important part of your childhood/youth. Add any additional activities to the bottom of the list.

Please put a star by any activities you enjoy now.

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>PART of Childhood</th>
<th>IMPORTANT part of Childhood</th>
<th>Important NOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEGO bricks or Robotics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Board Games</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building with wooden blocks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Games</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Game Boy or similar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer programming</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taking things apart</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Playing school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TV nature/science programmes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemistry kit, microscope or telescope</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planting in garden</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Care of animals/pets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visits to science museums</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visits to history museums</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visits to zoos, nature centres, aquariums</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Play at doctors/nurses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making explosives or other risky play</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making science collections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making non-science collections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making models</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Star gazing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Looking after house plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing up kitchen chemicals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exploring outdoors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Playing on playgrounds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Playing in sand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snorkelling or SCUBA diving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beach combing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guiding/Scouting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science club</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Survey adapted from Bulunuz and Jarrett (2002)
Thank you so much for your co-operation, and I look forward to meeting you again later in your course.
If you wish to contact me, please email me at
Appendix 2 Questionnaire to Primary School Teachers

QUESTIONNAIRES FOR PRIMARY SCHOOL TEACHERS

Dear Teacher

I am currently undertaking a PhD looking into issues surrounding science teaching in primary schools and how to best support training programmes. My hope is to increase enthusiasm about science in children going on to secondary school, in order to ultimately increase the numbers of engineers and scientists. I should be very grateful for your help in completing the following questionnaire, but I should like to make it quite clear that this is totally voluntary and you may withdraw at any time you wish to do so. Non-participation will not be held against you in any way, and all data used will be anonymous. There will be three questionnaires in total one now, the second and third at subsequent meetings or they could be emailed to you if you prefer, so long as they are done on different days to create some thinking space in between them. I am asking for your initials on each so that I can link responses, but your answers will be totally anonymous. The questionnaires are adapted from a survey undertaken by Chin-Chun Tsai I 2002

Thank you

Denise Balmer

Initials____________________________________Date_____________________________

Questionnaire 1 Beliefs of Teaching Science:

1a What do you think makes successful science teaching?

1b In your view, what is the best way to teach science

1c Describe what would be the ideal science teaching environment look like in your opinion?

Questionnaire 2 Beliefs about learning science

2a What do you think makes successful science learning?
2b What do you think about the responsibilities of students when learning science?

2c What is the most important determinant for success of learning science? Why?

Questionnaire 3 Beliefs about the Nature of Science

3a What would you say if someone asked you ‘what is science’?

3b What are the main characteristics of scientific knowledge?

3c What are the differences between scientific knowledge and other knowledge
**Appendix 6 Earth Science Education Unit evaluation form page 1**

**TO BE COMPLETED BY ESEU FACILITATOR, PLEASE:**

<table>
<thead>
<tr>
<th>Venue:</th>
<th>Date:</th>
<th>Facilitator:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of participants:</th>
<th>Workshops presented:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ESEU post-workshop evaluation**
(form applicable to Primary, Secondary and Scottish workshops)

Some information about your institution please

1. Name of your school/institution: ....................................................................................

2. If a school, please give the number of pupils:
   Some information about you and your background please

3. I am **male** / **female** (please delete as applicable)

4. I was taught or have studied Earth science / geology: (please tick as many as apply)

   - [ ] at school up to 16
   - [ ] at post-16 level
   - [ ] as a minor part of my undergraduate degree
   - [ ] as a major part of my undergraduate degree
   - [ ] at postgraduate degree level
   - [ ] as part of teacher training (other than this session)
   - [ ] other (please specify)
   - [ ] I have no Earth science background at all

5. Please choose and tick one of the 4 options below:

   - [ ] I am a teacher
     - primary
     - secondary
     - post 16
   - [ ] I am a trainee teacher
     - PGCE
     - PGDE
     - other
   - [ ] I am a technician
   - [ ] I am not a teacher, trainee teacher or technician

   How many years have you been teaching?
   ....... years
   Please respond to all of the questions below – thank you!

   - [ ] Please respond to all of the questions below – thank you!
   - [ ] Please ignore any questions which you do not feel are relevant, but we welcome your feedback!
   - [ ] What is your role?

Page 2 of ESEU evaluation form

6. The area(s) of science I feel most confident teaching is/are:
   biology [ ], chemistry [ ], physics [ ], Earth science [ ], all of them [ ], other .................
   Your views on the workshop please tick appropriate box

<table>
<thead>
<tr>
<th>High</th>
<th>↔</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

242
7. I found the effectiveness of the INSET to be

8. The interest of the INSET was

9. The relevance of the INSET was

10. The value of the INSET to me was

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>↔</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. The workshop has improved my Earth science knowledge and understanding</td>
<td>☐ ☐ ☐ ☐ ☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>↔</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. The workshop has given me new ideas for ways of teaching Earth science</td>
<td>☐ ☐ ☐ ☐ ☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>↔</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. The workshop has improved my confidence in teaching Earth science</td>
<td>☐ ☐ ☐ ☐ ☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>↔</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>14. The workshop will increase the amount of Earth science practical work I teach</td>
<td>☐ ☐ ☐ ☐ ☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>15. The workshop will increase the amount of Earth science investigational work I teach</td>
<td>☐ ☐ ☐ ☐ ☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>16. The workshop will increase the total amount of Earth science I teach</td>
<td>☐ ☐ ☐ ☐ ☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Only respond to question 17 if your workshop had an out of doors component:

17. The workshop will increase the amount of Earth science out of doors I teach | ☐ ☐ ☐ ☐ ☐ | ☐ | ☐ |

18. Please add some general comments about your experience of the workshop(s)
Appendix 3 Soil story

Basic Soil Formation:

The weather acts upon rock.

Plants grow on the weathered rock.

Along comes the army of bacteria — they eat up the nettles and extract their nectar onto the rock particles — we call it humus.

Along come the worms that mix up the humus with the rock particles to give us soil.

More plants grow — there is more litter for the bacteria to act upon.

The rain and other processes of weathering can still affect the rock surface and "weather" it further. The soil becomes deeper. Draw your own diagram to illustrate this!
Appendix 4 We all learnt today (WALT) sheet

VALT Explain our learning 13/11/15
s1 projects
I doing this activity I learnt in the different layers of soil. Separating roots
used sieves because then we could see which parts of the soil were rocks. No the sizes are not all the same, some are bigger and some are smaller. Some are smaller holes and some boxes we then smaller bugs would pass through and bigger bugs wouldn’t. I found roots and hidden rocks in the soil and a lot of soil air. I weighed 402 g. Soil permeability was trying to find out to see how long it took the water to drip through the soil. We need the universal indicator liquid to change the colour of the water and then the scale to see what colour it is. If its red its acidic, green neutral and blue is basic. Permeability means water can pass through it. Soil A was soft and let the water through straight away. Soil B was rough and hard and it let the water through in very slow. Soil C was squishy and it let the water go quite slowly.

Conclusion
I enjoyed most about the day was the water going through the dirt actively because it was exciting and interesting. Yes I was a good scientist because I kept focused on the job and read and used everything. I was successful because of my LP and being a good listener lesson? listener neutral

neutral
neutral
Appendix 5 Children’s comments about soil
All the comments listed are taken from the soil bubble diagrams, made before the lessons:

Without soil, some people wouldn’t survive because with soil we can grow food to help to help the environment.

Soil is in the garden (x2)
Soil is compost left to rot (x2)
Soil is earth (x2), mud (x2), muck (x2), ground (x3), mud (x4)
Soil is wet mud – dry mud and water = soil
Soil is a very dirty thing to use
Soil makes plants grow
Soil is rough and has minibeasts (as given) in it. It is dark gray/black/brown (x2) colour
Soil is underground, under grass
Soil is under our feet
Soil is dirt and you grow things in it (x6)
You use soil to grow flowers, bushes, trees, shrubs. Put a plant or flower in soil to make it grow
Soil helps plants grow but needs water
Soil grows on the earth
Soil makes flowers
Soil can be used for lots of things like trees
Soil is for playing games on
Soil is curious
Soil is something you put in a plant
You can dig it up
Worms make compost into soil
Soil id plastic
Soil is garden waste
Soil is a substance that can be used for many things like planting or making dens or moulding things
Soil is a comfy place to live

Comments about soil made after the soil lessons taken from bubble diagrams:

Soil is made out of weathered rock, humus, leaf litter, roots and dead nettles
Soil is made from litter, humus and weathered rock (x11)
Soil is made out of humus (x2)
Different soils let water through faster
Different soils let different amounts of water through
Soil can let water through
Soil is brown or black
You find soil under grass
Soil is better at growing than stones
There are different types of soil, soft, sandy (x5)
There are different layers to soil and the bottom one is bed rock
I learnt how soil forms (x4) (and explained verbally)

WALT (We all learnt today) comments
I learnt:
- what soil is made out of (x2)
- the soil story and layers of the soil
- new vocabulary (x6)
- about the soil profile (x3)
- how soil is made and leaf litter becomes humus
- soil is made of types of rock and humus
- permeability means water can go through something
- which soil was best and kept water for longest
- some soils hold more water than others
- different soils let different amounts of water through
humus is insect poo
some insects are bacteria
soil can make plants grow
what you have underground, and humus is a mixture of leaf litter, insect poo and worm castings
soil is different layers underground that make up soil
you can break the soil up (sieve) and see all the stuff in it

Comments about fair testing:
A fair test is when you have the same amount of the same things and you change one thing for us the soil amount was the same and same amount of water but we changed the soil type. And the time changed for the water to drip through (x11)
We used different soils.
(There were still a number of comments suggesting that everyone should be able to have a go at things and be nice to your friends. The idea had got through to about half the class.)

Unsolicited comments about soil work:
All the activities were really fun but the second one (permeability) was my favourite because it was very interesting and exciting I enjoyed the water and soil experiments because we got messy and it is fun doing experiments I thought science was fun
Appendix 7 SATRO Pupil Evaluation Form

Discovery Science Workshops
SUMMARY Pupil Feedback Form

<table>
<thead>
<tr>
<th>School</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Year Group</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Please <strong>one box only in each row</strong>)</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I have learnt more about science/technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I found it helpful to work with a partner or in a team</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Would you like to become a scientist or engineer in the future?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did you enjoy working with the volunteer scientists and engineers?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How has this activity made you feel about science?</th>
<th></th>
</tr>
</thead>
</table>
Appendix 8 SATRO Evaluation Form Comments from three workshops

- Happy. (5)
- I loved it and it was fun. Thank you. (4)
- Really interesting.
- I really enjoyed it
- Happy! Thank you.
- I feel good about science.
- Very happy and I want to learn more about rocks.
- It makes me feel like I would like to be a scientist when I am older.
- Very confident in science now, I like science more.
- It has made me feel a lot more confident.
- Made me feel excited, it made me feel clever.
- The activity made me feel happy about science.
- I feel very good about it and I enjoyed it very much, more than I thought. I am learning more things about rocks and I am happy.
- It has made me want to learn more about rocks.
- It has made me learn more about rocks.
- It makes me feel happy. I would like to learn more.
- It made me want to be a scientist when I am older.
- Great, no one could do better! I am amazed by all I've learnt.
- It made me feel very happy.
- This activity made me feel confident at science.
- It was great; I would want to be a scientist.
- It made me feel really happy because I got to see lots of different rocks. I had lots of fun.
- More confident!
- I loved it! I have learnt more about rocks and soils.
- Excited, happy and joyful.
- Happy, very happy.
- It was the best day of my life.
- The best day of my life.
- Excellent.
- I didn't understand it.
- Angry.
- Not interested.
- It made me feel happy because it was fun. (4)
- Brilliant, because you explained really well about fossils.
- I have always wanted to be a palaeontologist and it has made me want to be one even more.
- I used to not like science but now I feel more comfortable with it.
- It has changed my mind about how important fossils are! And I hope maybe I will be a scientist.
- It made me feel much more confident in science and I have learnt much more about rocks and fossils!
- Amazing, I want to learn more.
- It has made me want to do more science.
- Interested in finding fossils.
- I would like to find out more.
- It felt amazing.
- I feel interested in science.
- I feel more comfortable with fossils.
- More hopeful at becoming an archaeologist.
- Well it makes me feel like I want to be a scientist and learn more about rocks and fossils.
This activity has made me feel quite the same about science I wouldn't really want to be a scientist when I am older.

This activity has made me feel interested in science and like it is important.

It has made me more interested in science.

Good and smart.

It was very interesting because some science is boring but fossils are interesting.

It made me feel interested because I learnt lots about fossils.

It made me want to find out more about science and soils.

Amazing I want to learn more.

Good, want to learn more.

This made me feel interested about science because the rocks are very interesting.

I feel happy because you gave us information.

This activity has made me like science more because we have learnt more.

I feel happy and I enjoyed it because it was fun and she explained everything.

I feel like a scientist because Denise made me a scientist.

I feel amazed and excited; I couldn't believe my eyes because it was so interesting and fun. I would love to be what Denise is now.

It made me feel like a scientist because we were learning about science.

It makes me feel like I know a lot about science now.

It made me feel like I know about rocks and soils more, thank you!

I feel happy because I rather enjoy science.

Well I really like learning about rocks and soils and it made me feel scientific.

I feel smarter and know more about rocks and I feel very happy.

This activity has made me feel a bit better about science because I never knew there was so much information about rocks.

It has made me want to be a scientist because I know more about rocks and soils.

I really like science and am going to try and find lots of interesting stuff. I liked it because it taught me new things and I like learning.

I now feel very happy because I love working with Denise.

It really made me want to be a scientist because I really liked learning about rocks and soils.

It made me feel really great because I learnt new things about rocks.

It made me feel more interested in science.

Now I want to be a Geologist when I am older all because of Denise!!

This activity has made me feel happy because I love learning about rocks.

It made me feel great about science.

I liked all the wonderful rocks Mrs Balmer bought in to show us.

I have learnt that some rocks are smooth, some are rough. I also like it when Mrs Balmer drew animations.

I have also learnt that from dust to planets this is what we call the solar system.

We learnt about how rocks and soil were made.

How the world was created and how soil was made up and it took a long time and how planets were formed. I also learnt that all rocks are different. It was great to see lots of different rocks.

To make the soil it had to have the first layer of rocks [which] had to crumble.

I like that story at the end of the session because it was very interesting about how to make soil. I also enjoyed looking at the amazing rocks Mrs Balmer bought in and they were all sorts of different diamond and minerals in them. It was very interesting.

A lot of things especially colour appearance, smell, feel make up and lots more I learnt how the planets and the earth were made and a soil story and we felt lot
of rock from different countries and lots of experiments and how the moon was made.

• Where rocks come from – rocks are permeable, special stones. What rocks are made from, what the Earth is made from.

• Don’t guess what rock you’re studying. It could be something different. We were taught how earth and soil was made and the planets. We also had to identify which rock was which.

• Rock and soils – like granite, sandstone, slate, limestone and loads more. It was FANTASTIC!!! My stone was flint. I loved the stones too and one was really sharp and one was smooth. Mrs Balmer was a really good teacher. And we learned about awesome planets.

• I learnt some names of rocks and the names of minerals. Also how the earth was made and about soil. I liked the bowl sort of shapes.

• How the world was made. How rocks were made and how the moon was formed.

• Slate is easy to break. I liked her stones. I love it all.

• I learnt how soil was made.

• I have learnt that rocks all come from the ground. All rocks are very very old. I like the limestone because it felt smooth.

• I learnt how rocks were here and where they come from. And learning about more rocks. And looking at the special stones.

• We learnt about where rocks came from – it was fun and the rocks which we looked at today – some were hard and some were soft as well. The earth was made out of rocks and some stone.

• I learnt loads of kind of rocks and how soil and the earth was made and I learnt if granite was permeable and it isn’t.

• I learnt that all rocks are different and how the earth was made. And I learnt how soil is made. And I learnt that lime stone and sand stone are permeable.

• We learnt how the Earth was made and we learnt how planets were mead and how the moon was made.

• I have learnt today all about rocks form different countries and how the planets [were made]. I had lots of fun.

• I enjoyed things today. I want to be like you. Thank you for coming in today ‘bye’ and ‘thank you’!

• I liked holding all the different rocks and hearing the stories. I leant how the planets formed.

• I’ve learnt the story of rocks and soils and how planets came to be planets.

• I have learnt today about rocks and moon – it was fun to do the water. How the moon is made – of course the stars.

• I enjoyed learning about all the different rocks. I now know that soil is made up of water, air, litter and rock particles.

• How the earth was make. I enjoyed today very much

• I thought it was very good because I loved seeing the rocks and stuff.

• I’ve learned copper is green when it’s under the ground. Fool’s Gold stays in the air too long it will melt. Rocks are made up of minerals. How I liked it a lot.

• Very fun and it’s made me want fossils and crystals.

• It has made me feel like when I’m on a rocky beach, maybe look for some rocks and one day I might be lucky enough to find a diamond.

• I like fossils and have learnt a lot.

• I think it was really exciting and I would love to know more.

• I have become much more interested in fossils, rocks and minerals.

• I have really enjoyed it and it has made me want to find lots of different fossils, rocks and minerals.

• It has made me more interested in rocks and minerals.
I found this activity extremely educational, especially the crystal/rock part of the day. The instructors made it fun with plasticine and also they really made me more interested.

I have found it really interesting and fun especially the part when the lady was showing us the filters.

I find it much more fun and exciting now.

I like fossils.

That it's very interesting and there are endless things to discover. It was also very fun.

How it is very interesting and there are many things that go into one particular topic. It was very exciting seeing all the crystals.

Great, Fossils are epic!!

I want to learn more!

It has made me like science even more, I really enjoyed it.

Really really enthusiastic. Thank you.

Really interested in fossils and science. Thank you.

It made me feel like I want to go out looking at rocks.

It has inspired me.

I feel happier and I think it has made me more into science. I have really enjoyed today.

I have enjoyed today.

It made me feel normal, and I like science.

I feel like I already know loads! And it was really exciting learning about the different rocks, fossils, minerals and other things. Also it helped me to understand when we explained it with plasticine. I definitely want to become a scientist or engineer or fossil person in the future. Thank you!

It made me feel a bit more interested in science and they explained things I wanted to know, that I didn't know before.

It made it much more exciting for us and I really enjoyed it.

It's made me feel more confident with science and working with fossils.

I would like to collect some minerals and amethysts. I have certainly learnt a lot and I like science more.

I didn't' love it before this happened! I definitely prefer it as it's made me feel like fossils are very interesting and I would probably like to go and see more or find some.

Well a bit better but still not great although it was quite fun learning new things. I don't think I want to be a scientist though.

A lot more interested in fossils and science. I was amazed by the fossils!

It has made me feel a lot more excited about science lessons.

I find it easier to understand it.

It has made me more interested in minerals.

I feel like there's more to science than I knew.

It's made me feel more confident about science.

It has made me realise that science isn't boring and that some aspects are quite fun. It was interesting learning about rocks and how fossils were formed.

Now I know more about rocks and evolution.

This activity has made me feel more interested in science and fossils and I have learned as lot from this activity.

It has made me feel more confident in my understanding of fossils.

This activity made me feel more into science. Before I never liked science but now I like it a lot.

It is a really good way to explore the world for tiny rocks that are worth millions.

It has helped me a lot and I really liked the lesson.

It has made me feel that there is more to science. I never thought I'd see a rock that a diamond comes from. I really liked the amethyst and the fish fossils.
• Interested about minerals and fossils.
• It has taught me about fossils and minerals.
• It made me feel good and confident about science.
• It's made me a little more excited about science and I'm interested in the minerals.
• It made me like science even more. My favourite mineral was the tiny diamond in the rock.
• It made me feel really excited when she was taking out the rocks and the shapes of the bones.
• Great! It was really fun and I learnt lots of interesting facts.
• Not too much more interested, it was just a bit more fun than a usual science lesson.
• It makes me interested in fossils, volcanoes and rocks.
• Before I didn't know much about this but now that I have learnt it in this way, by actually seeing the rocks and minerals it has helped me learn more.
• It has made science more clear. the soil was formed.