Primary Science: 
An analysis of changing policy, 
policy text and practice

by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE OF CONTENTS</td>
<td>i</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>xi</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>xii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xiv</td>
</tr>
<tr>
<td><strong>CHAPTER ONE INTRODUCTION</strong></td>
<td>1</td>
</tr>
<tr>
<td>1.1 OVERVIEW OF THE STUDY</td>
<td>1</td>
</tr>
<tr>
<td>1.2 PRIMARY SCIENCE</td>
<td>3</td>
</tr>
<tr>
<td>1.3 POLICY TRAJECTORY MODEL</td>
<td>6</td>
</tr>
<tr>
<td><strong>CHAPTER TWO LITERATURE REVIEW</strong></td>
<td>12</td>
</tr>
<tr>
<td>2.1 INTRODUCTION</td>
<td>12</td>
</tr>
<tr>
<td>2.2 CONTEXT OF POLICY INFLUENCE</td>
<td>12</td>
</tr>
<tr>
<td>2.2.1 Philosophical and Cognitive influences</td>
<td>12</td>
</tr>
<tr>
<td>2.2.2 Political and policy influences</td>
<td>23</td>
</tr>
<tr>
<td>2.3 CONTEXT OF POLICY TEXT PRODUCTION</td>
<td>30</td>
</tr>
<tr>
<td>2.3.1 Implementation of National Curriculum (1989)</td>
<td>31</td>
</tr>
<tr>
<td>2.3.2 National Curriculum revision (1991)</td>
<td>33</td>
</tr>
<tr>
<td>2.3.3 National Curriculum revision (1995)</td>
<td>39</td>
</tr>
<tr>
<td>2.3.4 National Curriculum revision (1999)</td>
<td>42</td>
</tr>
<tr>
<td>2.4 CONTEXT OF POLICY PRACTICE</td>
<td>43</td>
</tr>
<tr>
<td>2.4.1 Teacher subject knowledge</td>
<td>43</td>
</tr>
<tr>
<td>2.4.2 Scientific investigations</td>
<td>50</td>
</tr>
<tr>
<td>2.4.3 Teaching strategies and conceptual understanding</td>
<td>51</td>
</tr>
<tr>
<td><strong>CHAPTER THREE METHODOLOGY</strong></td>
<td>61</td>
</tr>
<tr>
<td>3.1 INTRODUCTION</td>
<td>61</td>
</tr>
<tr>
<td>3.2 AIMS</td>
<td>61</td>
</tr>
<tr>
<td>3.3 RESEARCH DESIGN</td>
<td>62</td>
</tr>
<tr>
<td>3.3.1 Role of researcher</td>
<td>64</td>
</tr>
</tbody>
</table>
3.3.2 Ethical issues
3.3.3 Trustworthiness, issues of validity and reliability
  3.3.3.1 Survey
  3.3.3.2 Case study
  3.3.3.3 Group interviews
  3.3.3.4 Observations
3.3.4 Sampling strategy
3.4 METHODS OF DATA COLLECTION
  3.4.1 Questionnaire
  3.4.2 Individual interviews
  3.4.3 Group interviews
  3.4.4 Observation
3.5 DATA ANALYSIS
  3.5.1 Quantitative data
  3.5.2 Qualitative data
    3.5.2.1 Interview data
    3.5.2.2 Observation data

CHAPTER FOUR THE ELITES ........................................................ 95
4.1 INTRODUCTION 95
4.2 AIMS 95
4.3 METHODS 95
  4.3.1 Participants 95
  4.3.2 Materials 97
  4.3.3 Procedure 97
  4.3.4 Analysis 98
4.4 RESULTS 98
  4.4.1 Context of policy influence 99
    4.4.1.1 Curriculum 99
    4.4.1.2 Pedagogy 101
4.4.1.3 Assessment/accountability
4.4.1.4 Teacher development and subject knowledge

4.4.2 Context of policy text production
4.4.2.1 Curriculum
4.4.2.2 Pedagogy
4.4.2.3 Assessment/accountability
4.4.2.4 Teacher development and subject knowledge

4.4.3 Context of policy practice
4.4.3.1 Curriculum
4.4.3.2 Pedagogy
4.4.3.3 Assessment/accountability
4.4.3.4 Teacher development and subject knowledge

4.5 DISCUSSION
4.5.1 Context of policy influence
4.5.1.1 Curriculum
4.5.1.2 Pedagogy
4.5.1.3 Assessment/accountability
4.5.1.4 Teacher development and subject knowledge
4.5.2 Context of policy text production
4.5.2.1 Curriculum
4.5.2.2 Pedagogy
4.5.2.3 Assessment/accountability
4.5.2.4 Teacher development and subject knowledge
4.5.3 Context of policy practice
4.5.3.1 Curriculum
4.5.3.2 Pedagogy
4.5.3.3 Assessment/accountability
4.5.3.4 Teacher development and subject knowledge

4.6 CONCLUSION
7.5.3 Pedagogy 215
7.5.4 Assessment/accountability 217
7.5.5 Teacher development and subject knowledge 220

7.6 CONCLUSION 223

CHAPTER EIGHT CLASS TEACHER INTERVIEWS .......................... 226
8.1 INTRODUCTION 226
8.2 AIMS 226
8.3 METHODS 227
  8.3.1 Participants 227
  8.3.2 Materials 228
  8.3.3 Procedure 228
  8.3.4 Analysis 228
8.4 RESULTS 229
  8.4.1 Curriculum 229
  8.4.2 Pedagogy 234
  8.4.3 Assessment/accountability 239
  8.4.4 Teacher development and subject knowledge 242
8.5 DISCUSSION 244
  8.5.1 The class teachers 244
  8.5.2 Curriculum 246
  8.5.3 Pedagogy 251
  8.5.4 Assessment/accountability 256
  8.5.5 Teacher development and subject knowledge 260
8.6 CONCLUSION 263

CHAPTER NINE PUPIL INTERVIEWS .............................................. 266
9.1 INTRODUCTION 266
9.2 AIMS 266
9.3 METHODS 267
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.5.1 Curriculum</td>
<td>315</td>
</tr>
<tr>
<td>10.5.2 Pedagogy</td>
<td>317</td>
</tr>
<tr>
<td>10.5.2.1 Practical activity</td>
<td>317</td>
</tr>
<tr>
<td>10.5.2.2 Quality and purpose of talk</td>
<td>320</td>
</tr>
<tr>
<td>10.5.2.3 Written tasks</td>
<td>323</td>
</tr>
<tr>
<td>10.5.3 Assessment/accountability</td>
<td>325</td>
</tr>
<tr>
<td>10.5.6 Teacher development and subject knowledge</td>
<td>327</td>
</tr>
<tr>
<td>10.6 CONCLUSION</td>
<td>329</td>
</tr>
<tr>
<td>CHAPTER ELEVEN CONCLUSION</td>
<td>332</td>
</tr>
<tr>
<td>11.1 INTRODUCTION</td>
<td>332</td>
</tr>
<tr>
<td>11.2 KEY FINDINGS FROM LITERATURE</td>
<td>333</td>
</tr>
<tr>
<td>11.3 LIMITATIONS OF THE STUDY</td>
<td>337</td>
</tr>
<tr>
<td>11.4 THE POLICY TO PRACTICE CONTEXT</td>
<td>341</td>
</tr>
<tr>
<td>11.5 IMPLICATIONS</td>
<td>359</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>366</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>398</td>
</tr>
<tr>
<td>4.1 ELITE INTERVIEW SCHEDULE</td>
<td>398</td>
</tr>
<tr>
<td>5.1 SURVEY QUESTIONNAIRE</td>
<td>400</td>
</tr>
<tr>
<td>6.1 HEAD TEACHER INTERVIEW SCHEDULE</td>
<td>405</td>
</tr>
<tr>
<td>7.1 SCIENCE CO-ORDINATOR INTERVIEW SCHEDULE</td>
<td>406</td>
</tr>
<tr>
<td>8.1 CLASS TEACHER INTERVIEW SCHEDULE</td>
<td>407</td>
</tr>
<tr>
<td>9.1 PUPIL INTERVIEW SCHEDULE</td>
<td>408</td>
</tr>
<tr>
<td>10.1 OBSERVATION SCHEDULE</td>
<td>409</td>
</tr>
<tr>
<td>10.2 OVERVIEW OF OBSERVED LESSONS</td>
<td>410</td>
</tr>
<tr>
<td>10.3 TRANSCRIPTS FROM LESSON OBSERVATIONS</td>
<td>411</td>
</tr>
<tr>
<td>10.3.1 CT4A</td>
<td>411</td>
</tr>
<tr>
<td>10.3.2 CT1B</td>
<td>411</td>
</tr>
</tbody>
</table>
10.3.3 CT1C  
10.3.4 CT2B  
10.3.5 CT3B  
10.3.6 CT4B
LIST OF TABLES

Table 3.1 Overview of data collecting process 63
Table 3.2 Interview data collected from case study schools 84
Table 5.1 Barriers to teaching science 147
Table 5.2 Learning science 149
Table 5.3 Classroom organisation 150
Table 5.4 Pupil tasks 151
Table 5.5 Purpose of assessment 152
Table 5.6 Professional needs 153
Table 5.7 School development needs 154
Table 5.8 Professional duties 155
Table 8.1 Class teaching responsibilities 227
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DECLARATION

I declare that the thesis presented here is my own work. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

I declare that this work has not previously been submitted for a degree or diploma in any university.

Sandra Lesley Eady

Date

27 January 2007
ABSTRACT

This thesis sets out to examine the extent to which primary science is a complex interplay between educational and political perspectives which in turn has influenced and shaped the way primary schools interpret, reconstruct and implement science in practice.

This study uses a policy trajectory to consider the changing conceptions of primary science within the arenas of policy influence, policy text and practice in relation to its curriculum content, related pedagogy and assessment. In addition, it examines the nature and impact of professional development to support the implementation of primary science in practice. Evidence was collected through a series of interviews with elite figures in education, a regional survey of primary schools, along with in-depth cases studies in order to develop a deeper understanding primary science within the policy to practice context.

The findings would indicate that despite a succession of top down science education policy reforms, there are still concerns about the extent to which teachers have sufficient science subject knowledge to develop conceptual understanding, a clear idea of the purpose of science investigations and how to use formative assessment as an effective way of diagnosing pupil understanding. Furthermore, the evidence would suggest that the emphasis placed on summative assessment and accountability has narrowed teachers' conceptions of primary science.

The implications are that science policy reform needs to acknowledge existing practice and support a wider definition of science that includes an appreciation of the historical and cultural aspects of science together with an understanding of technological applications. In addition, a more robust infrastructure of professional development needs to be in place which places more emphasis on the science co-ordinator to support teaching and learning in order to provide teachers with access to a changing knowledge base and opportunities to update skills in primary science. Unless these implications are given serious consideration the unrelenting focus on performativity and accountability will prevent any real development of creativity and innovation in the primary science curriculum.
LIST OF ABBREVIATIONS

Assessment for Learning                        AfL
ASE/Kings Science Investigations               AKSIS
Assessment Performance Unit                    APU
Association for Science Education              ASE
Attainment Target                               AT
Cognitive Acceleration through Science Education CASE
Children's Learning in Science                 CLIS
Continuing Professional Development           CPD
Centre for Research in Primary Science and Technology CRIPSAT
Class Teachers                                  CTs
Department for Education and Science           DES
Department for Education and Employment         DfEE
Education Reform Act                           ERA
Education Support Grants                        ESG
Grants for Education Support and Training       GEST
Head Teachers                                   HTs
Her Majesty's Inspectorate                     HMI
Information and Communication Technology       ICT
Initiatives in Primary Science Evaluation      IPSE
Initial Teacher Education                      ITE
Key Stage One and Two                          KS1&2
<table>
<thead>
<tr>
<th>Organization</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Education Authorities</td>
<td>LEAs</td>
</tr>
<tr>
<td>National Curriculum Science Working Party</td>
<td>NCSWP</td>
</tr>
<tr>
<td>National Foundation for Educational Research</td>
<td>NFER</td>
</tr>
<tr>
<td>National Curriculum</td>
<td>NC</td>
</tr>
<tr>
<td>National Curriculum Council</td>
<td>NCC</td>
</tr>
<tr>
<td>National Numeracy and Literacy Strategies</td>
<td>NNLS</td>
</tr>
<tr>
<td>Newly Qualified Teacher</td>
<td>NQT</td>
</tr>
<tr>
<td>Office for Standards in Education</td>
<td>OFSTED</td>
</tr>
<tr>
<td>Primary National Strategy</td>
<td>PNS</td>
</tr>
<tr>
<td>Primary Science National Curriculum</td>
<td>PSNC</td>
</tr>
<tr>
<td>Primary Science Scheme of Work</td>
<td>PSSW</td>
</tr>
<tr>
<td>Qualifications and Curriculum Authority</td>
<td>QCA</td>
</tr>
<tr>
<td>Standard Assessment Tasks</td>
<td>SATs</td>
</tr>
<tr>
<td>Science Co-ordinators</td>
<td>SCs</td>
</tr>
<tr>
<td>School Education and Assessment Council</td>
<td>SEAC</td>
</tr>
<tr>
<td>Solids, Liquids and Gases</td>
<td>SLG</td>
</tr>
<tr>
<td>Science Processes and Concept Exploration</td>
<td>SPACE</td>
</tr>
<tr>
<td>Statistical Package for the Social Sciences</td>
<td>SPSS</td>
</tr>
<tr>
<td>Science Teaching and Action Research</td>
<td>STAR</td>
</tr>
<tr>
<td>Teacher Training Agency</td>
<td>TTA</td>
</tr>
<tr>
<td>Task Group on Assessment and Testing</td>
<td>TGAT</td>
</tr>
</tbody>
</table>
CHAPTER SIX: HEAD TEACHER INTERVIEWS

6.1 INTRODUCTION

In order to provide a more in depth exploration of conceptions of primary science the broad themes reported in chapter five will be used to analyse the case study findings presented within the next four chapters. The way in which the HT views science within the primary school may have considerable impact on its status as a subject and the way it is prioritised and resourced throughout the school. HTs are often considered not only 'mediators' of policy but as 'expert' teachers, who are likely to have witnessed the development of primary science, pre and post NC. This in turn will have contributed to their deeply seated values, knowledge and experiences in relation to their conceptions of primary science.

6.2 AIMS

This chapter aims to report and analyse HT views by examining their understanding of key influences and issues that have been influential in the last ten to fifteen years in each school context.
6.3 METHODS

6.3.1 Participants

The four schools were selected in the way described in the methodology chapter. Although not purposively chosen for their individual characteristics, the four HTs varied in gender and in their length of teaching experience. They ranged from recent appointments to those who had experienced several years of leadership.

Head 1 (HT1) was in his second year of headship at an urban school which was two-form entry with four hundred and twenty children on roll. SATs results were below the national average in English, maths and science. However the most recent OFSTED Report stated that the HT had,

created a good management structure which promises to be very effective in bringing about the improvements necessary to raise standards (OFSTED 2001, p.20).

Prior to this he had been a head of a small school in the locality.

Head 2 (HT2) was in her third year of headship with approximately four hundred and twenty four pupils on roll. The SATs results at KS2 for maths and English had been around the local and national average, although science scores were below. The most recent OFSTED Report (1999) did not refer to this HT, as she was not in post at the time of inspection.
Head 3 (HT3) had been in post for ten years. This small rural primary school had seventy pupils on roll and SATS results for maths, English and science at KS2 were above the national and local average at the time of study. OFSTED reported on the strong leadership and management of the HT who, at the time of inspection, was also overseeing science, as there was no co-ordinator. They reported that the

high quality of leadership and management promotes excellent ethos within the school in which teamwork and high expectations are key' (Ofsted 1998, p.21).

Head 4 (HT4) had been head of this rural school for five years which had three hundred and thirteen children on roll. SATs results for KS2 in English, maths and science were above the local and national average. OFSTED reported that

the head teacher provided a very strong and clear-sighted leadership and had managed the schools improvement very well, ably supported by the deputy head teacher. [The HT] promoted an ethos of teamwork very successfully' (Ofsted 2000, p.9).

Prior to this he was HT at another, smaller local school.

6.3.2 Materials

In the spring term prior to the main gathering of data, a pilot interview was carried out with a local primary HT who would not be part of the main study. An analysis of this interview, led to the compilation of the
final interview schedule containing twelve open-ended questions. Further details are outlined in the methodology chapter.

6.3.3 Procedure
The researcher carried out the interviews with the HTs at an agreed time during the year of study. Each interview lasted approximately one hour and took place in the head's office. The same questions were given to each HT and responses were audiotape recorded and later transcribed. The transcripts were sent to each HT to comment on in terms of accuracy of content and to modify accordingly to ensure that the transcript reflected their responses to the questions.

6.3.4 Analysis
The purpose of the interviews was to gain specific information regarding the HTs' understanding of primary science and how it was implemented in their school and analyse this in relation to their individual experiences and school context. A data trail was kept, starting from the initial interview transcripts and analysed in the way described in the methodology chapter. Then those responses that related specifically to the four broad themes were placed in a summary grid to enable further analysis. A description of what each HT said in relation to these themes was recorded. In addition the texts from each participant were compared, contrasted in light of their experience as
HTs implementing the PSNC (DfEE1999) and their own understanding of and beliefs about primary science.

6.4 RESULTS
This section reports what each HT said in response to each question, organised under the broad themes previously outlined. Any attempt to offer a broader view can be found in the discussion section to follow.

6.4.1 Curriculum
HT1, HT2 and HT4 felt that there was a strong link between science and everyday life, particularly in KS1. They felt there was great value in primary aged pupils learning science in order to develop understanding about the world around. However HT3 thought it was now harder for pupils to do this as she felt that there was a lack of space within the curriculum for the child to develop a real interest and depth of knowledge in science. She stated that there was a certain conformity to a prescribed content and the way it was assessed, and was concerned that it reflected a secondary style curriculum, which she felt to be inappropriate in the primary school.

HT2 thought that the PSNC (DfEE1999) valued knowledge rather than innovative ways of teaching it. She went on to state that the interest of the teacher affected the extent to which links were made to everyday
life; some were not as excited by science as others. HT4 saw tremendous value in children becoming 'scientists' in terms of investigating but thought not all teachers had the skills to support children to do this. He also felt links to everyday life were harder to achieve towards the top end of the primary school but still should be possible. HT4 suggested that there was a need to cover science in more depth with a greater focus on developing investigative science.

All HTs felt that recently science had declined in status in terms of time allocation and funding and that this was largely due to external pressure to focus on the NNLS. HT1 felt that the funding given for NNLS had been far greater than for science. HT2 thought pressure from the government would ensure a continued focus on NNLS. HT3 argued that since the PSNC (DfEE1999) the shift in the content of primary science from predominantly 'Nature Studies' to more physics and chemistry, had resulted in a reduction in pupils' knowledge for example in terms of identifying common flowers and birds. HT2 wanted the PSNC (DfEE1999) to be less prescriptive in terms of content; she wanted to be able to pick up on lost opportunities by allowing children to identify interests. HT4 suggested that a knowledge-driven curriculum was a barrier to allowing children to 'be scientists'.
6.4.2 Pedagogy

HT1 stated that the lack of resources had a significant impact on the taught curriculum in his school. He implied that availability of resources particularly influenced practical teaching, where a greater range of resources was needed. HT4 felt the government's policies on assessment seemed to have increased pressure to get high scores in SATs resulting in the teaching of scientific knowledge rather than teaching science to develop scientific thinking and exploration.

HT1 stated that teaching and learning in his school in KS1 was mostly experiential, whereas in KS2 he saw it as more formal with a greater use of textbooks. However he suggested the difference was not necessarily due to the abstract nature of science but more related to the perceived necessity to prepare pupils for tests. Furthermore, he did not see this changing until the SATs results in his school had increased, then he felt they could work on improving the quality of learning. HT2 also felt science teaching mostly focused on knowledge rather than process skills at her school, and stated this was partly due to parental pressure for neat books.

HT3 commented that teaching in her school was of a mixed quality although 'good teaching' was not necessarily reflected in high SATs scores. HT4 stated that within his school the quality of science
teaching was variable. He defined a ‘good’ teacher as being both knowledgeable and enthusing children in their scientific thinking.

HT2 stated that teaching process skills would help support children identifying their own interests. She wanted a change in the curriculum so that schools could be more imaginative in their approach to teaching science, as the only schools that could be more creative were those with high SATs scores. HT3 explained that whilst she and her staff had responded to changes imposed upon the science curriculum, they were still able to hold on to what they really believed about education.

6.4.3 Assessment/accountability

In terms of what pupils should know, understand and do by the end of KS2, HT1 said ‘officially’ pupils had to reach level three and four at the end of key stage tests, but on a personal basis he would prefer to emphasise the more social and spiritual elements, which are not easily assessed. HT2 stated she had to strive for level four in the standardised tests at the end of KS2 but was sceptical as to whether it was really necessary. On a personal level she stated that she would prefer pupils to have enquiring minds and a solid understanding of their place in the world. HT3 thought pupils should have a basic knowledge of the natural world, whilst HT4 wanted them to be discerning.
observers and critical of what they were doing. He went on to say that it was necessary for them to experience the scientific process as he felt this was important for developing transferable life and social skills.

HT1 and HT3 thought there had been a greater emphasis on science knowledge to match the demands of assessment and in the future thought that science would become more assessment based just like literacy and numeracy. HT1 felt that OFSTED inspections were the only way to ensure that the investigative aspect of science would continue to be taught, although he also thought that CTs who had an interest in investigative science would ensure it happened. HT2 agreed that it was easier to teach the knowledge and test it. All four HTs seem to identify the government as continuing to have a key influence on science in schools in terms of their focus on tests, performance of schools in other countries and support for new technology.

HT1 seemed to think that in his school the biggest influence on the science curriculum had been SATs and this had had a direct influence on pedagogy, which in turn meant that less time was spent on science investigation and more on scientific knowledge. HT4 saw SATs as a key influence but described how it was possible to manipulate science scores in a way that was not possible in numeracy and literacy SATs. For this reason he thought SATs in science should be dropped as it did
not tell the school anything significant. He felt that OFSTED was more useful in improving and monitoring science.

6.4.4 Teacher development and subject knowledge

HT1 stated that a ‘good’ science teacher should not necessarily be a subject specialist but they would be able to explore the unexpected and to motivate pupils through ‘investigation’. HT2 identified enthusiasm for the subject and an ability to inspire children as important qualities for good teaching. She also suggested subject knowledge was important, as was the ability to see opportunities to make links with other subjects. HT3 suggested a ‘good’ teacher would make the subject come alive and would have the ability to make children think. She went on to say that good communication skills were needed by children to convey what they had learned. HT4 emphasised the importance of teachers having an awareness and understanding of what it was to be a ‘scientist’ in the way they were able to focus children’s thoughts on the science process. He also felt that enthusiasm was important.

HT2 and HT4 identified the increasing importance of teacher subject knowledge as a requisite for good science teaching. They recognised enthusiasm was not enough. Whilst HT2 stated that the main change resulting from the PSNC (DES1989) had been that teachers needed to
update their own knowledge in order to teach upper KS2, HT4 felt that in many ways this placed unrealistic demands on the primary school teacher.

All HTs thought that monitoring had now become a significant part of the SC’s role. In addition HT1 (who had recently had an OFSTED inspection), thought that with this additional responsibility, the SC needed to feel more empowered. In the short-term his aim for the SC was to address areas of weakness identified by OFSTED and then in the long term to deal with improving pupil understanding. HT2 expected the SC to ensure appropriate resources were available and raise the profile of science by motivating and supporting staff. She also thought monitoring was important. HT3 viewed the role more in terms of generic co-ordination dealing with policy, schemes and monitoring. HT4 again had a more generalised view and felt that the SC should be updating schemes of work and teachers’ skills, and in addition they should be reporting best practice by monitoring teaching and SATs results. He thought that ten years ago SCs were not expected to monitor science in this way.

6.5 DISCUSSION

The HTs’ recent past and present experiences, along with their school context, which might have influenced their views, are explored and
analysed below. These are compared and contrasted in order to offer a broader perspective in relation to the identified themes already outlined.

6.5.1 The head teachers

HT1’s opinions about primary science were closely linked to the experience and outcome of his recent OFSTED inspection (2001), which had identified science as an area of weakness, and in the science SATs results at the end of KS2 (2000), which were also below the national average, although it should be noted that his school was in one of the most deprived wards in the county. He illustrated how this had influenced his decision to pursue a narrow pedagogy. Whilst he would like the children to spend more time experiencing things for themselves, he felt in the short term that raising attainment in SATs was perceived as the greatest priority. However, once he felt this had been achieved he wanted to focus on the quality of learning, particularly in KS2 by improving understanding through investigations. Thus, it could be argued from HT1 that external influences prevented engagement in creative science (content and pedagogy). HT1 also highlighted the impact of competing policies and policy text most notably the NNLS, which had resulted in a negative impact on science, because it had reduced the availability funding and resources for investigational science.
HT2 also had low attainment in science SATs and again seemed to think that a certain amount of formalised teaching in her school was necessary to improve these. Like HT1, she felt that the pressure of getting good SATs results restricted the freedom to be more creative with science and to include more investigative science. Although she would like to see teachers helping children to develop process skills and investigative work, she implied that the pressure to teach in a more formal way came not just from government policy but also from parental pressure. Whilst she identified the imbalance between content and process, which she attributed to external accountability, she also felt that good science was dependant on individual factors such as the ability of the teacher.

HT3 an experienced HT, had a clear view of the kind of science she wanted to develop within her school and her responses illustrated that she felt that the PSNC (DfEE1999) had alienated children from science. She thought that a basic understanding of scientific knowledge was important at primary level, but felt that content should focus on the environment and the natural world. In addition, she appeared to be very doubtful about the governmental initiatives that had influenced the teaching of primary science, including the introduction and subsequent modifications of the PSNC (DES1989b,
1991b, 1995 and 1999). She thought the government was not really concerned about the interests and development of scientific understanding of pupils and as HT she wished to protect her school to a certain extent from policy changes and create space and flexibility in order to pursue a more ‘child centred’ philosophy. However, it could be argued that her underlying confidence stemmed from consistently high SATs results, the smallness of her school and perhaps her length of experience as HT. Thus she could pay ‘lip service’ to government policy, yet still create space for her staff to teach in the way they felt was appropriate. Despite awareness that there was a need to improve the quality of teaching science there was no indication as to how she expected this to happen in her school.

HT4 was able to articulate the tensions and issues faced on a daily basis by teachers teaching science in his school. Part of the tension he felt was due to the relationship between teaching science for understanding as well as meeting the short-term demands of SATs. Like HT3 he was not convinced that test scores reflected good teaching. He too had science SATs results that were above the national average at the time of study, and argued that a certain amount of ‘cramming’ before the tests could maintain this. Although he was not an avid supporter of OFSTED inspections, he felt they were possibly more informative than test results. The pupils that attended his school
reflected the high socio-economic status of the rural locality, which may have been a contributing factor in the attainment of science test scores well above the national average. HT4 echoed similar views to other HTs in that the focus on tests had changed the SC’s role from one of support to one of monitoring.

6.5.2 Curriculum

The findings from the HT interviews reveal a significant tension between their perceptions of primary science and what the PSNC (DfEE1999) defined it as,

\[ \ldots \text{the imposed science curriculum values knowledge but is not always interesting to deliver for teachers (HT1)} \]

This was clearly evident in the way that HTs talked about what pupils should be able to do from an official and a personal view. Personal conceptions of primary science seemed to relate to their earlier experiences and an ideology that valued ‘discovery learning’ rather than an acquisition of knowledge which they argued had to some extent alienated pupils from learning about the world around them,

\[ I \text{ don't think children see any relevance in the science they do at school and everyday life. This is because they no longer look at the world around them (HT3).} \]

It would appear that in KS1 it was easier to relate science curriculum to everyday experiences

\[ I \text{ think the chemistry and physics should really be introduced into year six in preparation for secondary schools...here in primary schools...they are too young to appreciate it (HT3).} \]
Furthermore, it would seem that whilst their responses suggested they attached a greater value to developing scientific enquiry, they also felt this was in danger of being lost.

*I think there is still is an over burden of curriculum, we are told that there is a body of knowledge that has to be taught and got through I think it does place a strain on us doing the 'let's be a scientist' bit (HT4).*

However, in practice HTs seemed to go to considerable lengths to ensure that all science knowledge was covered, often at the expense of investigative work because of pressures of accountability.

*Are we teaching science to make children scientists or develop scientific ways of thinking, or are we teaching science at the moment to make them jump through hoops at the end of Y2 and Y6 (HT4).*

In addition, HTs expressed concern that changing educational policies relating to NNLS had put even more pressure on the time available for science.

*Science has now become more and more side stepped by other things such as ICT, literacy and numeracy initiatives...there seems to be a focus on more knowledge based science as this can be assessed (HT1).*

*...pressure from the government for literacy and numeracy, parent pressure remains for literacy and numeracy too (HT2).*

There appeared to be evidence of conflicting views of knowledge. On the one hand HTs presented a personal view of the science curriculum
consisting of knowledge as constructed and evolving, whilst on the other hand the prescribed PSNC (DfEE1999) presented a view of a body of knowledge to be learned. Thus the value of what was to be learned in science appeared to identify a tension between individual beliefs and values and those implicit within the PSNC (DfEE1999).

6.5.3 Pedagogy

Despite a strong sense of underlying beliefs and values that appear to suggest a preference for an investigative approach to science, it was apparent that teaching and learning strategies to enable this to happen were not frequently used and in fact all HTs seemed to be of the opinion that much pedagogic practice was linked to the preparation for tests. There seemed to be an assumption that pedagogy was variable within schools for several reasons. Whilst HT1 pointed to lack of resources, HT2 and HT4 thought pressure of SATs. Additionally HT4 acknowledged it might be a reflection of teacher expertise;

*I think there is great value in children becoming scientists but that's the bit I feel we are less good at teaching at primary level because we're not scientists, all of us...*(HT4)

They implied that pupils learn better in an environment where science was related to everyday life and was taught in a practical way, although no reference was made to eliciting children's ideas. The expectation to follow a knowledge-based science curriculum in a short space of time might suggest that such pedagogic practice, particularly
in KS2 was somewhat restricted to direct teaching and possibly rote learning. In fact HT1 suggested,

*In KS1, learning is about experiencing things for themselves. At KS2 it is more formal with textbooks to go through information and this feeds into the tests. We will stay like that until we raise the SATs results in science and then we can work on improving the quality of learning* (HT1).

Whilst HT3 implied the quality of teaching could not be based on SATs,

*the SATs results are good but it depends on your philosophy as to whether good science teaching is reflected in SATs scores* (HT3).

It could be argued that very little time or focus had been spent on teaching and learning in any of the schools as most of the responses centred on the issues and tensions surrounding testing and accountability rather than ‘constructivist’ views of learning.

*In this school its subject based but beginning to shift to process skills. There is a lot of parental pressure for neat books* (HT2).

Although HT3 and HT4 reported that the quality of teaching science was mixed, how science was taught, the significance of what children knew and strategies for challenging their existing ideas seemed not to be a key feature within the context of practice.

*Science taught in this school varies, sometimes it is very good and sometimes it is pedestrian* (HT3).

It might be assumed that SCs would be in a position to model good practice, however the HTs suggested that there was a greater expectation to spend time on monitoring the coverage of the PSNC
(DfEE1999), analysing test results and identifying gaps and weaknesses in pupil knowledge rather than developing and enhancing science pedagogy. Given that the SCs were all full time class based teachers in this study, it would appear that there was little or no time for them to support teachers in this way.

6.5.4 Assessment/accountability

It was evident from the HT interviews that the main reason why they were not able to promote their underlying beliefs and values about the PSNC (1999) and the way it should be taught was due to the external pressures of testing and annual publication of test results, along with regular OFSTED inspections. In particular, it would appear that contextual factors such as the status of the school in terms of its science SATs results had an impact on the way science was perceived.

_I would like to have more room for creative organisation of the curriculum. At present, this can only be done by schools with good SATs. They can be more creative and some are returning to a topic based approach (HT2)._

_We have just had an inspection and our results are low and [science] is an area of concern. So in the short term my expectations are linked to performance, to raise results. In the long term for years four, five and six to improve their understanding through investigations (HT1)._

This may help explain why HTs despite their personal beliefs felt obliged to focus on scientific knowledge in order to raise levels of
attainment by a certain age rather than improve the quality of teaching and pedagogic practice in order to support the learning process.

However, evidence from the interviews would suggest that HTs could be quite 'subversive' in the way they met the targets and achieved SATs results. HT1 also thought that short term cramming was necessary in order to raise scores to the national average, whilst HT3 said:

*With my staff they and I do what is necessary to cover our backs yet we keep hold to what we really believe about education (HT3).*

HT4 thought SATs was of little value

*... I won't call it cheating, but you can certainly revise for science ...so that children are performing on the day in a way you can't do for literacy and numeracy (HT4).*

*Personally I would take the science out of SATs as I'm not sure its telling anybody anything very significant (HT4).*

HTs presented a conception of science which located it loosely in terms of scientific enquiry, however it would appear that in practice they promoted an adherence to the knowledge-based element of the PSNC (DfEE1999) as this was what they perceived would enable them to achieve high results in SATs. HTs appeared to associate high-test scores with greater credibility amongst parents and an opportunity to secure a greater sense of power and control over what happened in
their schools. They also implied it allowed them to create space in order to pursue their beliefs in teaching science. It would appear that those schools with low science test scores would not take the risk of engaging in investigational science, whereas those with high test scores could afford to be more creative and flexible in the way they taught science.

Thus it could be argued that HTs would like science to be more practical but due to external pressures of accountability and performativity do not feel they have time or opportunity to do so. Some HTs felt they do not have the resources either. This tension between individual and governmental ideology appeared to make HTs focus on knowledge-based assessment and not on AfL. There appeared to be little concern for developing the pupils' long-term understanding of science and the most effective way that may be developed. Nevertheless conceptions of primary science as practical and creative arising from individual beliefs and expertise were still firmly embedded and if HTs felt confident were encouraged where possible.

6.5.5 Teacher development and subject knowledge

The findings suggest that HTs acknowledged the importance of subject knowledge but did not imply this was any more important than enthusiasm, and generic qualities. It could also be argued that the
pressures from NNLS had prevented teacher development in science even if this was desired. Furthermore, the responses of the HTs illustrate the direct impact of government policy (DES1992), which focused on inspection and assessment, and on the shift in the co-ordinator's perceived duties from an informal supportive position to a position of accountability in order to monitor teaching of science and analyse performance in SATs.

*This has changed in terms of monitoring, now it's about watching everyone else rather than advising (HT3).*

*Ten years ago it was almost unheard of that another teacher would monitor another teacher's teaching (HT4).*

However there was no mention by HTs if SCs had received appropriate support to monitor effectively and it could be argued that in order to do so good subject knowledge was important. Instead it would appear that this was now less a priority than appropriate management skills.

*The science co-ordinator has to be empowered. They have to have more power (HT1).*

Whilst HTs acknowledged the need for teacher development when science became a compulsory element of the NC, the interviews would suggest this was no longer a perceived priority just as long as teachers were enthusiastic about the subject and SCs had sufficient management skills in order to establish credibility.

*A good teacher should have enthusiasm about the subject...they should have good subject knowledge (HT2).*
There was also perhaps an assumption that current ITE along with the familiarity of the PSNC (DfEE1999) suggested that there is not a need to support teachers or SCs in the teaching of science. Equally there seemed to be little consideration for the CPD needs of both SCs and CTs in terms of developing appropriate pedagogy or pedagogic content knowledge.

6.6 CONCLUSION

From the HT’s perspective conceptions of science curriculum and pedagogy were determined by assessment and accountability, with SCs monitoring performance in SATs rather than providing support to improve the teaching of science. Ideally HTs wished to place a greater emphasis on scientific enquiry although the findings would indicate this might be more in terms of ‘discovery’ rather than a constructivist model of learning. Whilst there was a strong consensus that science should be linked to every day life, this did not suggest an awareness of acknowledging pupils’ existing ideas with a view to modifying or extending them to take account of scientific explanations. Evidence also indicated that external pressures to perform well in the tests, along with the introduction of the NNLS (1998, 1999), had also placed greater competition on the time available for teaching science, along side all the other curriculum subjects. From these HTs it appeared that
the science in their schools was closely driven by recent government policy and policy text rather than developing conceptual understanding. As a result, it could be argued that these HTs chose to put performance in tests, above what they considered to be 'real' learning which they felt took place when children had more time to engage in practical investigation and problem solving.

It would appear then, that across the case study schools there were similarities in the way HTs perceived primary science. The suggestion was that a 'good' science teacher would engage the children in practical, hands on science and would develop science skills, whilst those teachers less confident might be more likely to favour prescriptive teaching of science knowledge. However these views were also affected by the context in which the HTs found themselves. Where schools were struggling to meet government targets in terms of science SATs in line with the national picture, the HTs tended to adopt a more formal approach to teaching, where schools were excelling with SATs scores well above the national average, the HTs seemed to create 'space' in order to allow teachers to favour a more hands on investigative approach to science. Thus the HT's views would suggest that within the context of practice primary science is strongly framed first and foremost by accountability and testing.
Whilst the purpose has been to develop an analytical picture of key influences and practices within the context of practice, the views of the HTs reflect a unique understanding of the science curriculum influenced by their own reality and context. It cannot be known if these views are representative of other HT’s experiences, however it does provide tentative evidence that learning centred on practical activity and the varying importance attached to teacher subject knowledge are evident within HT conceptions of primary science. A particular suggestion from the findings of the HT interviews has been that the development of the primary science curriculum and pedagogy has been strongly influenced and possibly restricted by the emphasis on national testing and accountability and despite external pressures, HTs still hold on to strong beliefs about the importance of scientific enquiry and models of ‘discovery’ learning.

This chapter has begun to address the third question, how do schools interpret, reconstruct and implement primary science in practice? The next chapter will continue to outline the context of practice by examining the views of the SCs in each school.
CHAPTER SEVEN: THE SCIENCE CO-ORINATOR INTERVIEWS

7.1 INTRODUCTION
This chapter continues to analyse data relating to the context of practice by reporting the SC views. These were thought to be significant as SCs are accountable to the HT in the way science documentation, in the form of schemes of work and policies, are updated and implemented within their school. In some cases they have responsibility for the science budget and, to a certain extent; the SC operates as a mediator between the HT's wishes and the needs of the teaching staff, and has to balance external and internal pressures to ensure that the science curriculum is consistently and effectively implemented throughout the school.

7.2 AIMS
This chapter aims to examine key influences and issues that have affected SCs current conceptions of primary science. As with the previous chapter, findings and analysis will be organised under the common themes of curriculum, pedagogy, assessment/accountability, teacher development and subject knowledge.
7.3 METHODS

7.3.1 Participants

Although not purposively chosen for their individual characteristics, the four SCs varied in their length of teaching experience and the key stage in which they taught. They ranged from recent appointments to those who had experienced several years as SC.

Science co-ordinator 1 (SC1) had been in post for twelve years within the same school. At the time of study she was teaching a year four (Y4) class. The most recent Ofsted Report, stated that

provision for [science] has declined and standards have fallen significantly ...the school does not allocate sufficient time for teaching the subject and there are not enough opportunities for these pupils to undertake the independent investigative work expected of them... (Ofsted 2001, p.33).

Science co-ordinator 2 (SC2) had been in post for ten years in the same school. At the time of study she was teaching a year three (Y3) class. The most recent Ofsted Report reported that there was

a knowledgeable and conscientious science co-ordinator who monitors the teaching of the subject and provides effective support... (Ofsted 1999, p.39).

Science co-ordinator 3 (SC3) was appointed as SC during the year of study. She was also a newly-qualified teacher (NQT), teaching a
mixed-age class of years five and six (Y5/6). Ofsted reported that science (before the appointment of this SC) was co-ordinated by the head teacher...a particular strength of provision [in science] is the good use made of the environmental opportunities offered within the school area...(Ofsted 1998, p.29).

Science co-ordinator 4 (SC4) had been in post for six years in this school. At the time of study, she taught the reception class (YR) and was also KS1 co-ordinator. Ofsted reported that standards in science have improved since the last inspection [1996]... teachers also have good expertise in science and all aspects of the subject are covered systematically with a good emphasis on investigation...(Ofsted 2000, p.9 and p.11).

7.3.2 Materials

An interview schedule was designed to gather information from the four SCs and was piloted in the way described in the methodology chapter. The final interview schedule contained twelve open-ended questions.

7.3.3 Procedure

The researcher carried out the interviews with the SCs in much the same way outlined in the methodology chapter.
7.3.4 Analysis

A data trail was kept, starting from the initial interview transcripts and these were analysed in the manner reported in the methodology chapter. Responses that related to the broad themes were placed in a summary grid as described in chapter six.

7.4 RESULTS

This section reports what each SC said in response to each interview question. Any attempt to offer a broader view can be found in the discussion section to follow.

7.4.1 Curriculum

All SCs thought there was great value in learning science. SC1 and SC2 thought that the CT played an important role in setting up the context and providing children with the opportunities to find out about the world around them and to develop investigational skills. However, SC2 felt that some CTs were not fully aware that they had to help pupils make links with science and everyday life. SC3 expressed similar views but felt that ultimately science at this age should be fun and enjoyable. In addition to encouraging pupils to think, explore and question the world around them SC4 felt learning science gave pupils the opportunity to learn how to anticipate, predict and draw conclusions from their results which could then be discussed.
All SCs stated that PSSW (1998) formed the basis for science in their schools. In addition, SC2 explained that one CT planned science for both classes in the year group on a weekly basis. In addition classes in KS2 were encouraged to use a morning for science whilst teachers in KS1 had decided to teach it each afternoon in weekly or two-week blocks for the duration of the unit of work. SC3 explained that in her school, planning was based on a two-year cycle due to mixed-aged classes. SC4 explained how she matched in the foundation stage, curriculum with the corresponding unit of work in the PSSW (1998).

By the time pupils left the school, SC1 stated that she expected them to know about the science units they had covered from the PSSW (1998) that year, but also other things, such as how to set up their own investigations. SC2 stated that the aim was for the children to know enough science to attain a level four or five in science SATS at the end of KS2, although this put pressure on doing practical science. SC3 stated that it was important for pupils to be able to set up and carry out a ‘fair’ investigation by the time they left the school. SC4 stated that apart from retaining some knowledge of the units of work they had covered, she hoped they would have some interest and excitement in science. By the time they left KS1 she would expect them to have a greater scientific vocabulary and have experienced some structured
investigative work, whilst she would expect the children to have more independence in planning an investigation and following it through to writing it up by the end of KS2.

SC1 stated that she would welcome greater flexibility in the science curriculum so that it was possible to follow your own ideas and those of the children. SC2 and SC3 were not dissatisfied with the present science curriculum and felt it to be quite broad and therefore appropriate. SC4 felt more funding and further training was needed to deliver the curriculum content.

7.4.2 Pedagogy

SC1 stated that the main issues for teaching primary science were the lack of equipment and time constraints which meant that it was not possible to reinforce concepts so that children had a sound understanding. As a consequence, she felt that children did not always seem to like science, although this did not apply to the practical lessons. SC2 felt that a main issue was trying to improve pupil’s attainment in science investigations and interpreting data. She stated that she had tried to overcome this by buying in support materials, such as puzzles and ‘mini-SATs’ but still felt that children were better at science knowledge than investigations. SC3 stated that resourcing science was a main concern.
SCs had little knowledge or understanding of how science was taught throughout the school. SC1 thought there was no particular teaching strategy, whilst SC2 felt some CTs did more practical work than others, possibly because this suited their style of teaching. However, she was aware that there was greater pressure in Y6. SC3 suggested that teachers planned individually but she had no knowledge of the teaching strategies they employed. SC4 thought there were possibly too many work sheets being used and not enough focused writing, although she thought there was a core of excellent science teaching in the school.

Apart from SC3, an NQT, all SCs thought primary science teaching had changed dramatically. For example, SC1 thought science teaching was more widespread and children now seemed to know more than they used to, although there was not enough time to follow their interests and natural curiosity. SC2 stated that it was now quite clear what was to be taught in science, although it was considered less important than NNLS. However, she felt creative use of resources such as professional magazines and the Internet provided opportunities to vary the teaching strategies. SC4 stated that she could remember a time when very little science was taught and only in
a very prescriptive way. She felt that the NNLS had helped give some structure to science teaching.

7.4.3 Assessment/accountability

SC1 stated that staff at her school assessed science by using the learning outcomes in the PSSW (1998). She had also bought in 'mini SATs' this year with the aim of it becoming part of the school assessment for science. From this, the children were given targets to meet. SC2 gave a very detailed explanation of how science was assessed in her school. In general, she explained that teachers photocopied the learning objectives from the PSSW (1998) and then highlighted what they had covered. She had tried to get teachers to assess science skills by encouraging them to observe groups of children carrying out investigations, as personally she found this an effective way of assessing science. However she was aware that other teachers did not find this easy, particularly in KS1 and so other ways of assessing science were also necessary, for example, they were now using 'mini' SATs to support assessment.

SC3, who had recently taken on this role, seemed unsure about how science was assessed. She thought teachers assessed every lesson and there was an end-of-topic assessment which was passed on to the next teacher. SC4 felt that in KS1, it was necessary to assess whether
pupils had a basic understanding of science concepts, whereas in KS2 it was more about assessing their understanding of science vocabulary and the way they used it to explain their understanding. She stated that she had followed the science advisor’s guidance and had produced a 'skills round up' sheet in order to identify science skills after each unit of the PSSW (1998). In addition they used KS2 SATs as well as a QCA test, although she was not sure how useful this was.

SC1 did not seem to think that SATs supported pupil learning, as teachers would still basically follow the same learning objectives and activities from the PSSW (1998). She felt SATs assessment was for the parents' benefit. SC2 stated that the purpose of SATs was to provide public knowledge of how the school was performing, although she felt that it also ensured everyone taught science. However, the SATs results enabled her to pick out common questions that the children had found difficult so that they could focus on these areas in the future. She felt this was a positive way SATs could be used by the school. SC3 thought SATs could be a good teaching tool if given to Y5, in order to gauge their performance in preparation for Y6. Apart from this she felt that secondary schools most probably benefited most from SATs in Y6.
SC1, whose school had science SATs below the national average, felt that her main focus was to raise attainment, with Y6 being the main target at present. She stated that she had to monitor teaching in order to encourage colleagues to ask more open-ended questions in science lessons. However she felt that she probably would not have enough time to follow this up by talking through what she had observed with the CTs. SC2 also stated that part of her role was to develop assessment of investigation skills. In addition, the head was helping her to identify the most able pupils in science, as a result she would modify the PSSW (1998) in order to find more ways of allowing these pupils to work at and attain level five in SATs. SC3 saw her role as advising teachers what to do in lessons. SC4 stated that for the first time, she was going to observe her colleagues teaching science, as well as look at science SATs results to see if they met with the school's expectations.

7.4.4 Teacher development and subject knowledge

SC1 stated that a 'good' science teacher would model scientific attitudes such as 'curiosity' and 'enthusiasm' and would be able to see and make the links in science as well as have a basic knowledge of the subject. In addition, they should be confident enough to admit to the children if they did not always know the answer. SC2 expressed a similar view but felt scientific attitudes and skills were fostered by the
teacher's ability to ask 'good' questions as well as demonstrating a 'love' of the subject. SC3 stated a 'good' teacher would encourage pupils to develop scientific attitudes as well as have 'good' subject knowledge. In addition it was important for the teacher to be able to engage the children in conversation and discussion rather than getting them to look for the answer in a book. SC4 thought that a 'good' science teacher would be someone who was really excited by what they were teaching and very clear about the learning objectives, so that the pupils too, knew what they were learning. In addition they would follow though investigations and be able to manage discussion, using open questions. Like SC1, she also thought that a 'good' teacher would have the ability to admit to the children if she did not know the answer. SC4 thought that the depth of teacher subject knowledge had a direct effect on how well science was taught.

Before the PSNC (DES1989), SC1 stated that her role had been to oversee science resources and organise science events. However now it was to increase SATs results and monitor teaching. SC2 stated that part of her current role was to raise the profile of science but also to develop assessment particularly in terms of able pupils. SC4 described how her role had initially focused on producing the science policy and scheme of work for the school as well as talking to teachers about
science in order to develop a clearer picture of what science resources were needed.

7.5 DISCUSSION
So far the focus of this chapter has been to report SCs' perceptions of science within the context of practice. The rest of the chapter will attempt to provide a broader perspective by analysing these views first in terms of the SC's individual and contextual factors and then in relation to the broad themes identified in the results section.

7.5.1 The science co-ordinators
SC1's conceptions of science were influenced by considerable expertise and the Ofsted inspection. She had first-hand experience of the development of primary science since its introduction in 1989 and subsequent modifications of policy and documentation. Yet it would seem from the recent Ofsted inspection (2001) that she had been unable to sufficiently influence colleagues' practice in order for them to plan investigative science. In addition the low SATs results had led her to accept that there needed to be a greater emphasis on a formal knowledge-based science curriculum with measurable outcomes resulting in a clearly defined role of monitoring and target setting as SC. Whilst she promoted 'constructivist' approaches to science in her
classroom, it would seem she was also under pressure to adopt 'quick fixes' for raising the SATs results in KS2.

SC2 said that she was very interested in science and initially had attended a twenty-day science course to help prepare her for the role. She received additional funding for science from governors and parents indicating the importance placed on developing science in the school. Although Ofsted (1999) referred to her 'conscientious and supportive' role, the findings suggest she was not in a position to have clear overview of the type and quality of science teaching throughout the school. However, she was able to give more detailed responses as to how teachers planned and assessed science. Her views also reflected the tensions she faced between developing scientific enquiry which she believed to be of great importance yet maximising opportunities for pupils to achieve high attainments in the tests. In her opinion the main issue she faced within the school was raising attainment in SATs.

_A weakness is getting high levels in investigations and data interpretation...I have brought in extra materials for mini SATs [it] wasn't measurable before._

This would suggest that preparation for tests in Y6 dominated the way science was taught and while it might be assumed that in order to improve investigations more practical work would be planned, it appeared that published revision papers were being used instead,
implying that there was little time to engage with investigations properly. Whilst SC2 advocated a preference for investigational science she appeared very aware of the additional pressures on Y6 teachers to improve SATs scores. Thus in reality it seemed there was little chance of persuading colleagues, particularly in Y6, of the value of formative assessment or the need to assess investigations other than by tests. Nevertheless although SATs was not the best motivation for teaching science she was happier that it was taught in this way rather than not at all.

Although a mature teacher, SC3 was an NQT and, it could be argued, still held views about science that reflected her recent ITE course. However she did not appear able to offer any view of how investigations could be developed in the context of her mixed Y5/6 class or throughout the school. Despite lack of pedagogic content knowledge, she felt that her previous science background provided her with the necessary subject knowledge and confidence for her recent appointment as SC. However, it could also be argued that her inexperience as teacher and SC might reduce her ability to influence practice in science. Despite the size of the school, (three classes) she was not yet in a position to have an overview of science teaching and assumed barriers to teaching science largely related to the availability
of resources rather than a preference or confidence in planning practical investigation.

Her views about SATs suggested that she questioned not the appropriateness of the tests as a method of assessment but the timing of them in terms of their usefulness. As a teacher with Y6 pupils she did not articulate the tension she must have faced between her beliefs about an investigation-driven science and the pressure to revise for SATs. However she seemed particularly keen to develop an understanding of science through investigations rather than by acquisition of knowledge from books. In some ways it could be argued that her limited experience of primary science, other than teaching from the PSSW (1998), would not provide the expertise needed for the role of SC.

SC4 like the others, claimed to enjoy science. Her commitment to investigational science was a strong theme throughout the interview, not only in the way she emphasised the importance of scientific enquiry over subject knowledge, but also evident when she explained what a child should know and do by the end of KS2. She argued that a 'good' teacher should place an emphasis on investigations favouring a skills-based approach which drew upon relevant knowledge. She also stressed the importance of subject knowledge as one of the qualities of
a good teacher. She demonstrated an understanding of the progression of investigational skills from KS1 to KS2 and also a sound understanding of progression and the interrelationship between skills and knowledge. This had probably been enhanced through the development of the school scheme of work over time which, possibly reflected her beliefs and values about science, unlike the PSSW (1998). It could be argued that her experience as a SC and familiarity with the PSNC (DES1989b, 1995, and DfEE1999) on which she had produced and modified the school scheme of work, allowed her to be critical of new initiatives and documentation, such as the PSSW (1998) and most recently, the mini SATs tests. However unlike SC1 and SC2, there was less pressure to focus on performance in national tests, possibly because her school was already performing well above the national average.

7.5.2 Curriculum

From the SC’s interviews it would seem that the PSSW (1998) largely defined the content of primary science. It appeared to underpin all aspects, from planning what and how science was to be taught; through to what would be assessed within each year group, with little consideration as to whether this was appropriate for all classes.

*You are going to give the children the same work despite what [level] they get (SC1).*
Furthermore, there seemed little reference to the PSNC (DfEE1999) as the statutory document. For example, SC2 explained how teachers would:

photocopy the unit of work [and then] highlight what's been covered, and assess from those objectives (SC2).

SC4 was the only one who had questioned the appropriateness of the PSSW (1998) particularly as to whether it provided enough depth or challenge for children to achieve NC level five. It could be argued that the reason for this was that she already had implemented a detailed scheme of work over several years. Whereas it was possible that other schools who did not originally have a detailed scheme of work, were happy to adopt PSSW (1998).

At the beginning I made the scheme of work...more recently I have changed to QCA ...but it's boring. One teacher pushed towards this because of the changing structure of the growing school ... (SC4).

Despite the apparent prescriptive nature of the PSSW (1998), all SCs seemed to agree an emphasis should be placed on scientific enquiry.

I would put an emphasis on investigations, so that they are finding out for themselves, carrying out fair investigations and setting up experiments (SC3).

Whilst SC4 was of the opinion that:

The value of learning science is to get children thinking, exploring and questioning about the world around them. I want them to anticipate, predict and discover from results and discuss them (SC4).
Although SCs 'valued' science as an opportunity to develop skills, the framework and pressure of accountability did not allow this to happen. As a consequence, SCs placed greater priority on getting a specific level in SATs rather than developing scientific skills.

_*We aim to get them through SATs at level four or five – it has become this and it can’t be ignored...they do cover practical things but the system puts pressure on this. I doubt if they are getting a repetition of skills, the depth [of understanding] and feelings of satisfaction of doing a fair test (SC2)._*

Despite expressing some concern regarding the tension between the balance of science skills and content, SCs were not willing to suggest any radical changes for science possibly indicating they were not as concerned as it might appear or that other pressures in other subjects provided more of a focus.

**7.5.3 Pedagogy**

Whilst they were able to articulate how content was covered and assessed in each year group due to adherence to PSSW (1998), they were unsure about which teaching strategies were employed throughout the school,

_*... I can’t really say how it’s taught, [in this school]. I would hope its organised and structured...another important issue is learning how to differentiate and group within class (SC4)._*

In fact the SCs were only able to provide generalised views of practical work, developing ‘skills’ and ‘doing’ investigations. As a result there seemed to be no knowledge whether or not teachers had a secure
understanding of the role of investigative science (Foulds et al. 1992, Goldsworthy 1998). However whilst they were unable to describe pedagogic practice throughout school, possibly because opportunities for doing so did not exist, it was evident that SC1 and SC4 had some understanding of and used constructivist approaches to develop conceptual understanding within their classrooms. For example SC1 stated;

I use discussion stimulus to begin with ...then usually questions that we’ll find out later. The idea is to plant seeds in their minds and then focus on what I perceive to be the conceptual starting point. But it doesn't always go this way if children jump side ways in their thinking. I do follow the PSSW but if I want to swap because of the children, then I will follow their lead (SC1).

Although the SCs put a great deal of emphasis on children developing and applying scientific skills in order to learn about the world around them, it was not clear as to how SCs were supporting teachers to ensure that this happened as apart from SM and SC4, who had been given time to observe teaching, it was difficult for them to provide advice on appropriate teaching strategies. This was particularly crucial as SC2 pointed out the important pedagogic role teachers played in pointing out the links for pupils which many teachers were not aware of. SC2's knowledge of specific weaknesses in pupils' interpretation of scientific data stemmed from her analysis of the most recent SATs scores rather than an observation of teaching. However, she sought to
remedy this through investing in revision papers rather than promote or model practical experience.

Although SC1 and SC3 felt that inadequate resources restricted the way science was taught in their schools along with the amount of time available, it could be argued that the findings would imply that the real barrier to improving the teaching of science was the fact that SCs were not given the opportunity or time to really support and update knowledge and skills for teaching science, as priority had to be given to analysing assessment data from SATs and judging the strengths and weaknesses in pupil subject knowledge.

7.5.4 Assessment/accountability

SCs varied in their views regarding assessment although with, perhaps, the exception of SC3, all were able to provide detailed explanations of how assessment worked in their schools. However concerns, particularly for SC2 appeared to be around an over-reliance on summative assessment. For example, she stated:

_We have mini SATs, these [at the moment] are an ‘add on’...but these tests are not the answer to everything, otherwise we could be just teaching to the test (SC2)._ 

This might suggest that although she felt it was important to provide teachers with the necessary materials to assess pupil understanding, she did not want to advocate one method of assessment. However it
would appear that she met with considerable resistance when attempting to encourage other forms of assessment, particularly in relation to scientific investigations,

Mostly I've tried to suggest observing small groups but people say this doesn't work...I kept handing out this form that enables you to sit down with the children and write down detailed comments about what the group is doing while they're investigating [but] I think its been the least successful (SC2).

It was not clear from the findings as to why there was an over-reliance on paper and pencil tests, although SC1 was of the opinion that;

Now the main thing is to get SATs results up, that's the main focus... We are targeting year six (SC1).

And so for her the supplementary assessment materials were an essential part of the school's assessment programme

We bought mini SATS, I've not yet tried it. ...The mini SATs assessment is part of the school assessment. ... This is the first year its been used and we will grade A, B, C and will pass on the results to the next teacher (SC1).

This might suggest in this school at least, that because performance in science SATs was below the national average and science had been identified as a weakness in a recent Ofsted inspection, this was having a considerable influence on the method of assessment adopted. Moreover, it would suggest that teachers focused their assessment predominantly on attainment rather than eliciting pupils' existing ideas in order to diagnose weaknesses or 'misconceptions to target for future learning. It was notable that SC4 whose school had high SATs results
still used the same 'mini-SATS' although she had doubts about their value.

"We also use KS2 SATs and a QCA test, although I'm not sure how useful that is (SC4)."

However despite this apparent over-reliance on summative assessments, in general, the SCs felt that SATs did not help the children learn science with SC1 stating that SATs was for bureaucrats and for parents, whilst SC3 thought:

"...Secondary schools get something out of it; even then they might be a level three in one bit and a level four in another. It's a teaching tool, good for year five to see where they are, for example, for planning... (SC3)."

However SC2, who appeared to value formative assessment, also felt that SATs could be beneficial as it helped her to identify areas of weakness in pupil understanding.

"However SATs means that science can't become a forgotten area...like geography or music or become under funded, so in some ways SATs protects it. It ensures everyone teaches it (SC2)."

It would appear that, having identified areas of weakness; revision topics were used as a way to boost understanding rather than probing existing explanations in order to further conceptual understanding. Consequently there seemed to be little evidence of formative assessment, instead it appeared that teachers were largely relying on forms of summative assessment with which SCs were not totally happy. Although it was not apparent in the findings, it does raise the
question as to what extent science lessons might consist of summative assessments rather than conceptual development and scientific enquiry, in other words, how much teaching for conceptual understanding of science actually takes place and how much is based on revision for SATs?

In terms of assessing science, SCs felt teachers struggled to assess science skills, even through summative assessment; the focus was clearly on assessment of knowledge, because this appeared easier and more straightforward. SC1 stated that in her school, a formal knowledge-based test was administered at the end of the topic. SC3 had a similar end of topic assessment to assess knowledge, SC4 did not give any explanation of how, or if skills were assessed. It could be argued that the assessment of scientific enquiry is more effective where the pedagogy takes account of the pupils’ active participation in their own learning as where pupils are passive learners, it is difficult to assess process skills. In this sense engaging pupils in science investigations or through discussion rather than pencil and paper summative assessments might be a more appropriate method of assessment. Thus the difficulty faced by SCs to engage colleagues in the assessment of process skills may reflect their preference to teach science in a more formal way or reflect that little independent practical
work takes place for what ever reason, which does not provide many opportunities for practical application of process skills.

7.5.5 Teacher development and subject knowledge

Tensions were evident when SC1 and SC4, explained how their roles had changed over the years. They faced conflict between supporting science with a purpose to foster enjoyment and make links with the outside world and supporting science merely to focus on raising attainment in SATs. This perhaps illustrated how it was difficult in practice for SCs to develop fully their role or have any impact on monitoring the teaching of science as specified in the Standards for Subject Leaders (1998). Not only did SCs not know how science was taught, they were rarely given the opportunities to find out or model good practice. SC1 who, as a result of a recent Ofsted inspection, had been given time to observe science stated:

*I'm observing questioning to encourage open questioning but I probably haven't got time to talk about it [with the teachers] and follow it up (SC1).*

It would seem that whilst she was able to gain a valuable insight into how science was taught in her school, there did not appear to be time built in for valuable feedback, essential for supporting and guiding teachers in relation to improving their practice.
This example would suggest that the pressures of assessment and accountability, particularly in terms of addressing school and government targets, had mainly influenced the SC’s role. Where SCs were not given time to observe science it could be argued that they may have less of an overview of science in their schools and thus were poorly equipped to support teachers particularly in improving the quality of teaching and learning in science. As a result reality meant that there was a greater emphasis on ensuring colleagues covered science knowledge and had appropriate materials to carry out assessments. SC1 explained that her main focus was now to support teachers to raise pupil performance in the national tests, whilst SC2 said her present role was to develop assessment and look for ways of elevating aspects of the PSSW (1998) so that it was geared towards NC level five. Thus it could be argued that in both of these schools meeting external assessment targets had a greater influence than improving the quality of teaching.

SCs varied in their opinions regarding the status of science subject knowledge for teachers. In fact SC3, a NQT, who had a science degree, was the only one who identified subject knowledge as a prerequisite for teaching,

_They should be well organised but still be flexible and have good [subject] knowledge, because [children always] come up with questions. If you want to engage them in conversation, you need to be able to engage_ (SC3).
Other SCs, focused on motivational characteristics such as enthusiasm and excitement and an ability to develop investigational skills, although SC4 implied that a good teacher would be able to 'present' learning objectives to children so they know what they are looking for. Thus it would seem that the low value placed on science subject knowledge was possibly balanced by greater emphasis placed on a 'pedagogy of love and enthusiasm' for science. However evidence from the SC interviews would suggest that irrespective of whether they has a sound understanding of science, SCs had little opportunities to influence the teaching and assessment of science to improve learning. Whilst SCs seemed relatively unconcerned or unable to develop science pedagogic content knowledge or there was little external support available for science CPD.

7.6 CONCLUSION

The conclusions drawn from the SC's conceptions of science suggest there seemed less emphasis and time spent on developing skills or conceptual understanding in primary science but greater importance appeared to be attached to assessment. Furthermore evidence from the SC interviews suggested that more status was given to summative assessments rather than formative assessments, in order to develop learning. Although they expressed a preference for children finding out
about the world and working practically, there did not seem to be an awareness of eliciting children’s ideas as a basis for diagnosing their understanding and therefore the next stage in learning.

Findings from all SC interviews claimed that the non-statutory PSSW (1998) was the basis for planning, teaching and assessing science in their schools. Not only did it specify what content to be taught, but it also provided the learning objectives and outcomes by which pupils were assessed. It could be argued that this had replaced PSNC (DES1999).

The other main influence determining the nature of science in primary school was the annual publication of the national test results at KS1&2 and to a lesser extent Ofsted inspections. As a result, and regardless of personal views, all the SCs and particularly SC1 felt they had no choice but to support fellow teachers, to increase pupil performance in tests by providing teachers with revision resources with a focus on measurable outcomes rather than improve the quality of teaching and learning of science. Although not totally evident from the interviews, it would appear that such a focus might perhaps favour more direct modes of teaching. This was due largely to their interpretation of the content of the PSSW (1998) and to their perception that the SATs (up
to the time of study) mostly assessed knowledge rather than science skills.

Whilst the purpose has been to provide a description of key influences and practices within the context of practice, the views of the SCs reflect their own unique understanding of the science curriculum influenced by their beliefs and experience together with the context in which they worked. It cannot be known if these views are representative of other SC's experiences, however it does provide tentative evidence that the SCs faced tensions in the way they were able to support and influence the teaching of primary science. A particular suggestion from the findings of the SC's interviews has been that the development of the PSNC (DfEE1999) and pedagogy has been strongly influenced and possibly restricted by an emphasis on national testing and accountability.

This chapter has continued to address the third question, how do schools interpret, reconstruct and implement primary science in practice? The next chapter will provide further evidence of practice by examining CTs conceptions of science across the case study schools.
CHAPTER EIGHT: CLASS TEACHER INTERVIEWS

8.1 INTRODUCTION

Chapters six and seven have presented conceptions of science from the perspectives of HTs and SCs and have shown how these relate to individual experiences and beliefs as well as external and contextual factors. This chapter will examine the views of ten CTs as it is they that ultimately plan and deliver science in their classrooms. Whilst CTs are accountable to HTs they are expected to interpret curriculum plans and reconstruct learning experiences in science taking account of pupil needs, the range of resources available, together with the time allocated for science. They do this in conjunction with their own beliefs and prior experience of teaching science.

8.2 AIMS

The aim is to report CT views by considering how their understanding of key influences and issues are reflected in their conceptions of primary science in practice. In line with chapters six and seven their views will be presented within the broad themes of curriculum, already outlined.
8.3 METHODS

8.3.1 Participants

The ten CTs were selected in the way described in the methodology chapter. They varied in gender and in their length of teaching experience. They ranged from recent appointments to those who had experienced several years of teaching, some in more than one school witnessing the introduction and revisions of PSNC. Table 8.1 below summarises the location of teachers within schools.

<table>
<thead>
<tr>
<th>School 1 (urban)</th>
<th>KS1</th>
<th>KS2</th>
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<tbody>
<tr>
<td>CT1A</td>
<td></td>
<td>CT1B, CT1C</td>
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<tr>
<td>School 2 (semi-urban)</td>
<td>CT2A</td>
<td>CT2B, CT2C</td>
</tr>
<tr>
<td>School 3 (rural)</td>
<td>CT3A</td>
<td>CT3B</td>
</tr>
<tr>
<td>School 4 (semi-rural)</td>
<td>CT4A</td>
<td>CT4B</td>
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CT1A taught for fifteen years and at the time of study was teaching a Y1 class. CT2A had been teaching since the advent of the PSNC (DfEE1999) and taught a Y2 class. She also had the additional role of KS1 co-ordinator. CT3A had taught for several years including prior to the implementation of the PSNC (DES1989b). She presently worked part time in the current school teaching science in a mixed year one and two (Y1/2) class. CT4A had taught for three years and had a Y2 class. CT1B, a deputy head teacher had ten years teaching experience, and currently taught a Y5 class. CT1C was in her third
year of teaching and currently had a Y6 class, which she had returned to after Christmas, having been on maternity leave. CT2B an NQT taught a Y4 class. CT2C was in her third year of teaching and taught a Y6 class. CT3B had recently moved to this school having trained and taught in Northern Ireland. At the time of study she had a mixed-age class of Y3/4 pupils. CT4B had been teaching for two years and had a mixed class of Y4/5 pupils.

8.3.2 Materials
An interview schedule was designed to gather relevant information from the ten CTs. It was compiled and piloted as described in the methodology chapter. The final interview schedule contained twelve open-ended questions.

8.3.3 Procedure
The researcher using the interview schedule carried out the interviews with the CTs as described in chapter three and six.

8.3.4 Analysis
A data trail was kept, starting from the initial interview transcripts and these were analysed as described in the methodology chapter. Comments relating to the themes were placed in the summary grid as described in chapter six enabling further analysis.
8.4 RESULTS

This section presents the results using the broad themes of curriculum, pedagogy, assessment/accountability and teacher development and reports in detail what each CT said. Reference is made to the exemplary comments, which can be tracked through the data analysis process outlined in the methodology chapter. A broader view can be found in the discussion section to follow.

8.4.1 Curriculum

CT1A stated that science was a valuable part of the curriculum for young children and most importantly allowed them to learn about the world around and engage in the environmental aspects of science. As an experienced teacher she did not like the prescriptive nature of the science curriculum and wanted more freedom to decide what was appropriate for her class. CT2A stated that she did not think it mattered too much what subject matter was studied but felt it was more important for children to learn to think and question for themselves. She thought learning science at this age enabled them to have a better understanding of the world and provided an opportunity to do many more practical things at school. CT3A stated that in science children should learn to think in a 'scientific' and not a generalised way. She thought it was a valuable experience for children to learn science at
this age as it was completely different to other subjects. However, although there were lots of links to every day life, she felt it was important for teachers to make these explicit. She also thought science enabled those children who were not good at written work to achieve. Although CT4A felt science was a valuable part of the curriculum as it enabled children to think in different ways and apply skills and knowledge, she felt that not all aspects were easily linked to children’s every day lives and that the PSSW (1998) was not very good at providing opportunities to make these links.

CT1B felt there were strong links between everyday life and science, and in his class pupils learned skills, enquiry and specific concepts. He thought it was important for pupils to learn about what goes on around them and how things work and how to investigate although he felt that often pupils did not understand the results they got or even why they were doing the investigation in the first place. As a result it was important to structure their thinking not just with the use of writing frames and questions, but also through using whole class discussion and brainstorming. CT1C, a Y6 teacher, felt that the children mostly learned knowledge. She felt that learning science enabled children to be aware of things around them, to ask questions and also to carry out fair investigations. She too felt it was necessary for the teacher to help children see the relationship between science and everyday life. CT2B
thought it was more interesting for children to learn about the world around them through practical activity rather than learning from a book or listening to the teacher.

CT2C felt that whilst the children learned facts, they also learned about teamwork and scientific skills, thus it was important for them to follow through the scientific process from prediction to finding conclusions as the practical aspects of science made them more curious to find out more. However, CT2C thought that only some topics were more relevant to every day life and as a consequence, helped less able children relate science to their own experiences for example, living things. CT3B stated that 'curiosity' was the most important thing to learn, so that pupils were motivated to follow up questions. Science gave the children knowledge of life and encouraged them to have an interest in nature, although she felt pupils did not immediately see the link with every day life. It enabled them to ask questions and test their ideas. CT4B said that science captured interest and made children think rather than just accept things. It broadened their understanding of the world around and enabled them to learn that science was cross-curricular and linked to the outside world. In addition, it gave them foundation knowledge for secondary school. CT4B also thought that teachers needed to help children to recognise the relationship between science and every day life.
By the end of KS1 all CTs thought it was important for children to have developed an interest in the world around them, and to have experienced practical activities. In addition CT3A stated that although she expected them to have fulfilled the requirements of the PSNC (DfEE1999), she felt it had become increasingly more important to question what they see and to make predictions based on thought. CT4A was of the opinion that the acquisition of skills, and relevance of science to every day experience, was more important than the content of the PSNC (DfEE1999).

All KS2 teachers felt it was important for pupils to have developed an understanding of and an ability to carry out science investigations by the end of KS2, with most placing a particular emphasis on fair testing. In addition CT1C and CT2C thought it important for pupils to have a wider vocabulary by the time they left the Y6 class and to be more proficient in the scientific process in terms of interpreting results and forming conclusions. Whilst both CT2B and CT3B thought pupils should have developed some scientific skills including recording, drawing and interpreting graphs, CT2B considered that pupils should also have sound background knowledge of the topics covered. For CT4B an appreciation of the importance and relevance of science was also a priority.
Most CTs raised concern about the limited time to cover science. CT1A thought that the units of work in PSSW (1998) were fragmented. In addition she felt that from experience the sub topic 'senses' in the unit of work on 'Ourselves' needed much more than one lesson in order for young children to develop an understanding and enjoyment through exploration of the senses. CT3A felt that some science topics needed a greater allocation of time, particularly 'materials' and 'life processes'. She also stated that she could not see the relevance of teaching the unit of work on 'variation' to Y2 pupils. CT1C and CT2B thought the number of science units should be reduced so that a realistic time could be spent on fewer areas. In addition CT1C thought a reduction in the amount of subject knowledge would allow more time for practical science. However, CT2A felt minor modifications to the science curriculum could be made by CTs selecting alternative activities that might be more appropriate for the class yet would address the same learning outcomes in the PSSW (1998). CT2C felt that the balance of science topics was just about right and would not like to see any more changes, although felt that the lack of time to do science properly was a key issue, as was the availability of resources. CT3B was concerned that science was becoming similar to the secondary science she experienced at school in that there was too much emphasis placed on knowledge. Furthermore, she felt that the
class below did similar things to her class in science. CT4B thought that the lack of time and resources needed to do science well was an issue. She was also concerned about repeating topics and that whatever was done in science was not given the same status as work in English or mathematics.

8.4.2 Pedagogy

All teachers stated that they used PSSW (1998) as a basis for planning and teaching primary science on a weekly basis. CT2A was the only teacher who stated that she blocked consecutive afternoons for science usually over a whole week, as she felt this sustained interest and enabled young children to remember more from one lesson to the next. CT3A, who had a mixed-aged class said she combined topics and learning objectives from the PSSW (1998) for Y1/2 as well as using other teachers’ books, whilst CT4A stated that prior to this year she had used the schools’ scheme of work, which was more comprehensive and had greater flexibility than the PSSW (1998).

CT1B said that whilst PSSW (1998) had made life easier, the plans only gave the learning outcomes and did not include detail about how the science might be organised. However, CT1C stated that she also used past SATs papers with greater time given to topics not covered since Y4. CT2B an NQT, said he followed the PSSW (1998) very
closely as he felt it had good ideas and was easy to use. If he needed additional resources or ideas he would ask colleagues. CT2C also felt the PSSW (1998) had a good structure. However CT3B, who had a mixed Y3/4 class, stated that she found PSSW (1998) complicated to plan from and thus supplemented it with other ideas. CT4B was the only teacher who claimed that she took into account the children’s previous experiences, often changing plans as the children took her in different directions through their discussion and questions. She also stated that she read around at her own level to develop subject knowledge and also at the children’s level.

CT1A was concerned that there was not enough time for children to ‘investigate’ and ‘play’, and the PSSW (1998) had forced her to move a way from ‘hands on’ experience. She was also concerned that the children did not spend enough time developing their knowledge of nature in any depth. She stated that children were just taught the content of the PSSW (1998). CT2A was concerned that PSSW (1998) and SATs could be restrictive at KS1 and thus was not always appropriate because it could lead to doing things in isolation, she explained that by teaching science every afternoon throughout the week she was able to give the children a consistent and coherent learning experience, and could make science as practical and as relevant as possible. CT4A’s main concern was to make science
relevant at this age so that it was enjoyable and the children could
relate it to their own experience.

CT1B, a deputy head teacher, stated that he personally had no
concerns about science however he had noticed that other teachers
tended to teach factual science rather than plan practical activity. He
felt there were good reasons for this in terms of the time needed for
finding and preparing resources and felt some teachers were not
willing to give up their lunch hour. CT1C was concerned that a lot of
children in Y6 were ‘turned off’ science by the way it was taught. CT2B
said he was thinking of following the SC’s lead and teaching science in
the morning.

CT1A, CT3A and CT4A stated that they taught science for just over an
hour each week in the afternoon. In contrast CT2A stated that science
at this age was not calculated in terms of hours, but was blocked so
that a complete unit of work would be covered over one or two weeks.
CT1B said he would like to spend more time on science investigations
but felt this was now an ideal rather than reality. CT1C stated that
since the beginning of the spring term they had covered a lot of
science topics. CT2C said she spent an hour and a half each week on
science whilst CT2B and CT3B both allocated an afternoon a week for
the subject. CT4B said that although she taught science once a week,
she had never really calculated how much time was spent on it in terms of skills and knowledge but felt one balanced the other.

CT1A stated she organised science as a whole class activity with groups doing practical activities. CT2A stated that she used a variety of strategies in order to give the class a wide experience of all aspects of the subject. She used investigation sheets to help structure their work although often re-designed them depending on what aspect she wanted the children to focus on. CT3A stated that she used a lot of practical situations when teaching, emphasising 'enquiry' and adding 'knowledge' afterwards. CT4A described her approach in terms of a logical progression through the science process. She also stated that through her teaching she wanted them to see the relevance to everyday experience.

CT1B used investigations as much as possible, involving pupils in the whole process, particularly fair testing. He also used a range of teaching strategies such as group work, paired activity and whole class teaching. CT1C felt dissatisfied with the way she taught science as she was teaching mostly information in 'bite size' chunks rather than engaging the class in practical work. This was because teaching was focused on cramming for SATs, although, after the tests she would teach a practical, environmental topic. CT2B hoped he taught science
in a fun and interesting way so that the children got more from it, although this was not always possible because of the topic. CT2C said that her science teaching was variable and had changed over the time. Initially she had taught in a traditional way but now took her lead from the SC. As a Y6 teacher, she ran short revision sessions where the class would be encouraged to ‘brainstorm’ questions from SATs papers. CT3B said the format she used for most lessons was a whole class introduction and then splitting into mixed-ability groups culminating in a plenary. CT4B used a variety of strategies including differentiated groups, circus and ‘round robin’. Although she had never used the same way twice, she preferred to organise pupils to work in groups rather than in pairs, giving limited information at the beginning of the lesson and then using discussion after the practical part of the lesson to develop understanding.

CT1A felt that a key change was that now children were encouraged to write everything down and this had taken the fun out of science. CT2A thought science had become more formal with a greater emphasis on children recording rather than engaging in practical work. She felt that SATs had influenced the science taught at the end of KS2 more than it had done at the end of KS1. However she thought that PSSW (1998) had had a significant and positive effect on teaching in that it enabled better coverage than before and saved teachers time when planning
lessons. CT1B did not think science had changed much over the last few years and had not affected the way he taught it. CT3B thought that the PSSW (1998) made things much more explicit and there was a greater focus on assessment compared to the science curriculum in Northern Ireland. CT1C, CT2B, CT2C and CT4B had only been teaching between one and three years and thus did not feel able to comment on how their teaching of primary science had changed.

8.4.3 Assessment/accountability

CT1A stated that assessments based on the PSSW (1998) unit of work did not always suit the least able pupils and as a result, she supplemented this with oral assessment. CT2A used observation and questioning as the predominant way of assessing children in her class. Each year methods for carrying out TA for SATs were discussed, particularly science which had not been taught in Y2. CT3A stated that she based assessment on PSSW (1998) learning outcomes and at the end of each topic and wrote a personal note about each child in relation to their level of understanding. CT4A assessed understanding by directing questions at particular pupils, listening to their responses and explanations as well as assessing their written work.

CT1B used an elicitation activity at the beginning of the topic in order to find out children's common ideas and misconceptions. He also
assessed at the end of the topic to see how these ideas had
developed. Half termly assessments were passed on to the next class
at the end of the year. CT1C conducted half termly teacher
assessments, and in addition assessed the fortnightly homework,
which generally consolidated what was done in the lesson. CT2B
explained that he carried out his own assessment at the end of each
topic. In addition, he observed pupils at work and made notes as he
went along, and sometimes the children assessed each other. CT2C
used the PSSW (1998) outcomes for assessment, but preferred not to
rely on the written work in their science books, as it was often teacher
led. Instead she listened to their conversations when they worked in
groups and used quizzes. Earlier in the year she used past SATs
papers as well. CT3B was not totally satisfied with her methods of
assessment but she had tried to assess skills by observing pupils
measuring and planning fair tests along with assessing the kinds of
questions asked by pupils. CT4B stated that she used a variety of
strategies, including oral responses as well as written explanation.
She assessed investigations by asking questions and listening to their
responses. She reported that she used a ‘brainstorm’ technique at the
beginning and end of the topic to assess learning.

CT1A felt that the purpose of assessment was to see what the children
could remember; whilst CT2A felt that the SATs was really a
measurement for the school and did not help the pupils in their learning, as it told you what they knew rather than what they could do and this sometimes affected what you taught in science. CT4A felt that SATs focused you on assessing the pupils against the NC levels. Last year it was easier to assess against the level descriptors when she focused on 'plants'. This year it had been harder to assess children’s work on 'forces'.

CT1B thought SATs put a lot of pressure on pupils even although it was mainly a benchmark for the school and its performance in league tables, however it was a useful 'snapshot', which could be compared to TA. CT1C felt that SATs did not serve many purposes other than to assess what has been learned so far. She thought there was too much assessment for the children and that it would be more meaningful if there was half the amount of science to cover. CT2C felt that despite the pressures of SATs, science had more weighting and recognition in the eyes of the parents. She felt that it was also useful for (year seven) Y7 in secondary school. CT4B felt the purpose of SATs was to focus the teachers on teaching science thoroughly. However she felt this had unfortunately resulted in a lot of schools cramming for the SATS.
8.4.4 Teacher development and subject knowledge

CT3A had initially been concerned about her subject knowledge, particularly when teaching 'forces'. CT1C was also worried about the depth of her own understanding, as this became a particular problem if there were bright pupils in Y6. CT4A thought that the PSSW (1998) had helped to support the non-specialist science teacher in the way it had made explicit what the learning objectives should be. Whilst CT1B felt the PSSW (1998) supported planning, he thought there should be more external involvement in science at primary level as this would help remove the pressure from teachers at the top of KS2. For example, he would like a greater input from local secondary schools giving presentations in science. CT3B felt that she would like support to try other ways of organising science.

CT1A stated that a 'good' science teacher needed lots of visual aids in order to stimulate interest when introducing the topic to young children. It was also important to have some knowledge of the science topic and to be able to differentiate according to the ability of the class and to make good use of related texts. CT2A stated that in order to feel secure in teaching science, a teacher needed to have sound background knowledge. Furthermore she felt it was important to understand the skills involved in science in order to engage children in the scientific process. CT4A accepted that a teacher's enthusiasm for
science was important but felt that sound subject knowledge would enable the teacher to more effectively identify which aspects children do not understand, as well as explain things clearly and in ways children can relate to.

CT1B felt that a 'good' teacher should always be enthusiastic, whilst, CT1C expected teachers to have the same general skills needed to teach any subject at primary school. However she also stated that she would expect a science teacher to be confident in subject knowledge in order to deliver the curriculum in a coherent way that was accessible to the child. CT2C said a 'good' teacher should have sound subject knowledge so that they were not thrown by children's questions and would participate and encourage the pupils to get involved in the learning, as well as researching questions along with them. CT3B thought that a 'good' teacher would engage children in lots of practical activities and have a breadth of ideas. They would be enthusiastic about science and stimulate the children to find out answers to questions in a structured way. Additionally they would know how to bring science down to the children's level and make the activities fun and meaningful. CT4B said a 'good' teacher would be prepared to find out questions they do not know the answers to and support pupils to see the connections between science and every day life. It was important to be enthusiastic as well as have a good understanding of
the science topics. Moreover, they would encourage pupils to question
the approach used in investigation and would be able to assess where
the children were in their learning and know how to extend their
knowledge and understanding.

8.5 DISCUSSION

The discussion now presents a broader view of the findings and will
analyse these in relation to the curriculum, pedagogy,
assessment/accountability, and teacher development and subject
knowledge.

8.5.1 The class teachers

CT1A had started her teaching before the introduction of the PSNC
(DES1989) and its subsequent modifications. It was apparent that she
still looked back to the 'good old days' and despite the curriculum
pressures her conception of science was one that focused on
environmental science and 'discovery' learning. CT2A started her
teaching around about the advent of the PSNC (DES1989) and in
order to boost her subject knowledge and confidence had embarked
on a twenty-day funded science course in the 1990s. It could be
argued that much of what she learned on this course was still evident
in the way she taught science, favouring an emphasis on developing
process skills in order to develop conceptual understanding. Her
approach suggested she had sound knowledge of learners and how they construct understanding. CT3A shared the teaching of the mixed-aged Y1/2 class and taught only science. It would seem that her approach to planning reflected the fact that she too had started teaching pre NC (1989) and thus was confident to use a range of resources and supplement suggested activities in the PSSW (1998) for what she considered to be more appropriate ones. CT4A was recently trained and until this year had used the school's science scheme of work. This may be why she was keen to supplement some PSSW (1998) activities for ones she felt were more appropriate or more familiar.

CT1B’s confidence in teaching science might reflect the position he held and many of his comments seemed to refer to other teachers in the school as well as himself. His approach would suggest he placed a significant emphasis on children articulating their ideas through discussion. CT1C a Y6 teacher despite recent training lacked of confidence and was teaching Y6 for the first time and perhaps many of her negative responses reflected her own insecurity with this age group and lack of subject knowledge. It could be argued that CT2B’s views regarding science were still a product of his college teaching course, together with guidance from the SC. His only experience of science was in the form of the PSSW (1998). CT2C’s conception of
science reflected the additional pressure of assessment she faced at the end of KS2. Despite this she tried to include a variety of approaches to science openly admitting that the only time for investigations was after SATs. It could be argued that having only recently moved to England that in some ways CT3B's views were similar to a new teacher experiencing the science curriculum for the first time. This may explain her concerns over teaching strategies, assessment and spending enough time on practical work. She felt that in comparison to Ireland that 'here there is greater depth of assessment [although its] similar in content level' (CT3B). CT4B appeared to have a sound background in science, helped by a previous career as science technician. It was evident that she felt using pupils' existing ideas as a starting point was an important part of developing conceptual understanding. She also seemed keen to experiment with a range of teaching strategies demonstrating a keen interest and enthusiasm in what she wanted the children to achieve in science.

8.5.2 Curriculum

Ideally, CTs appeared to favour involving the children in practical investigational work. However in reality, constraints of time, resources and an emphasis on knowledge resulted in a great deal of compromise in terms of teacher beliefs about the science they would like their
pupils to experience and how they might facilitate this. For example CT1B felt investigations were now often an ideal. Thus what children received, as 'science' appeared to be fragments of knowledge often taught in isolation once a week. Furthermore, because there appeared to be no shared conceptions or understanding within each school about what defined an investigation and its relationship to teaching and learning, teachers emphasised different elements.

Most conceptions of primary science were strongly framed by the PSSW (1998) and to a lesser extent the PSNC (DfEE1999). As a result CTs did not base their planning on the knowledge and understanding of pupils in their classes but on what the prescribed unit of work suggested pupils of a particular age might learn.

...QCA has been introduced but is not mandatory but it's made [science] easier to teach and [there's] probably more uniformity in schools now but not in a bad way (CT1B).

Thus it could be argued that most CTs possibly spent little time eliciting children's ideas about what they knew and understood, as they intended to follow the prescribed content and suggested activities within the PSSW (1998). Moreover, this reliance on PSSW (1998) meant that some CTs appeared detached from what they were teaching and did not have any real ownership of the science taught. Those that seemed more concerned about developing conceptual understanding in relation to pupils' current understanding were able to
gauge the appropriateness of the PSSW and modify accordingly.

However those with little knowledge of learners merely taught the suggested activity and in this way they seemed to be passive participants in the planning process.

Others felt a necessity to adapt aspects of the PSSW (1998). For example, CT1A felt she would select what was 'appropriate', whilst CT4B explained:

I look at what is in the QCA and glance at the NC to see [its] origin. Then I look at theory to see what children need [to know]...[and] I think about what experiences children have had ... (CT4B)

This might suggest that any modifications made were as a result of taking into account pupils' prior learning and experience.

In terms of learning science many of the CTs interviewed seemed to suggest that in an ideal world, it was more important to acquire scientific skills rather than assimilate a large amount of scientific knowledge, much of which in their opinion did not seem to have much relevance to pupils' everyday lives. In fact CT2A claimed,

It doesn't matter what subject area, it's about what can you find out (CT2A).

Whilst CT4B thought:

[I want them to] appreciate the importance and relevance of science, that's my personal view (CT4B).
However these views seemed to conflict with the way that they felt they were forced to teach science particularly in KS2. Here CT1C, a Y6 teacher, admitted that she taught ‘mostly knowledge at the moment’.

Even in KS1, the policy documents namely the PSNC (DES1999) and the guidance materials; PSSW (QCA 1998) together with the emphasis on national publication of test results seemed to favour the delivery of knowledge-based curriculum for science, with CT4A stating:

*I would expect them to have a good grasp of the National Curriculum at their stage and know what a prediction is...I would expect them to learn to ask questions and think laterally. Content is not so important, but skills are and relevance (CT4A).*

Nevertheless, the superficial covering of subject knowledge in a small amount of time was a concern across both key stages. CT1A stated:

*...They have to explore, but this isn’t in the scheme of work, you don’t get to do as much as you like or as in depth. The lesson plans require resources, which you’ve not always got (CT1A).*

Whilst CT1C thought that:

*The science curriculum should be reduced; the number of units ...and then it would give us time to do the others properly. This would mostly reduce the amount of knowledge to get through. Practical work is more memorable and enjoyable (CT1C).*

These documents seemed to advocate a broad coverage at a basic level, whereas the CTs felt it would be more beneficial and more meaningful to the pupils if they could teach less knowledge but in more depth.

*We’ve done six topics this year and it does seem to cram a lot in...perhaps [we should have] fewer topics throughout the year...so you have more time to go into a bit more detail (CT2B).*
Throughout the interviews it became apparent that many of the responses the CTs gave illustrated the dilemma they faced in terms of teaching scientific skills or focusing on content. Although science process skills were embedded within the PSSW, the teachers felt they were required to focus more on the content. Where skills were taught it appeared that there was a greater emphasis on prediction and conducting fair tests, which might imply a limited understanding of the wider definition of investigational work. Furthermore it was evident that not all aspects of an investigation were covered and little indication that it was also a way of generating reliable evidence which may challenge or extend pupils’ existing ideas (Foulds et al. 1992 and ASKIS 1998).

For example, CT4A stated:

...I recap what they know, by brainstorming, then introduce new things that they will be doing. If it’s an experiment then I ask them to predict how they would do it fairly, before carrying out the experiment. I don’t try to fit all procedures in, but just do it in stages (CT4A).

Whilst CT3B felt;

... it teaches them a logical way of answering questions if [we are] going to [do a fair] test, then we need a scientific sample (CT3B).

Even Y6 CTs, CT1C and CT2C stressed the importance of fair testing, although developing a wider vocabulary was also considered important.
To know the importance of fair testing why we need to retest things. They don’t always appreciate this when they come to Y6...They’ve made predictions before Y6, but conclusions are difficult, they see it as something different. [They should be able to] use science language far more precisely in description and use of words (CT2C).

And CT4B also argued that it was important to:

be observant to know and appreciate the importance of a fair test and notice problems with a poor test. ...to see themselves as scientists in the making (CT4B).

Very few CTs suggested that pupils’ ability to interpret results were also of importance, although CT1B thought,

the classic is to do experiments but they don’t understand what they get out of an investigation, the results [and] why they did them (CT1B).

Thus the findings would suggest that the reality of teaching science was in some situations far removed from the CTs’ ideals. In some cases there appeared to be limited understanding of the rationale behind practical science and the significance of planning based on pupils’ existing ideas in order to develop conceptual understanding. Consequently it could be argued that CTs focused on aspects of investigations they felt most comfortable with which mostly centred on ‘fair testing’.

8.5.3 Pedagogy

How much science and the way it was taught, appeared to be heavily influenced by the amount of time CTs felt they had available and in many cases this was seen not to be enough, largely due to the
demands of NNLS. Time was also given as a key reason for the fact that they could not carry out investigational and practical science properly, if at all. Linked with this at KS2 was the large body of knowledge teachers felt that they needed to cover in order to prepare the children for SATs. This became an increasing pressure for CT1C and CT2C with Y6 classes as they felt that not only was it necessary to cover the themes specified for the year group, but also important to carry out intensive revision of science taught in previous years, in preparation for SATs at the end of KS2 and there seemed no additional time given to revision.

It would appear from the evidence here that most teachers only taught science once a week and then for approximately an hour and a half in the afternoon. This might suggest that time limited the range of teaching approaches in order to cover the specified content as in most cases the aim seemed to be to complete the lesson by the end of the afternoon. However, there was evidence that in one school a different approach to organisation provided opportunities to work in different ways.

*We block units so that science is done every afternoon over one or two weeks depending on the length of the unit of work to be covered (CT2A).*

This approach suggested that activities started one afternoon could be continued the next day and work conducted at the beginning of the
week could be compared to that at the end, without pupils losing the thread of what they were doing as well as building conceptual understanding. It could be argued that CT2A, (who was also KS1 co-ordinator) had encouraged her colleagues to work in this way in order to maximise opportunities for investigative science as she stated:

[Science has] become more formal and there is a big emphasis on recording for the sake of evidence. What are getting less now are occasions for [practical work] (CT2A).

Thus those CTs who were determined to live out their beliefs in the way that they taught and had the knowledge, confidence and authority to do so could organise the curriculum in such a way that allowed this to happen. Thus it would appear that CT2A's conceptions of science were based on her understanding of the capacity of young learners' young children ...remember better without gap [of time] in between the lessons' (CT2A) rather than influenced by external pressures to impart knowledge. However, it could also reflect a wider primary ethos of integration of subjects and a resistance to compartmentalising knowledge into subjects for an hour a week.

CT1B also appeared to find ways to teach investigational science. He stated:

[I do] investigations as much as possible...involving them in ... processes of experimenting and the fair testing element (CT1B).
In fact, CT1B was sceptical about the real reasons other CTs, (particularly in his school) said they were unable to teach practical science. He felt that:

*In practice lots of teachers are happier looking at factual information using text books for science rather than doing practical with children...[this is due to] a lack of confidence. Time is also a reason for [teachers] not doing practical science... (CT1B).*

This might indicate that although a ‘knowledge-based’ curriculum and the pressure of national tests were a significant influence on how science was taught, some CTs were still able to create space to teach in the way they believed. This might suggest that for those who did not want to teach in a practical way the PSSW (1998) and SATs could be used as an excuse for their lack of confidence and/or ability to teach investigational science. However CT1B thought that:

*QCA has supported teachers doing practical science I suppose...but still some teachers just don’t like the lack of control you have when doing practical work (CT1B).*

Yet, CT1C was convinced that it was the pressure of national testing that prevented her from doing investigational work rather than organisational issues:

*I’m teaching in] lots of bite size chunks this term, putting in information rather than [doing] practical [work]. [I use] science readings in English. After SATS we will do the environment and that will be more practical, at the moment its blatant cramming for SATs (CT1C).*

Nevertheless CT3B suggested that she would like to expand her repertoire of a traditional three-part lesson:
I tend to use a whole class delivery and then in groups and then I get them together at the end. I would like to try other ways of teaching e.g. round robin etc (CT3B).

Furthermore, some CTs emphasised the importance of the teachers' role in helping pupils see the relevance of science to everyday life particularly in KS2, for example CT1C stated:

*For some children [there's] very little link. It depends on how relevant we make it (CT1C).*

However, there was a strong indication from interviews that restricted time to teach science might prevent this from happening. Therefore, findings from the CT interviews would imply that the lack of practical work in science cannot be seen as totally the result of SATs, although there is strong evidence here to support this. Other underlying factors are also significant depending on the context, confidence and expertise of the CT.

We have seen evidence here that if teachers feel strongly enough about teaching science and have the knowledge, experience and confidence, then despite the pressures of SATs they were still able to find the time to engage in practical activity as a context for developing understanding. However if they object strongly to teaching in this way or lack the confidence/knowledge to do so, the tests and content-driven curriculum provided a convenient reason for focusing on direct teaching methods. Thus it could be argued that there was still a significant need to deepen teacher understanding of pupils as learners.
as well as a deeper knowledge of science content in order to deliver a practical-based science curriculum and to teach science in a way that supports learning. Moreover, teachers needed to understand why this approach was effective in challenging children's 'unscientific' explanations in addition to increasing motivation, rather than just providing evidence for summative assessments.

8.5.4 Assessment/accountability

All CTs seemed to use PSSW (1998) as a basis for summative assessment and most claimed to use a range of methods including observations and questioning although it was not apparent from the interviews the extent to which teachers assessed scientific enquiry. It would appear that most CTs were very skilful in planning work to conduct summative assessments. For example CT4A, a Y2 teacher, was able to describe the strategy she used for enabling pupils to achieve levels two and three at the end of the year.

*To get level three you need Attainment Target one (AT1) and one other AT. This time we concentrated on forces, planning for investigations based on AT1 and AT4. It was done so that I could assess for Level two and three (CT4A).*

In another school, CT1C was able to list in detail the range of summative assessments planned and experienced by her Y6 class:

*There's a science assessment every half term. These are our own assessments and then there is the ongoing assessment you do along with the science homework, which they have*
alternate weeks. The homework usually consolidates what’s been done in the lesson (CT1C).

This might suggest that CTs felt an increasing necessity to have evidence of what their pupils had attained by the end of a science topic in terms of predicting levels of achievement for SATs.

[The SATs] at KS2 and KS1 is to focus teachers, to make sure teachers are teaching it. [There’s] lots of cramming, it’s sad. Lots of schools doing revision is one thing, cramming is another (CT4B).

It is not surprising perhaps that few CTs explicitly stated that their assessments were for the benefit of the children in terms of moving them forward in their learning. In fact, it would appear that some CTs did not necessarily see formative assessment as a priority. For example, CT1A felt assessment was ‘about seeing what they remember’.

The findings would indicate that CTs were more confident and possibly more familiar with summative assessment.

[SATs] focuses you on assessment, otherwise TA can be subjective and you are not totally sure if you’ve got it right…(CT4A).

CT2A, CT1B and CT4B provided some evidence of formative assessment. For example CT1B explained;

I usually start the unit with an elicitation activity…I picked this [method of assessment up] when I was training to be a teacher. I also do end of topic assessment usually from schemes (CT1B).
 Whilst CT4B said:

...At the beginning [of a topic] I use brainstorm and also at the end. I give them back the original sheet or a clean sheet so if they have misconceptions we can revisit them. Its very interesting six weeks later when three or four children produce a carbon copy of their original brainstorm ... they [are still] thinking in the same way (CT4B).

These CTs, (from different schools) appeared to make greater use of a range of assessments for different purposes. However, the Y6 teachers in three of the four schools found that their assessments were heavily influenced by what children might achieve in SATs in fact CT2C said:

We have] a separate revision session. [These are] short sessions, [where we] brainstorm questions [from SATs papers] (CT2C).

The evidence suggested that CTs in Y2 and Y6 spent a considerable amount of time and energy on revising science taught in previous years as well as the current one. For example CT1C a Y6 teacher in another school said:

...I looked at all the units in the QCA and old SATs papers and we spend more time on the topics not done since year four... We do old SATs papers every lesson, making sure everything is covered (CT1C).

This was also an issue in KS1 where CT2A stated:

Each year we discuss how we will do teacher assessment for SATs and particularly ways of assessing areas you've not taught (CT2A).
Although CTs did not specify how much time was spent on 'revision' rather than developing conceptual understanding, it would appear a considerable amount of teaching time was focused on the former, particularly in Y6 and to a certain extent in Y2. However one of the reasons CTs were faced with this dilemma seemed to be due to the steady pressure put on them by government policy to be accountable by providing evidence in the form of ever-improving test results and through regular Ofsted inspection, that academic standards within their school were improving year on year.

Despite a focus on assessment, CTs had divided opinions about the benefit of SATs. For CT2A it was a measure for government whilst CT2C stated:

> SATs give the subject status alongside literacy and numeracy. [Without SATs] parents would not be so interested in science. ... SATs testing, gives it weighting and recognition. [SATs is important] for Y7 teachers, it is valuable to them (CT2C).

However CT1B in another school had mixed views and said:

> SATs give a benchmark; it puts pressure on the children. It's really for league tables and schools to look good and not for the children... But there needs to be something we can measure them against (CT1B).

In some ways it seemed that CT expectations of their pupils' engagement and achievement in science were dependant upon the year group they were teaching and their position in school. Thus those in Y6 were more concerned with subject knowledge and vocabulary
whereas non-SATs year groups put more emphasis on skill development. Nevertheless, in all cases it could be argued that the additional time and effort teachers put into summative assessment could be better spent on encouraging pupils to articulate existing ideas so that teachers could plan appropriate learning experiences.

8.5.5 Teacher development and subject knowledge

Although CTs were not asked a direct question about subject knowledge some raised concerns in this area.

For me the main concern was teaching forces, it was straightforward in the end, but at first I thought oh dear. If you’re not a science specialist and had to do the planning it can be quite daunting – it’s the terminology really (CT3A).

Y6 teachers felt they particularly faced issues in relation to subject knowledge although it would appear they found ways of dealing with this.

[My] own depth of knowledge, I [passed] the [science] standards at college but there’s still a problem if someone in year six is very bright … then you have to get the encyclopedias out. I think a lot [of children] get turned off science (CT1C).

… I used a college book (S. Farrow) now [its] not so necessary for the background knowledge (CT1C).

With the exception of CT2C, it was perhaps notable that no one mentioned seeking advice from the SC. It could be argued that some support for science, both in terms of developing science subject knowledge or pedagogic content knowledge would enable CTs to
employ a wider range of teaching strategies. In fact findings from CT interviews implied that a part from science inputs during ITE, CTs trained in the last decade may not have received any further support in teaching science. Furthermore any current support from SCs would appear to be in the form of conducting summative assessments rather than improving the quality of teaching. However this did not seem to be of great concern to the CTs particularly as some were of the opinion that:

[the QCA is] quite clear, [its] got a few good ideas and if I need any extra resources, books or ideas I get them from colleagues and myself really (CT2B).

It could be argued that the PSSW (1998) had in many respects filled the gap for science CPD, and because it provided lesson objectives and outcomes as well as suggested activities, it possibly made CTs feel relatively secure in their teaching of primary science.

The benefit of QCA is you know you are covering [science]. QCA lays out learning objectives, it gives the non-specialist science teacher more help at that level (CT4A).

However one CT thought that schools were in need of more specialist support, particularly in KS2.

I would like a more workshop based approach to science with external programmes with visitors coming in, a link with primary and secondary [school] ... It takes the pressure off teachers who are not experts. [We] need this on a more regular basis (CT1B).

Evidence from interviews would suggest that only a few CTs identified subject knowledge as an important quality and some did not mention
this at all. In all four schools CTs identified generic aspects of good practice for a teacher generally in terms of developing a good relationship with children, displaying enthusiasm for learning, provoking thinking and questioning. Several advocated that:

...A good science teacher is enthusiastic about the subject, stimulates enquiry in children’s minds, finds out answers to questions but follows a structure. They get through the curriculum, skills, concepts, and the basics (CT3B).

Yet on the other hand, Y6 teachers in particular acknowledged the importance of engaging with the subject by having good science subject knowledge and an ability to put over concepts clearly so that children could understand what was important.

[Someone with] subject knowledge, [and who is] not thrown by children’s questions. A willingness to research with the children as well...You’ve got to get equipment out and get children involved. They benefit if this happens (CT2C).

CT2A, who placed great value on investigational science, distinguished between knowledge of content and skills in science as a necessity.

...background knowledge, to know what you’ve talking about. Understanding the skills involved in science, the practical nature is important and this can get lost (CT2A).

This would imply that not only did some CTs not perceive a need for CPD but that, on the whole, focused more on having adequate subject knowledge for covering the curriculum and being familiar with the terminology with the support of PSSW (1998) rather than acquiring sound conceptual understanding at their own level and developing appropriate teaching and learning. However other CTs, who appeared
to have a deeper understanding of the nature of teaching and learning science, were aware of the need to develop not just subject knowledge but also conceptual understanding and pedagogic content knowledge through a range of teaching strategies in order to move pupils on in their learning.

8.6 CONCLUSION
The discussion has traced the broadly related themes evident in the CT interviews. To a certain extent accounts have shown how conceptions of science in their schools were closely driven not by their own understanding and opinions about primary science but by external pressures arising from a content- and assessment-driven curriculum along with contextual factors. The CTs in Y6 were particularly influenced by expectations of performance in SATs and as a consequence, this seemed to have an impact on the way they chose to teach science. Many appeared to feel frustrated that a focus on knowledge and summative assessment meant there was not enough time to engage in practical investigative science as they wished. However, despite this conflict it would appear that some teachers were able to focus on practical science despite being in schools where recent SATs results (2001) were below the national expectation. This might suggest that although external policy put a certain amount of
emphasis on direct teaching strategies, (White Paper 1993) there were possibly other reasons why teachers did not engage in practical science. For example, it could be argued that CTs' lack of subject and pedagogic content knowledge might be a contributing factor.

The views of the CTs represent their own understanding of the science curriculum based upon their own experience, the context in which they work and their own beliefs about teaching. Whilst it cannot be assumed that these views are representative of other teachers' experiences, it does provide some tentative evidence that competing perspectives, policies and ideologies have resulted in tensions faced by the CTs. A particular suggestion from the findings was that the planning, teaching and assessment of science had been dominated by the PSSW (1998) and the national tests. This in turn may have placed restrictions on the way some CTs chose to teach science. However the extent to which this may have restricted pedagogy was brought in to question by the fact that some CTs appeared to find space to teach the investigative science in which they believed and in a way that developed conceptual understanding. Although it was not clear as to why some teachers were able to pursue their ideals whilst others were restricted, findings from the CT interviews would indicate that this was not necessarily linked to school SATs results or socio-economic intake. Evidence from the data would suggest that lack of CPD in relation to the development
of teacher subject knowledge and appropriate pedagogies may be a significant factor, along with some CT's reluctance to teach in this way.

This chapter has considered further evidence in relation to the third research question and the next chapter will continue this process by analysing pupil group interviews from three of the SC classes and KS2 CT classes.
CHAPTER NINE: THE PUPIL INTERVIEWS

9.1 INTRODUCTION

Chapters six, seven and eight have reported and analysed interviews from HTs, SCs and CTs across four primary schools in relation to the broad themes identified in chapter four. Chapter nine will now examine pupils’ views and experiences of primary science. The pupils’ views are thought to be significant as they are the receivers of the ‘taught’ science curriculum and the ones who are monitored and assessed on what they know, understand and can do. Their conceptions of science are likely to be influenced by prior experience and this in turn will affect the way they interpret knowledge and engage with the teaching and learning process.

9.2 AIMS

This chapter aims to explore children's' conceptions of science through their interest and enjoyment for the subject together with perceived experiences of primary science in their classrooms and out of school in order to provide another perspective.
9.3 METHODS

9.3.1 Participants

Group interviews were conducted with pupils in KS2 across the case study schools. These consisted of pupils from KS2 CTs and SCs interviewed in chapters seven and eight (see methodology chapter for an overview of groups and further discussion on the limitation of group interviews with young children).

9.3.2 Materials

The interview schedule described in the methodology chapter was used to gather information from the groups of pupils. An analysis of these interviews revealed that the children’s responses were often one-word answers or took the discussion away from the questions on the interview schedule. This led to modifications with fewer key questions and more prompts which formed the compilation of the final interview schedule.

9.3.3 Procedure

The researcher carried out the interviews with the pupils at agreed times throughout the year of study. In most cases this took place on the same day as the observed science lesson in which the children were involved. Each group interview lasted no longer than twenty
minutes and took place outside of the classroom. The same ‘warm up question’ was given to each group of pupils, followed by the key questions. Where necessary, the researcher used various ‘prompt’ questions in order to refocus the group on the key question if they had wandered from the subject, or to encourage other pupils to answer if only one pupil in the group responded. The group interviews were audiotape recorded and later transcribed. The transcripts distinguished only between the researcher’s questions and the pupil responses. It was not thought necessary to identify individual pupil responses, other than to display them on a separate line in the transcript. Pauses over ten seconds were noted in the transcripts as this often signified pupil thinking time or difficulty in responding to the question.

9.3.4 Analysis

A data trail was kept; starting from the initial group interview transcripts and analysis was carried out in the way described in the methodology chapter.
9.4 RESULTS

This section reports the results of the pupil group interviews, in KS2.

9.4.1 Curriculum

Although intended as a 'warm up', it was interesting to note that pupils did not indicate a particular liking of science at school. Most associated science with 'finding out'. G1B and G1C from school 1 found it difficult to define science other than stating it was sometimes enjoyable and linked to finding out, whilst G2SC from school 2 described science as both interesting and boring, defining it as experiments you might investigate. However, G2C from the same school thought science was about 'finding out' and experiments, for example when learning about electricity they also thought there was a link between science and maths. However G4B associated science with finding things out about 'nature', although they were uncertain if the written element of experiments could be classified as science.

Some groups (particularly G1B, G1C, and G2SC) found it difficult to compare science with other subjects. G1B and G1C thought science might be more important as they did more now than they used to although they did not find it very interesting. They also thought it was 'about the world'. G2SC explained that science was different to other subjects in that it involved 'experimenting' on different things, which...
you would not do in English, and Maths. Pupils from G2C also described science as ‘a lot of subjects put together’ because it involved English, maths and History. However G3SC thought science was different to other subjects because it was not ‘made up’ like sums, nor was it just writing down or like reading a ‘false story’. It was about the world and knowing the ‘truth’. G4B gave mixed views stating that science varied from other subjects in that it involved practical work. Another way science was different was because it involved learning about nature and not necessary about people. On the other hand this group also thought that science and other subjects such as maths and English were quite similar, as well as ‘art’ as it involved drawing things.

The younger children agreed science was different (Groups G1SC, G2B and G3B) and G3B suggested that it was ‘not what you learned but what you did’ that made it distinctive. G1SC also picked out differences for example they felt that literacy was reading and science was ‘important stuff’, whilst G2B felt that you find out more in science than in other lessons. They also thought it was more useful and interesting. G3B felt it was different because in science you ‘work things out together and do tests.’ When probed they added that you ‘test things in science which you do not do in English and maths’. They also felt that you did not just write down answers but you ‘used your eyes’ more and that science had more to do with the outside world.
There were mixed views about who could do science. Overall, there was a feeling that you needed the right equipment and had to be able to read and this excluded very young children. For example Groups G1C, G2C, G4B and G2B, thought probably anyone could do science. In fact G2B thought anyone could be a scientist except babies although one pupil added that even babies 'test their dummies out'. However G2SC thought it was important to read and use equipment and this excluded young children. G1SC felt not everyone could be a scientist and even when probed said they did not like acting like scientists, as there was 'too many long words and it took ages'.

G1B and G1C thought science was useful but could not give any reasons why, whereas G2SC thought science prepared you for life and taught you the 'basic' things. Pupils from G2C went further and suggested that science could 'cure you' and it had 'provided us with computers.' G3SC were of the opinion that not only was learning about what happens in the world important, but they also thought science had 'made our lives easier.' Pupils from G4B also thought our lives were 'better as a result of science', for example they felt it gave us knowledge to know 'how to look after ourselves'. They also thought that learning science made us 'ask questions' and that this was the only way we would 'find the answers'. More specifically they thought
knowledge of science was important and useful ‘if you were going to be a teacher, a scientist or an electrician’. G2B thought it was important that we knew about ‘dangerous things’ whereas G3B said science had given us useful gadgets such as electric toothbrushes’. All thought science important or useful either in terms of gaining greater knowledge about the world or in terms of making our lives easier. There appeared to be no variation between schools (other than groups from school 1 who could not offer any examples as to why science was important), or between upper and lower KS2.

G1B thought scientists did ‘sophisticated science, invented things and found things out’. However pupils from G2C thought that ‘scientists mostly worked on finding a cure for diseases’. This view may also be a reflection of the fact that a local pharmaceutical company was a large employer in the area and also had links with the school. G3SC gave the example that scientists ‘generally discovered new things and knew all about space’. However pupils from G4B thought ‘scientists did experiments and tried to prove each other wrong’. They also thought scientists were ‘trying to discover more weapons’. G1SC said scientists ‘discovered and found things out’ whilst G3B had a wider view and said that scientists ‘worked things out’ and gave a variety of examples of what scientists did such as ‘discover medicines, engage in problem solving like detectives, finding things good for the
environment'. Those that were asked this question tended to think of scientists as 'a bit removed from the general population and as having status'. Some pupils from G4B indicated that what scientists did was not 'clear-cut' but 'uncertain', that is their purpose was to disprove each other.

G1C thought 'Edison and Pasteur were famous scientists', whilst G2SC named 'Newton, Einstein and Da Vinci'. G2C said they had learned about 'scientists' through their 'Victorian' project such as 'Jenner, Pasteur and Nightingale'. They also named 'Marie Curie, Einstein and Newton'. In most cases they could remember the names but not much about them. G3SC thought that 'Robert Louis Stephenson, Alexander Bell, Isombard Kingdom Brunell, and Florence Nightingale' were famous scientists but again could not remember much about them. G4B thought 'Einstein, Newton and Darwin were the most well-known', whilst G2B were only able to name 'Einstein', the others mentioned were fictitious characters. Only one pupil from G2C mentioned someone else's dad who was a scientist and worked at the large pharmaceutical company near the school.

9.4.2 Pedagogy

G1B said they particularly liked the 'sound' experiment they had done which involved observing how the vibrations from a ruler could be
recorded as waves by putting a pen on the end of the ruler. G1C when probed about what they liked in science referred to a practical investigation they had previously done. They said they enjoyed science most of the time but added that you need to ‘read as well as do experiments’ in order to learn anything. Pupils from G2SC also identified ‘experiments’ as the aspect they most enjoyed about science. One pupil stated he also enjoyed science when his dad bought home some chemicals. G2C children also from the same school all said they preferred ‘experiments’ to ‘written work’. Pupils in groups G3SC and G4B also enjoyed practical science whilst G4B added that they preferred activities to writing, although one said they liked to find out more after doing the experiment.

All pupils interviewed from Y3 and Y4 across the schools said they ‘enjoyed the practical aspects of science work’, specifically identifying investigations and experiments although some groups also identified particular topics as enjoyable. Groups in lower KS2 tended to give a greater explanation of what they liked in science whereas groups in upper KS2 with the exception of G1B generally referred to liking ‘practical work’. For example pupils from G1SC mentioned ‘friction and electricity’, whilst pupils from G2B had enjoyed exploring ‘habitats and electricity’. G3B also enjoyed science relating to ‘nature’ whilst pupils in G4B said they liked ‘investigations and experiments’. They also
described practical work on ‘vibration of sound and gases’ as particularly enjoyable.

Groups representing pupils in Y5 and Y6 all disliked ‘written work’ in various forms. Both G1B and G1C said they did not enjoy ‘written work related to science, particularly if it involved answering questions from the textbook’, nor did they like ‘reading about science or recording investigations in books’. G2SC and G2C expressed a similar view but also disliked having to ‘listen to the teacher’. G3SC and G4B who were from different schools expressed similar opinions. Groups representing pupils in Y3 and Y4 mentioned other aspects of science. For example, G1SC did not like ‘friction and electricity because there were too many long words’ and G3B mostly enjoyed the ‘science they could do outside’. These groups also disliked of elements of written work as well as listening to the teachers or waiting for others to finish’. Whilst G2B did not like having to ‘think for tests’, G4B felt that ‘writing from the board or copying from a sheet was not enjoyable’.

All pupils regardless of the school they attended acknowledged that science could be done elsewhere. Some described what they had personally experienced at home, whilst others listed possible alternatives to doing science at school. For example, pupils in groups G1C, G2SC and G3SC thought they could learn science, particularly in
'museums and from books' and they gave examples of 'simple investigations' some had tried at home, such as 'separating soil, copying experiments from children's television programmes and from a science magazine, making a volcano and cooking with chocolate'. Pupils in G4B said you could do science everywhere, 'it was about what you did and the questions you asked', for example 'if you picked a leaf off a tree and dropped it to see what happened, this could be science'. Pupils in Y3/4 were also of the opinion that science could be learned elsewhere, for example G2B said you could learn about science 'at home, in your garden and even testing swings out in the park could be science', whilst one pupil in G3B explained how he had learned about 'birds in his Nan's garden', and another described how it was possible to 'test which vegetable would be best to power an alarm clock or bulb'.

All groups were able to list the knowledge-based science themes they had covered at school and started with the most recent ones. Some commented on how well the teacher taught the science topic and this seemed to link with how much they enjoyed it. Whilst pupils in Y6 listed topics covered, other year groups described mostly practical science lessons and were able to talk about aspects of these in more detail and with enthusiasm. For example G2B recalled past lessons on 'habitats, circuits, the body and forces'. They described how they used 'a force
meter' and also how the teacher taught the lesson, rather than the science learned, whilst G4B explained the work they had covered on sound and described the practical elements of solids and liquids for example, when they 'melted chocolate'.

Groups of pupils in Y5 and Y6 were asked an additional question in relation to their understanding of 'an experiment'. The groups provided a range of explanations of an 'experiment'. For example, group G1B, G1C and G4B thought that experiments meant 'testing something out and seeing what happened' although those in G1C also thought that sometimes the teacher told you what happened. G2SC suggested that an experiment required 'the right equipment' and thought it was 'important to listen so you did not get it wrong'; whereas G2C felt it 'involved mixing things and seeing what happened'. G3SC stated that an experiment was 'working things out'. All groups consistently identified parts of the scientific process, particularly that variables have to be 'tested out and that they need to be observed to see what happens'; although no one mentioned specific skills such as prediction, fair testing, hypothesising and interpreting data or drawing conclusions.

9.4.3 Assessment/accountability

Pupils from Y6 tended to list the themes covered in science. For example both G1C and G2C, which contained Y6 pupils but at different
schools, listed a large number of topics they had covered in relation to revising for SATs although they were unable to recall much about the topics. G3SC, a mixed-age class of Y5 and Y6 also mentioned lots of revision although one pupil felt this had been quite enjoyable.

All groups suggested learning science would enable them to do better at secondary school and eventually would help them get good jobs. In fact, they viewed it as an important and necessary part of school, even though it may not be their favourite subject. Pupils from G1B and G1C also thought it ‘helped you to answer questions on TV quizzes and in the future would enable them to help their children with homework’, whilst G2SC also suggested science ‘helped you learn about the world, for example which animals were in danger’. G4B also thought you could not really get by without science and viewed it as ‘educationally important’ in that it supported other subjects. They also felt it would not be possible to ‘do science’ if you did not have maths and English. G1SC felt science gave greater knowledge to know what to do if ‘we hurt ourselves or if we were working with particular equipment’ whilst G2B suggested it was important for an electrician to ‘know about electricity in order to do his job’.
9.5 DISCUSSION

9.5.1 Curriculum

Pupil views of science were certainly influenced by the way content was organised within the science lessons received at school and, as a consequence they generally recognised 'science' in terms of 'topics' or 'units of knowledge' planned from the PSSW (1998), although in Y6 it would appear that previous SATs were also a direct influence.

Enjoyment of science appeared to vary according to how it was taught rather than the actual content. However there was evidence of other experiences and influences on science from outside school and these appeared to be positive.

Evidence from the interviews would suggest that some groups of pupils held different views on the nature of science although it was not possible to ascertain if these reflected experiences from their science lessons or elsewhere. However, the regular teaching of science might indicate that influences from school were greater. For example, pupils in a mixed Y5/6 class presented a traditional view of science suggesting:

*It's not like reading a false story...it's about knowing the truth* (G3SC, Y5/6).

Whilst pupils in a Y4/5 class in school 4 presented a more contemporary view and thought scientists were engaged in disproving each other's findings, thus suggesting that there is no real truth.
They try to prove each other wrong, one scientist says one thing and they don't believe it and they try to get them wrong...yeah if one scientist says red is red and the other scientist says red is blue! (G4B, Y4/5).

This could reflect pupil experiences in science for example their teacher CT4B in school 4 frequently engaged her class in activities where they were given opportunities to prove and disprove statements through investigations, whereas other teachers might take a more direct teaching approach implying one right answer that has to be learned.

Evidence of tensions that teachers appeared to face in relation to scientific enquiry and content were also apparent in pupil definitions of science. A Y5 class in school 1 viewed science in terms of knowledge; 'I would just say [it is] the subjects you do'. However a Y3 class from school 2, referred to practical elements such as 'its things that you are doing, experiments that you are investigating'. Nevertheless it would appear that pupils held wide interpretations of investigations which again could reflect the range of practical activities organised by their teachers loosely referred to as 'investigations'. Whilst some groups identified 'testing' as a key element others talked in terms of 'working things out and others referred to practical activity such as 'mixing', things. Some groups gave quite detailed explanations, for example:

You don't have to work things out so much ...you just do tests and work it out together...you sort of test things...you do different things you don't just write down your answers, you feel
things and use your eyes more ...its more to do with the outside (G3B, Y3/4).

Furthermore, it would seem that science topics were more memorable to classes of Y3 and Y4 pupils. They appeared to have engaged in a greater amount of practical work and as a result had some understanding of the aim of the investigation, for example, G4B said:

we just found out which materials kept things warmer and cooler...had ice cubes...lots of tango bottles...we wrapped materials around them...and every five minutes we stuck, a thermometer in...to see if it had changed (G4B, Y3/4).

However, pupils were not able to explain what they had learned or why some materials were insulators. Whilst G2B class said:

well you get this...force meter...see how much it weighs...and then you have to write it down in your book that's fun that is (G2B, Y4).

Whereas pupils in Y6 were not able to give much detail and only listed topics recently covered possibly suggesting that hardly any practical work took place and much of science was book based or revision.

Sound, electricity, Circle [circuits]...Gravity...Friction...Forces. Dissolving, not the most exciting...we've done more because of the SATS... (G2C, Y6).

Another typical response was:

[I like science] when its practical...but we have to write about it afterwards...I'd rather just do the practical...I just like the bit where you get to do the activity and not the writing (G4B, Y4/5).

Again the pupil responses to the way science links with every day life suggested that the focus was on subject knowledge rather than on application of skills. However, some felt that the content learned at
school could be directly applicable to certain jobs such as becoming an electrician, an engineer, or a scientist. For example, they thought the topic 'electricity' might have some relevance if they needed to know about electricity in the home. It was difficult for pupils from all four schools to see the direct relevance of science unless they wanted to be a scientist (however no one interviewed did). Furthermore, not only was science content-driven but also preoccupied with pupils acquiring the 'correct' vocabulary. One pupil explained:

\[ I \text{ don't like being scientists because there are too many long words...I'd rather be a footballer (G1SC, Y4). } \]

This might again reflect the emphasis on scientific knowledge, and the emphasis on the use of scientific vocabulary although not necessary on understanding. Another key reason given for learning science was to help their children do their science homework when they were parents themselves, which again may indicate an emphasis in science homework at School 1 (G1C, Y6). Although pupils cited investigational science as more enjoyable, it would appear that there was not a clear understanding of why they did investigations. Most of the knowledge gained through 'learning' or 'doing' science at school was equated with passing exams or a test, thus, suggesting that the predominant science they received was not developing long-term understanding or transferable skills.
Although teachers and the PSNC (DfEE1999) seemed to have the biggest influence on children's views and definitions of science, there were notable examples where parents and grandparents appeared to have influenced pupil's interest and these tended to reflect positive views of science. In fact one child from G2SC recounted in detail how he engaged in science at home:

...my dad made this little see through box and it's got matchsticks in it and there's a nut between the two matchsticks...and the birds have got to pull out the red ones to get the nuts... (G2SC, Y3).

Other positive images of science reflected museum visits, looking at books and using the computer. Furthermore, television also seemed to generate interest and act as a motivating influence. For example one group said:

You could get...science experiments on TV and see what experiments they do and copy them if they are not dangerous...I've seen one where you put salt in and put the string in it...(G2C, Y6).

Pupils varied in their views about the relationship between science and other subjects. Groups within schools 2 and 4 were able to identify similarities with other subjects.

I think actually they are quite alike because you actually have to do writing which you do in English, you do sums which you do in maths and you draw things which is in art (G4B, Y4/5).

G2C and G4B took the view that there were similarities or overlaps, in terms of the application of skills such as writing, measuring and doing
calculations rather than content knowledge. Another pupil in another school explained:

Science is a lot of subjects put together. [Because] there's writing, that's like literacy and maths, it's like measuring and history it's like finding out all the scientists (G2C, Y6).

Other groups felt science was distinctly different as it was 'important' and involved practical work and learning about nature. For example, G1SC felt that you would not learn about topics such as electricity in literacy.

Science is different because there are different things like electricity, you don’t really use electricity in literacy do you.... Or maths...Literacy is reading and science is ... important stuff (G1SC, Y4).

Interestingly this view came from school 1 which had linked science with literacy in the top end of KS2. However it might also reflect the extent to which science has become removed from other subjects.

Another group explained it as:

You don’t have to work out so much things...You just do tests and you work it out together...You sort of test things, with Maths and English, you don’t usually get to test things.... or get different objects in your hand apart from pencil and paper...You do different things you don’t just write down your answers, you feel things and you use your eyes more...And it's more to do with the outside (G3B, Y3/4).

Whilst some pupils within schools 2 and 4 could see the overlaps of science with other subjects, other pupils in schools 1 and 3 viewed science as an entity in its own right with a certain amount of status.

Furthermore, findings would suggest that younger pupils were perhaps better at articulating the distinctiveness of science from other subjects,
again possibly because of greater opportunities to engage in practical work, whereas older pupils could see the links between other subjects particularly literacy and numeracy as much of their science possibly involved applying these skills rather than teachers making explicit links.

9.5.2 Pedagogy

As previously mentioned it would seem that pupils’ level of enjoyment and enthusiasm for science was influenced by the way their teachers taught it and in particular, the way activities were set up for pupils. It would seem that where science involved ‘hands on’ experience or so called ‘investigative’ work, then pupils found this enjoyable and memorable, where science consisted of mostly revision, note taking, writing up the whole investigation or committing facts to memory, science was not seen as exciting.

For example, several pupils from G4B said:

...experiments, like Mrs. C showed us...she made like some gas and bubbles and she put a balloon on top and she put water both inside and vinegar and shook it all up and all the gas came out and blew the balloon up. [I like it] when we do fun experiments, once when we had lots of experiments and we had to go round and do them (G4B, Y4/5).

Whilst a pupil from G1C said:

[In the autumn term] we did the body but she didn’t really explain it very well (G1C, Y6).

Another pupil from G2SC said:

[I don’t like it] when we listen to the teacher as she goes on and on (G2SC, Y3).
Whilst this might imply that teacher explanations and transmission of knowledge were unpopular, it would appear that although some pupils enjoyed practical activity they were not able to provide an indication of the concept but more often could only describe what happened rather than why. They also found some aspects of investigational work tedious.

I don’t think it’s fun when you just write, write, write and add things up that’s boring...like filling in graphs and tables afterwards to show your results (G4B, Y4/5).

It could be argued that it was not necessarily investigative work that pupils enjoyed, but science that was taught in a creative or unusual way. For example, G2B said:

It was a couple of weeks ago and Mr. W had this quiz thing on the computer and he recorded us with a camera and he put a microphone in front...and he asked us what a force was... (G2B, Y4).

Whilst G3SC recalled:

We had to get into our own food chains...where we sat in the centre of our classroom we had the sun and different creatures...and different chains coming off (G3SC, Y5/6).

Furthermore, their interest in a particular science topic appeared to diminish as a result of the number of times they felt they were repeating work which might suggest that despite built in progression in the PSSW (1998), in practice pupils often felt they were repeatedly experiencing the same things. However, this was most evident in Y6 where pupils recalled that:
She knows we know it but she just wants to make it a lot clearer, but it’s really boring because we do it loads of times (G1C, Y6).

This seemed to be the case with Y6 pupils, particularly in schools 1 and 2, where science SATs were low and to a certain extent in school 3 where pupils appeared to spend a lot of time revising topics they had covered in previous years. Consequently, this seemed to cause a certain amount of resentment with Y6 pupils:

we do lots of revising...we don't get to do many experiments because we've already done it (G2C, Y6).

It would seem that because these pupils are in Y6 and would be taking SATs towards the end of the academic year, they spent a significant amount of time revising science topics, covered in previous years without the bonus of engaging in practical work. In fact whilst such intensive revision was possibly aimed at improving retention of knowledge and understanding, previous discussion would suggest this was not necessarily the case. Instead it would appear that it was the younger pupils in KS2 who had frequently engaged in practical work in science lessons who seemed more enthusiastic about science, and were possibly more knowledgeable about the topic and the concepts covered. Although writing up the investigation afterwards might have reinforced this, it certainly appeared that the interest and motivation gained from practical work for some resulted at least in better recall of what they had done and what happened although not necessarily why.

It would seem that experiential and creative ways of teaching science
were more effective at enthusing pupils about science although not necessarily furthering conceptual understanding. In addition they seemed to be much more part of younger pupils’ experience than those at the top of KS2. However it could also be argued (based on the evidence from previous chapters) that the greater focus in KS2 was on direct teaching, which required little teacher explanation, or probing pupil explanations.

The findings from the group interviews would suggest that there was a strong link between interest and enjoyment of science and how it was taught. In many cases it did not seem to matter about the knowledge or content, whether it was a topic on friction, sound, electricity or habitats, the greatest enjoyment was when they had ‘hands on’ experience. G1B said:

*I like sound waves … like yesterday when we hit the ruler and put a pen on it and made wiggly lines (G1B, Y5).*

Whilst G4B said:

*I just like the bit where you get to do the activity and not the writing (G4B, Y4/5).*

Much of what the pupils valued would appear to support the view that children were more motivated and thus able to learn more effectively when engaged in hands-on activities which incorporated creative teaching strategies. They appeared to find these more stimulating, triggering their natural sense of curiosity about phenomena and how
things worked. However there was little evidence that such activity was used to encourage pupils to articulate explanations in relation to their existing ideas. Conversely there was a strong link between their dislike of the subject and writing and recording science. The findings here might suggest that creative and innovative methods to engage pupils in learning were sporadic and occurred more frequently further down the school when pressure from SATs was not so imminent and possibly where science subject knowledge for teachers was not as challenging. It might also appear that pupils from school 1 where the organisation of science at the time of the study could be considered to be a reaction to poor SATs and an Ofsted report that identified science as a weakness, were experiencing a more traditional transmissive approach to teaching science. They particularly disliked the kind of writing they had to do which involved ‘doing the questions out of the book’. However pupils in school 4 whose SATs were above average were able to enjoy a greater variation in approaches to science, nevertheless they also expressed preferences for some aspects of practical science and a dislike for having to write about it afterwards.

9.5.3 Assessment/accountability

The findings reported so far would suggest that pupil experience of primary science seemed strongly linked to assessment (particularly to the national tests at the end of KS2) and as a consequence had a
direct influence on enjoyment of science particularly in Y6. The main motivation or rationale for doing science for many of these pupils was to get good marks in tests, particularly in SATs and perhaps later on do well at secondary school in order to get a good job. G1B emphasised the importance of science in order to:

*Get a decent job, get a degree in college (G1B, Y5).*

Whilst G2C emphasised you learned science in order to:

*have a better chance in your exams or SATs (G2C, Y6).*

Similar views were expressed across all four schools and were most prevalent in Y5 and Y6. Again this would suggest that much of the teaching of science was directly aimed at preparing pupils for tests.

*...we don't get to do many experiments because we've already done it. You have to revise it and it's like doing it again and it gets boring (G2C, Y6).*

Y6 pupils in another school explained why they had covered a lot of science

*...She hasn't really said what we are on, we're just doing loads of different things for SATs...We're doing one thing for one week and another the next week...So we can just to go over things...for SATs...We did light and sound in year 5 but Mrs. T our teacher just wanted to go over it to check that we knew it (G1C, Y6).*

There was a notable drop in enthusiasm for science in Y6 where a great deal of time was spent on revision, with the results from the group interviews implying that there was a distinct difference in the kind of science experienced in Y6 compared to the other year groups.
For example, pupils in Y6 felt that part of the necessity for recording and writing in science was again linked to preparation for SATs:

*If we’ve done an experiment we have to write it down... so you can revise... you have to look back for the tests, look back and see what we’ve done* (G1C, Y6).

Not all groups felt that recording results was directly related to revision. For example G2C suggested it enabled comparison with other results collected from the investigation. In some instances it would seem that science revision consisted of the teacher describing the investigation and the results and then required pupils to commit this to memory, rather than engaging them in a real investigation. Some pupils rationalised this by stating:

*you have to do the reading you can’t really just do the experiments [as] you don’t learn much* (G2C, Y6).

Rather than developing their own explanations, pupils seemed to be offered book explanations without a chance to develop any understanding of these or relate them to practical experience.

Evidence from the group interviews would indicate that pupils seemed to accept that tests and exams were part of life and were a significant reason for learning science at school. In fact in one group some pupils seemed to actually enjoy tests,

*we’ve done a whole book of science which is quite fun in places because you get a load of information and then a test about it and then another load and a test...* (G3SC, Y5/6).

Much of what pupils said reflected the current emphasis on assessment and attainment that appeared to favour short-term
memory recall rather than developing conceptual understanding, and application of skills to other contexts. For example, the findings from the group interviews would imply that much of what had been learned about famous scientists was meaningless to these pupils because apart from the name, they could not remember why they were significant people in science and how their discoveries had led to tremendous advances within our everyday lives. Furthermore, some of the names given were not scientists.

This might suggest that a lot of curriculum time was taken up revising past topics for national tests, rather than developing and extending pupil knowledge and understanding of scientific concepts or providing pupils with a deeper appreciation of the cultural and historical significance or technological application of science. Thus it was questionable as to how much 'deep' learning and conceptual understanding had actually taken place during this year. In fact it could be argued from the evidence here that the narrow conception of science together with the way science was organised and assessed in the case study schools was having an increasingly more negative effect on pupils, whilst science experienced outside school was providing a more positive experience for those who had opportunities to engage with it.
Whilst there were many similarities in views held by pupils and their apparent experiences across all four schools, there appeared to be a subtle difference in pupil interest and motivation for science between upper and lower KS2. In addition some differences were more notable between schools 1 and 2 and the other schools. Those pupils interviewed from schools 3 and 4 with high SATs at the time of research seemed possibly to reflect a more positive and diverse view about science. On the other hand, pupils in school 1 and 2 where SATS were low, at the time of this study, generally reflected a more limited understanding and experience of science. For example pupils could not distinguish it from other subjects such as English and mathematics and openly stated that they did not like science especially when they had to do work from the textbook, (Groups G1B, G1C, G2SC and G2C). This might reflect the more traditional approach adopted in this school since SATs and Ofsted. However socio economic status might also affect pupil views as whilst pupils in school came from a deprived locality, pupils from school 4 came from a relatively affluent one.

9.6 CONCLUSION

The discussion has traced the broadly related themes emerging from the pupil group interviews and analysed how they might reflect teacher conceptions of primary science. To a certain extent pupil accounts
have shown how the balance between skills and content within the curriculum, and related pedagogy had a significant influence on their enjoyment of science. They also illustrate how the assessment agenda had particularly influenced the rate of science topics covered and possibly the way teaching was organised in Y6.

Throughout the interviews it was apparent that many of the responses the pupils gave reflected the dilemma their teachers actually faced in terms of balancing skills and content within the science curriculum. Although the pupils clearly preferred practical work, as they thought it to be more interesting, they felt that in order to do well in tests it was important to acquire knowledge and facts. Notably there was a difference in the amount recalled by upper KS2 compared with lower KS2 pupils. Although the former had covered many more topics, they were only able to list the topics without remembering much about them or expand what they had learned. They could only give fragmented facts or snippets of information and seemed to spend less time on practical work or investigations. On the other hand, pupils in lower KS2 seemed to experience more practical and investigative work and, possibly as a consequence of this, were able to recount in some detail what they had done during the investigation. However they could not always say why they had carried out the investigation or what they had learned about a particular science concept from it, or how the concept
could be applied to a different context or situation. Thus regardless of year group, there was little evidence of developing understanding in science. Furthermore there was little indication that pupils had any appreciation of the historical and cultural influences on science or much understanding of technological applications of science.

Whilst there seemed to be similarities in the views expressed across the case study schools possibly due to following the same centralised science curriculum and having to take the same centralised tests, there was some tentative evidence to suggest that in schools 1 and 2 which were struggling to raise SATs levels in science, pupils were less excited about science as it tended to represent a lot of written work and listening to the teacher. As a consequence, many of the pupil conceptions of science reflected the notion that science was about acquiring science knowledge in order to pass tests rather than developing transferable skills and scientific ways of thinking. On the other hand pupils in schools 3 and 4 which were excelling with SATs scores, well above the national average, more frequently had a positive view of science and expressed a wider range of opinions for learning science.

Whilst the purpose of this chapter has been to report pupil perception of primary science within the school context, it is acknowledged that
external experiences of science stimulated by parental interest and science activities outside of school may have also helped to shape views. Furthermore, it cannot be known whether pupils' views are really representative of the whole the group or even reflect the majority of views held by the class. However, a particular suggestion arising from the findings was that pupil interest and motivation for science was strongly linked to the way in which it was taught, rather than by content. In particular creative and interactive teaching methods were preferred although it cannot be assumed that always led to furthering conceptual understanding. Therefore in order to examine the range of pedagogic practice within a commonly prescribed curriculum it is necessary to explore classroom practice and this is the focus of the next chapter.
CHAPTER TEN: OBSERVED LESSONS

10.1 INTRODUCTION

The findings from chapters six, seven and eight suggested that primary science within the case study schools reflected the dominance of national testing and a content-driven curriculum, which possibly hindered teachers' ability to do much investigational science. Chapter nine has shown that to some extent pupils' views are consistent with this and that although pupils frequently expressed a preference for practical, creative teaching, this may not necessarily develop conceptual understanding.

What is enacted in classrooms is a product of complex interactions between pupil and teacher, influenced by participant knowledge, beliefs, values and experiences as well as external factors such as science educational policy and related texts. In addition the teacher has to balance intended teaching and learning within the present context he or she might find themselves in and in response to pupil needs and availability of resources. Furthermore, the amount and quality of teacher professional development in conjunction with a
teacher's own prior knowledge and experience of science may also influence the way science lessons are planned and delivered.

10.2 AIMS

This chapter will look at how primary science is orchestrated in terms of the planning, teaching processes, the outcomes of the lesson and the knowledge teachers draw upon in order to create learning experiences in science. It will do this by analysing a sample of science lessons which are broadly based on the theme of 'solids, liquids and gases' (SLG) as defined by the PSSW (1998, revised 2000).

10.3 METHODS

Throughout the academic year 2001-2 a maximum of three lessons were observed for each SC and CT in the study, (a total of forty two lessons, see appendix 10.2). The researcher negotiated with the school SC and participating CTs when it would be possible to observe the science lessons. Prior to each observation the researcher briefly discussed with the CT the intended learning objectives and content of the lesson and its origin in terms of planning and focus and the role of assessment if appropriate. An initial analysis of all observed lessons was conducted in order to draw out broad themes, but in terms of reporting for the thesis it was only possible to select from the main sample. Thus, six lessons, sharing the common theme of SLG and
spanning teaching across all four schools and both key stages were analysed in detail and are reported here.

10.3.1 Participants
The six CTs were not intentionally selected due to their individual characteristics but because at some stage during the period of study they taught science lessons planned from units of work on themes related to SLG (PSSW 1998). However, despite this there was considerable variation in terms of their expertise, position in school and age range taught. In summary, CT4A had five years experience in KS1. CT1B was a deputy head teacher with seven years experience across both key stages, CT1C had taught for two years; CT2B was a NQT and ICT specialist. Finally CT3B had taught for four years in KS2 three of which had been in Northern Ireland and CT4B had two years teaching experience in KS2 and prior to teaching, a background as a science technician.

10.3.2 Materials
In order to decide on the most appropriate method for classroom observation, methods were discussed and piloted in much the same way as the interviews described in the methodology chapter. Further discussion of the observation and recording techniques piloted can also be found in this chapter. The final focus for the lesson
observations centred on the way CTs constructed science in the classroom and the kinds of ‘knowledge’ they drew upon to do this as well as documenting any surprises or unexpected events.

10.3.3 Procedure

The SLG lessons all took place in the afternoon. The researcher sat at the back of the class making field notes and did not participate in the lesson other by observing action as previously described. Observations of these lessons were recorded in the way described in the methodology chapter and extracts from field notes, which typified elements of each lesson, can be found in appendix 10.3.

10.3.4 Analysis

The purpose of the lesson observations was to gain an insight into how teachers actually interpreted primary science within the classroom and the kinds of knowledge they drew upon to do so. A data trail was kept, starting from the lesson observation transcripts and further details of the initial analysis of all lessons can be found in the methodology chapter.

In order to exemplify themes emerging from the initial analysis a more in depth analysis of the SLG lessons was conducted. These lessons were selected as they were all based on aims and a common content
prescribed by the PSSW (1998) and were taught by CTs across the four schools with varying experience and responsibility.

The transcripts from each of the six selected lessons were described and analysed in relation to the broad themes of curriculum, pedagogy, assessment and teacher subject knowledge. Within these themes, further dimensions emerged in relation to the analysis of teacher and pupil interaction in terms of

- practical activity
- quality and purpose of talk
- the purpose of written tasks.

Code, operational and theory notes were made in much the same way as described in chapter six in order to aid analysis and build theory (Strauss and Corbin 1998).

10.4 RESULTS

A detailed description of six exemplary SLG lessons are presented in this section with a broader view offered in relation to the themes and dimensions in the discussion.

10.4.1 CT4A

CT4A's lesson was based primarily on the first and third learning outcome of 'unit 2D 'grouping and changing materials' she did not
appear to give the class the opportunity to achieve the second learning outcome which stated 'recognise what would make a test fair', yet she seemed to address the one for the next activity on recording observations. CT4A's notion of 'solids and liquids' with her Y2 class were based on ice melting and the significance of warmth, also the concept of evaporation. These ideas were elicited by asking open-ended questions at the beginning of the lesson. She guided the 'discussion' so that the class were ready test out these ideas through an investigation she had already set up. This required the children to use process skills such as prediction, fair testing, measuring. Whilst the lesson largely resembled the suggested PSSW activity, CT4A made some significant modifications, for example she decided not to focus attention on the importance of conducting a fair test as suggested in the unit of work but instead focused on the skill of measurement in order to generate data to record in a table. She also chose to model the investigation process for the whole class rather than allow pupils make their own decisions.

The introduction focused on what pupils knew about the ways in which ice would melt more quickly (transcript 10.3.1). Rather than asking pupils how they might test out their ideas and address the notion of fair testing, she stated,

\[ \textit{you are going to work with the person next to you, you will have three paper towels each...then I will give you the ice cubes, one} \]
lot to keep on the table, one lot to put on the windowsill and one lot put outside (transcript 10.3.1)

She simplified the investigation further by choosing three rather than five places for testing this out, in addition, CT4A decided not to probe their understanding of a concept of a fair test by showing the class a large or small piece of ice as suggested by the PSSW but made the decision to provide each group with three small ice cubes. She spent a considerable time demonstrating how to measure the ice cubes with a ruler and record the results, although the children still found this hard to do. CT4A provided a simple recording sheet with space to record the measurement of the ice cubes after every five rather than fifteen minutes as suggested by PSSW. CT4A devoted a lot of time to the organisational aspects of the lesson, for example getting pupils to work co-operatively in groups of twos or threes and directing them where to put the ice cubes. Because the lesson was conducted on a hot sunny day the ice cubes outside melted after the first five minutes which was unexpected by the CT and made measuring with a ruler problematic.

The investigation was brought to a close once the ice cubes outside had melted and back on the carpet, a conclusion was briefly established from the class that the ice cube outside melted first because it was in the sun. Whilst open questions had been used mostly at the beginning of the lesson to stimulate thinking CT4A tended to use more closed questioning at the end of the investigation,
choosing not to probe the answers in any depth. Pupils then returned to their desks in order to copy down the teacher’s summary about the investigation from the board and into their books (transcript 10.3.1).

CT4A appeared to assess by asking questions to briefly ‘elicit’ children’s ideas at the beginning and then observed groups as they conducted the investigation. She seemed to focus her observations on how they measured the ice cubes. Throughout the lesson it appeared that CT4A generally observed what they did, in order to make summative assessments.

10.4.2 CT1B

CT1B’s lesson covered the learning objectives and largely followed the suggested PSSW activity of planning a fair test of evaporation in unit 5D. CT1B’s notion of liquids and gases was based on factors affecting the rate of evaporation and also the concept of fair testing in order for groups of pupils to plan their own investigation based on their existing understanding of the concept of evaporation. CT1B began by encouraging the whole class to share their ideas about the definition of evaporation in relation to SLG (transcript 10.3.2). CT1B then explained that he wanted the class to ‘come up with an experiment in which we can investigate evaporation’. He then focused the questions to probe their understanding of a fair test in science. He provided a
scenario and invited them to suggest why each aspect was not a fair test (transcript 10.3.2).

Having established their understanding of fair testing, CT1B returned to the concept of evaporation. He reminded them about earlier observations of puddles and the relationship between evaporation and the size of the surface area. This was followed by a short demonstration in which CT1B put ‘TCP’ on some cotton wool and placed it on a table. In another part of the room he sprayed perfume into the air. He then asked pupils to explain how the smell of the ‘TCP’ and perfume reached them. CT1B then repeated the learning objective ‘so you are going to learn to devise a fair test’ (transcript 10.3.2).

Pupils were then asked to work in groups to plan an investigation that would explore evaporation. Their ideas were to be recorded on a large sheet of paper to share with the rest of the class and for using the following week when they would conduct the investigation. CT1B concluded the lesson by getting groups to share their ideas with the rest of the class. Whilst giving each group some brief feedback by interjecting his own thoughts, he also invited other groups to comment.

CT1B closely controlled the lesson by asking for information through questions which appeared pre-planned and carefully structured to scaffold learning or conceptual understanding, seeking answers from
several pupils and using the responses as a basis for them to extend or modify their answers before going on to the next question, thus building in thinking time. Pupils were predominantly engaged in structured class or group discussion. CT1B fed in knowledge to help develop conceptual understanding, before allowing the class to work independently in groups to plan their investigation on paper. They also read as a class an extract about evaporation.

CT1B placed little emphasis on developing skills other than planning, but placed considerable emphasis on reinforcing understanding of evaporation. Practical activity and written work formed a minor part of this lesson whilst a substantial amount of time was spent on teacher/pupil talk. This appeared to allow CT1B opportunities to engage in formative assessment in the way that he asked open questions and responded to, extended or challenged answers given, and in the way he listened to their ideas for investigations at the end. He also collected in the group planning sheets to enable further assessment of the initial ideas before the next lesson (transcript 10.3.2).

10.4.3 CT1C

CT1C's plans were based on unit 4D as part of a revision programme for her Y6 class. The separation activity was conducted in groups with
the teacher providing a work sheet directing the order of materials to be separated. CT1C focused mostly on operational aspects of the activity which made it difficult to know if pupils achieved the learning outcomes suggested by PSSW (1998).

CT1C spent about ten minutes on the introduction, going through all the materials at the front and discussed how they might be used in this activity and what equipment might be used to help separate the materials. She then gave out work sheets, which guided them through the practical activity. The class were organised into mixed ability groups for the duration of the lesson and after explaining what the materials and equipment were for, CT1C carefully controlled the collection of equipment by inviting one person from each table to collect a specific item. She wrote the learning objective up which differed slightly from the PSSW

\[\text{We are trying to separate various materials from a mixture'}\text{ and then told the class ‘it’s now necessary to let you have a go for you to understand it. We have not done so before because some children cannot behave well enough and they ruin things before they start} (\text{transcript 10.3.3}).\]

As some groups started to pour the sand through the sieve into the pot, CT1C reminded them that they were expected to make a dry mixture without sieving anything yet. Once all tables got the dry mixture prepared and there was discussion in groups about what it looked like.
CT1C instructed groups to separate paper clips from the mixture using a magnet and then to use the sieve to separate the stones. Fifteen minutes later CT1C stopped them again and recapped on what they had done so far and the different ways of getting the paper clips out of the stones. CT1C continued to use directional talk to guide the class through the activity stage by stage, despite having a work sheet with instructions.

Pupils were not asked for their ideas or suggestions they were expected to act upon instructions. Although there were many opportunities for pupils to explain what they were doing, CT1C was keen that they went through the process of ‘doing’. Pupils were not encouraged to discuss with each other in a structured way. Neither were they asked to record observations or asked why particular methods of separation were successful. CT1C appeared to assess informally by observing the way the groups worked on the activity, although this appeared more to see that they were doing things ‘correctly’ rather than probing their understanding about what they were doing. Occasionally an open question was asked but more in terms of focusing attention rather than assessing understanding or to challenge thinking (transcript 10.3.3).
10.4.4 CT2B

CT2B's plans were based on unit 4D although he made some significant modifications to the activities and chose to focus on the effect of heat on solids, thus addressing two of three learning objectives. CT2B constructed his own activities within the wider context of making a TV programme on 'solids and liquids' (transcript 10.3.4). He decided to use chocolate, wax and a lava lamp to illustrate the effects of heat and widen pupil experience, rather than ice and water as suggested by PSSW (1998). As a consequence, pupils did not achieve the learning outcomes specified. Much of the lesson focused on the importance of heat for changing a solid to a liquid.

The introduction of the lesson was used to set the context for the television programme (transcript 10.3.4). CT2B used his ICT expertise to set up a microphone, video camera and screen so that the class could watch pupils who volunteered answers to questions for the TV show. CT2B's initial questions were used to 'elicit' children's ideas and current knowledge regarding solids and liquids. For example, which things are solids? What are liquids like? Which things are liquids? How are solids and liquids different? How are solids and liquids the same? In each case he accepts the answers given and recorded them.
After each question he asked for 'volunteer reporters' to summarise these for the TV show. CT2B then demonstrated the effects of heat on chocolate, wax and the lava lamp. After each activity pupils were encouraged to copy down five key questions to answer in their books (transcript 10.3.4). CT2B then checked answers with the whole class before conducting the next demonstration.

After the demonstrations CT2B used another series of pre-planned questions to assess general understanding of solids and liquids (transcript 10.3.4). Whilst pupil responses to open questions were largely descriptive, rather than scientific, CT2B did not challenge or probe responses to any great extent in order to stimulate thinking and further understanding (transcript 10.3.4). Instead CT2B encouraged pupils again to 'volunteer' as reporters so that their explanations for solids and liquids could be recorded for the video. The lesson concluded with the class watching the TV programme they had made during the lesson.

Pupils engaged mostly in oral and written tasks based on their prior knowledge and observations of teacher demonstration, with CT2B using a predominance of teacher talk to direct and organise groups rather than provide teacher explanation or pose open questions. CT2B informally assessed general understanding through questions and
written responses, but these seemed to be summative rather than formative.

10.4.5 CT3B

The lesson was planned from unit 4D using both learning objectives from PSSW along with the suggested activity although CT3B decided to just use coloured water as an example of a liquid and by doing so seemed to reduce pupil's to think about or experience how other liquids might behave. CT3B planned the illustrative practical activity so that the pupils practiced the skill of measuring volume accurately; less emphasis was placed on ensuring that pupils understood why liquids took the form of the container (transcript 10.3.5).

CT3B kept tight control over the lesson and started by briefly recapping what pupils could remember about the difference between solids and liquids from last week's lesson. She engaged the pupils in limited discussion, often accepting the first 'correct' answer given or providing answers if they were unsure. Rather than explain the purpose of the lesson, she drew their attention to the different sized containers and focused attention on the skill of measuring volume. In fact she spent a considerable amount of time demonstrating with the aid of a pupil how to make accurate measurements. Once she was satisfied that the class understood what to do, she stated;
right so we will measure volumes this afternoon, I have a sheet. Measure 100ml of water using the measuring cylinder. You will be pouring this into different shaped containers. Talk to your group about what shape the water will be (transcript 10.3.5).

CT3B carefully controlled the collection of equipment and then allowed the groups to start. Some groups were confused about the amount of water and measured out 1000ml instead. CT3B stopped the class and showed them again. Although organised in groups, pupils mostly worked individually whilst CT3B monitored their progress. Towards the end of the lesson she focused the class on why some of their measurements appeared inaccurate. She concluded the lesson by displaying two statements about solids and liquids and asked 'so what does volume mean?' When one child said 'the amount of water' she corrected this by saying 'or the amount of liquid and that's what we are measuring' (transcript 10.3.5). Throughout the lesson CT3B kept a close control of the activities giving clear and precise explanations of what she expected the pupils to do. Teacher questions were used to acquire information and recall knowledge rather than to probe misconceptions and build on children's ideas. CT3B appeared to informally assess by observing how accurately the children measured volumes and stopped the lesson to correct this (transcript 10.3.5).

10.4.6 CT4B

CT4B planned using the learning objectives and activities largely based on those suggested by PSSW unit 5C. She decided to use
section three as the starting point for this topic in order to elicit pupils' ideas and as such planned 'a series of short activities' as a 'round robin'. Groups of pupils were asked to carry out the tasks with the aim of noting down their observations in preparation for a class discussion at the end of the lesson. CT4B devised a worksheet with a brief instruction for each activity followed by a question to focus observation (transcript 12.8.6). CT4B's notion of gases was based on gases becoming visible when objects are immersed in water, as 'air' bubbles floating to the surface.

CT4B introduced the lesson by explaining the activities and organising pupils into 'science ability' groups. She spent some time explaining the tasks and the questions on the worksheet. For each activity CT4B encouraged the pupils to observe, discuss and share their ideas with each other, emphasising that they had to base their answers on observed evidence (transcript 10.3.6). They were encouraged to use their skills of observation and to a certain extent reasoning along with existing knowledge to construct their understanding of where bubbles came from and that the 'spaces' between particles were not empty.

CT4B had anticipated each group would spend two to three minutes on each activity but it actually took between five and ten minutes to complete each one, which resulted in the class spending most of the
lesson completing the practical tasks leaving only five minutes at the end for discussion. Rather than getting the class to reflect on each activity as originally intended, CT4B concluded the lesson by posing a question to the whole class ‘are these holes scientifically empty?’ followed by ‘how could we prove that?’ in order to get the children to think about and apply their knowledge of SLG to what was in the spaces between the particles of porous rock (transcript 10.3.6).

Because CT4B miscalculated the time required for the practical tasks, she was not able to probe or extend conceptual understanding further in relation to the activities experienced. CT4B appeared to elicit and assess children’s ideas throughout the lesson by general observation but also by specifically observing groups as they conducted the activity, which involved squeezing a sponge under water (transcript 10.3.6).

10.5 DISCUSSION
The purpose of the lesson observations presented in this chapter was to develop an understanding of how teachers reconstruct and implement their conceptions of primary science in practice. The six exemplar lessons based on the PSSW topic of SLG are now discussed in more depth in order to exemplify the broader issues relating to practice.
10.5.1 Curriculum

Whilst the PSSW (1998) seemed to break down the overall SLG concepts into manageable activities there was an assumption that teachers had sufficient subject knowledge of the concepts in order to maintain an overview of the progression of ideas as well as the role of process skills. In fact within the observed SLG lessons, only CT1B seemed able to plan learning experiences that enabled him to make links with the wider picture, He appeared to have a better overview and understanding of the concept of evaporation and as a result built this into the lesson to help support and reinforce pupil understanding in preparation for the investigation they were planning to conduct in the following lesson (transcript 10.3.2). Whilst CT4B had organised her lesson with the aim of eliciting pupils' initial ideas about gases at the beginning of the topic, and demonstrated a secure understanding of the concept, she spent a disproportionate amount of time on unanticipated organisational aspects of the lesson such as ensuring that groups moved from one activity to the next and were recording their observations, rather than probing and assessing pupils' initial understanding (transcript 10.3.5).

Because CT4A, CT1C, CT2B and CT3B appeared unaware of the overall progression of ideas or the knowledge constructed within a lesson, the activities often appeared fragmented and isolated from the
concept. For example although CT3B stated that they would be learning about solids and liquids she organised the PSSW activity so that it focused predominantly on the skill of measuring the volume of a liquid, rather than drawing attention to the way liquids took the shape of the container. Furthermore, rather than provide examples of different liquids, she decided to focus on water. Consequently when she summarised the learning in the lesson, pupils failed to make the connection that the concept of liquids changing shape applied to all liquids and not just water (transcript 10.3.5). In CT2B's lesson a greater emphasis appeared to be on recording observations (largely descriptions) in order to make the TV programme rather than developing an understanding of the concept of the effects of heat on solids and liquids (transcript 10.3.4). CT1C focused on operational aspects of separating materials rather than scientific understanding.

Those who focused on practical activities did not provide pupils with links to the wider concept; instead knowledge constructed within the lesson was often decontextualised. For example by deciding not to show the class a big and a small piece of ice CT4A did not provide an opportunity for them to consider the importance of a fair test. In addition by modeling the investigation for the pupils she reduced the opportunities for pupils to plan or make decisions about the
investigation or to consider the recorded results in light of the original question (transcript 10.3.1).

Those teachers who seemed to further conceptual understanding and therefore appeared to have a good knowledge of SLG modified or merged suggested activities to make a more coherent learning experience. Furthermore, they demonstrated an overview of the concept and were able to link the lesson to the wider picture. They also selected teaching strategies to support pupil understanding. Those who did not seem to further conceptual understanding and therefore appeared insecure in subject knowledge often followed the PSSW (1998) closely and omitted aspects which they thought were inappropriate or too complex for their pupils, for example CT4A and instead focused on generic practical skills. As a consequence, they were not aware that they were closing opportunities for pupils to develop scientific understanding.

10.5.2 Pedagogy

10.5.2.1 Practical activity

The way in which CTs combined subject and pedagogic content knowledge along with beliefs about learning was reflected in the emphasis they placed on constructing practical, oral and written tasks within their lessons. In fact, by far the greatest emphasis was placed
on practical activity; perhaps implying that these teachers felt learning should be experiential.

However, whilst practical activity was a significant feature of these lessons, it was notable that teachers interpreted and organised this in quite different ways. Whilst CT4B instructed the class to carry out a series of activities, and record observations ready to share with the class (transcript 10.3.6), CT2B used a similar organisational strategy but chose to demonstrate each activity whilst pupils observed and wrote down their observations (transcript 10.3.4). In another lesson, CT4A modeled a science investigation for pupils to copy, whilst CT1C directed the Y6 class through a problem solving activity to separate a mixture of dried solids (transcripts 10.3.1, 10.3.3). Thus it was evident that a teachers’ conception of ‘practical work’ encompassed a wide range of activities, a few of which could be classed as investigations instead most were focused observations or largely illustrative tasks and not always conducted by pupils.

On the whole, the practical activities were highly structured and closely controlled by the teachers and in many cases pupils were provided with opportunities to practice and use process skills, but were not given any indication as to why they needed to collect data or evidence in this way and what it might be used for. For example in CT1C’s lesson it
was evident that pupils were overwhelmed by the equipment provided and had little idea of what they were supposed to do with, for example, the filter paper or sieve. As a result CT1C closely directed each stage of the practical activity to ensure that pupils achieved 'success', but in doing so reduced the opportunities for pupils to engage in problem solving (transcript 10.3.3). Whilst this may indicate a lack of confidence or experience of organising science, it may also suggest a narrow understanding of the purpose of practical work or a mistrust of pupils evident by the comment made at the beginning of the lesson. As a consequence some teachers would appear to close down learning opportunities within the activity in order to make it manageable both in terms of control and also in terms of 'knowledge' or 'skill' to be learned, rather than using it to challenge pupils' alternative ideas.

Whilst it was not clear from these lessons as to why teachers chose to construct predominantly practical tasks, other than a belief that pupils learned better this way, it could be argued that an emphasis on practical/investigational work reduced the amount of time to develop conceptual understanding as teachers spent a great deal of time organising and directing groups through the practical process rather than on constructing explanations of what was happening. In fact, the findings would indicate that this reduced the demands on teacher subject knowledge as although time consuming, it was easier to
demonstrate a concept through an illustrative practical activity and let pupils come to their own conclusions about what was happening, rather than structure explanations by probing pupils' ideas and using these to further understanding, an example of 'discovery' getting in the way of learning.

However, the pressure to get through a knowledge-based curriculum could also result in more illustrative practical activity rather than investigations to enable experiential learning to take place within a restricted amount of time. However, it might indicate that teachers had little understanding of the role of practical work or investigations in developing procedural or conceptual understanding. Whatever the reason, it would appear that the outcome was that pupils did not have many opportunities to plan their own investigations or articulate their understanding in light of evidence.

10.5.2.2 Quality and purpose of talk

It could be argued that the quality and type of 'talk' during the SLG lessons was also indicative of how much conceptual understanding was developed during the lesson. In all SLG lessons a significant proportion of time was spent engaged in 'speaking and listening', which included listening and responding to teacher instructions and questions and, in some cases, discussion with peers. For example, it
would appear that one of the reasons why CT1B was able to extend conceptual understanding in his lesson was because he spent a significant part of the time asking pupils questions and encouraging thinking and reasoning in order to develop and articulate procedural and conceptual understanding. In fact teacher/pupil and pupil/pupil discussion was a key feature of this lesson in that there was not only a predominance of open questions to ‘tease’ out pupil ideas and encourage pupil thinking, but the progression of questions also helped to scaffold learning and conceptual understanding in small steps (transcript 10.3.2).

CT4B also showed potential of challenging pupils’ ideas to engage in higher order thinking by asking them to think of questions they would like to explore in relation to the activities they experienced, and at the end of the lesson when she posed open ended questions for discussion (transcript 10.3.6). However it would seem that a severe underestimation of the time required for practical work resulted in little opportunity for the all-important discussion. In fact it could be argued that more learning may have taken place if practical tasks had been reduced or organised in a different way. In contrast, CT2B seemed unable to use questions skillfully enough to draw meaningful information from pupils at the end of the lesson. Although the context was innovative and questions were carefully structured and open to
elicit pupil ideas, responses were not challenged, extended or probed in order to develop understanding, perhaps suggesting a lack of confidence in his subject knowledge. In fact, despite creative use of ICT, it was debatable if the learning outcomes were 'scientific' as pupils were encouraged to 'describe' rather than 'explain' changes from solids to liquids and vice versa (transcript 10.3.4).

In contrast, CT4A, CT1C, CT213 and CT313 used talk mostly to instruct, direct and provide teacher explanation, irrespective of pupil ideas. Consequently pupils had limited opportunities to discuss and develop these or attempt explanations by thinking aloud. For example CT3B focused on 'telling' and 'showing' the pupils what to do at the beginning of the lesson with little opportunity for class discussion, often giving a brief teacher explanation (transcript 10.3.5).

Although the PSSW (1998) and available time and resources may have some impact on teaching approaches it would seem that skilful questioning was a greater influence on learning. Despite working from a prescribed PSSW (1998), the quality of ‘talk’ in science lessons appeared under developed by many teachers possibly because they did not have sufficient knowledge of learners or subject knowledge to know how to develop or extend pupils' understanding of SLG. On the other hand it could signify a concern or pressure to get through the
planned activities before the end of the lesson with limited time to develop understanding, particularly as science would not take place again until the following week.

10.5.2.3 Written tasks

The exemplary lessons reflected a range of purposes for writing and recording. In some of the activities the written elements seemed to be a way of 'transmitting' or consolidating knowledge rather than challenging or extending conceptual understanding. However whilst written tasks did not form a major part of any of the observed SLG lessons, CT2B's SLG lesson perhaps included the greatest amount of written work, although this was separated by three teacher demonstrations of the effects of heat on solids. Pupils were given a framework of questions to record observations in their books after each demonstration. Whilst it would appear to focus observation on the process taking place, the phrasing of the questions encouraged pupils to 'describe' rather than 'explain' what was happening (transcript 10.3.4).

At the end of CT4A's lesson there appeared to be a necessity to consolidate the process by writing up the investigation rather than pupils discussing their findings and reflecting on what they mean. In this sense it would seem that CT4A thought that 'knowledge' should be
transmitted in a factual way and was secondary to the experience, thus once children had ‘done’ and ‘experienced’ the activity, science was over (Foulds et al. 1992). However, it could also indicate the perceived external pressure CT4A felt to provide evidence of practical work (transcript 10.3.1). In CT1B’s lesson where conceptual development was a significant feature, there was notably less emphasis on written work, instead pupils spent the main part of the lesson discussing ideas as a class and were given opportunities towards the end of the lesson to capture the group discussion for planning an investigation on a large piece of paper (transcript 10.3.2).

Whilst there may be a variety of factors affecting the emphasis the teachers placed on written work in relation to conceptual development and practical activity, these exemplary lessons would again suggest that those teachers who were confident with subject and pedagogic content knowledge were better able to structure activities so that there was not the necessity to ‘transmit’ knowledge though written work, but to ‘construct’ understanding through discussion. The need for ‘evidence’ in books might be another reason why some teachers, for example, CT4A and CT2B structured the activities to allow time for writing (transcripts 10.3.1 and 10.3.4).
10.5.3 Assessment/accountability

The extent to which teachers conducted formative assessment during SLG lessons varied and although learning objectives had been shared with pupils at the beginning, they were rarely referred to or reflected upon in terms of pupil learning at the end. In all lessons apart from CT1C, CTs briefly recapped on what the children know or could remember about a particular aspect of SLG. However in CT4A, CT2B, CT3B’s lessons it was doubtful if this really provided evidence that the aim was to elicit pupils’ initial ideas in order to plan for conceptual change as neither of the teachers probed these to any great extent or returned to them at the end of the lesson. CT1B was the only teacher who appeared to place any significance on pupil responses and use these as a basis for structuring further questions throughout the lesson (transcript 10.3.2). However, CT4B who aimed to elicit pupil understanding of ‘gases’ after experiencing the series of activities did not have enough time to do this in the way she had intended (transcript 10.3.6).

Teachers seemed more concerned that pupils had experienced the lesson rather than what they had learned. CT2B appeared to build in assessment opportunities by getting the class to write down answers to a set of questions after each demonstration. Although this provided ‘evidence’ in pupil books it was not clear how this might be used to
support learning, in terms of informing the next lesson or summarising understanding before moving on to the next PSSW learning objective and suggested activity (transcript 10.3.4). Whilst CT1C’s lesson, was aimed at revising the separation of solids there was little evidence of assessment other than through observation and then perhaps for summative purposes only (transcript 10.3.3). In some ways evidence from these lessons may suggest that there was in fact little point in conducting much formative assessment, particularly as teachers were intending to follow the next learning objective and suggested activity in the PSSW (1998) regardless of pupil understanding, or in the case of the Y6 teacher when each lesson was aimed at revision. In this sense teachers appeared to ‘informally’ make summative assessments at the end of the lesson in relation to the learning outcomes specified in the PSSW. CT1B was the only teacher who purposefully used questions to elicit children’s ideas and used these as a basis for the next question he posed (transcript 10.3.2). External factors such as the pressure to perform well in tests and to assess pupil’s achievements influenced the way science activities were constructed and on balance, there appeared to be greater evidence of summative rather than formative assessment taking place (transcript 10.3.1).
10.5.4 Teacher development and subject knowledge

Most of the SLG lessons observed would suggest individual factors such as a teacher's experience and expertise along with external influences such as performativity and accountability influenced the way primary science was re-enacted in the classroom. It would seem that teachers possibly compromised by largely constructing learning experiences to include illustrative practical work accompanied by questioning or discussion. How effective such a teaching strategy might be seemed dependant on subject and pedagogic content knowledge along with knowledge of appropriate curriculum materials.

Those teachers with sound subject knowledge were able to make discussion purposeful and challenge existing ideas and misconceptions in relation to more scientific and often abstract concepts. Those with restricted knowledge resorted to descriptions rather than support pupils to develop explanations. For example in CT4A's lesson it was evident that she did not probe conceptual understanding of melting to any depth at the end of the lesson and whilst CT2B, an NQT created opportunities within the lesson to probe pupils' ideas and understanding, he appeared satisfied with descriptions of the melting process rather than explanations (transcripts 10.3.1, 10.3.4). CT3B on the other hand, relied on illustrative practical work to develop the generic skill of measuring in
isolation (transcript 10.3.5). It could be argued that weak or fragmented subject knowledge meant that teachers had little appreciation of the overall concept they were developing and therefore the appropriate teaching strategies to do this resulting in a greater emphasis on ‘doing’ rather than ‘understanding’. CT1B on the other hand, appeared to be knowledgeable about teaching strategies and was in a position to enable conceptual development and scaffold thinking around the concept of evaporation to enable pupils to plan an investigation (transcript 10.3.2).

Despite a limited amount of time for science, most exemplary lessons contained a substantial element of practical activity indicating a strong belief that pupils learned best through hands-on experience. However it would appear that activities organised in this way possibly resulted in less conceptual understanding, as teachers focused pupils more on organisational issues and generic skills and some failed to see the relationship between testing out initial ideas and developing conceptual understanding within a practical context. However, where teachers had a greater understanding of what they wanted pupils to learn conceptually within a limited time period, practical activity was reduced in order to facilitate class discussion and reasoning.
Evidence from the observed lessons would indicate that whilst a reliance on PSSW (1998) ensured that a range of science was taught consistently, and provided a series of related activities in order to illustrate concepts, teachers may benefit from an overall understanding of the concepts, the big ideas in science, along with a knowledge of appropriate teaching strategies and curriculum materials in order to plan appropriate activities to further conceptual understanding.

10.6 CONCLUSION
The exemplary lessons have illustrated how CTs interpreted and translated centralised guidance materials (PSSW 1998) into science lessons. To a certain extent the learning experiences constructed by the teachers in these lessons have illustrated how tensions are reflected in practice. For example the emphasis the teachers placed on practical, oral and written tasks in science lessons influenced the extent to which they were able to develop skills, knowledge and conceptual understanding. This in turn has highlighted the importance of science subject knowledge and pedagogic content knowledge in order for teachers to successfully identify and extend pupils' conceptual understanding. Contextual factors such as timetabling and resourcing science in relation to other curriculum priorities as well as external pressures to be accountable and perform well in SATs also had a bearing on the way science was organised in the classroom and
in some respects seemed to act as a barrier for conceptual understanding.

The observed lessons showed that the prescribed science curriculum along with the preoccupation with performativity and accountability might have forced some CTs to place greater emphasis on pupils producing written evidence of science rather than developing conceptual understanding. It also encouraged CTs to focus on summative rather than formative assessment in science lessons. The findings might also indicate that there could be a link between a teacher's confidence with subject knowledge and the extent to which they probe pupil understanding though skilful questioning. As a result the quality of teacher/pupil discourse varied as did the extent to which learning in order to reinforce conceptual understanding. In this sense the quality of pedagogic practice would appear to be driven by teacher expertise as well as by the national, measurable outcomes agenda stemming from educational policy rather than by a knowledge and subsequent development of learning reflecting individual pupil needs.

Whilst the purpose of this chapter has been to examine how teacher knowledge, beliefs and expertise are played out in practice, the teacher’s observed SLG lessons reflect their own unique understanding and interpretations of teaching and learning of primary
science and the way in which they use the PSSW (1998) to assist
them in that process. It cannot be known whether the practices
reported here represent typical practice although the SLG lessons
reported here were all typical of the other observed lessons taught by
these teachers (see appendix 10.2). Equally it cannot be known what
influence the presence of the researcher had on the way lessons were
orchestrated. Furthermore, it has to be acknowledged that the
researchers' observation and interpretation of events will reflect her
knowledge and experience of science education. However a particular
suggestion arising from the findings was that the ongoing debate about
the need to develop teacher subject and pedagogic content knowledge
in relation to the balance of knowledge and science process skills was
an important factor in the way the exemplary SLG lessons were
orchestrated. The next chapter will draw together the broad themes of
the data chapters and consider the findings in relation to the original
aims of the research.
CHAPTER ELEVEN: CONCLUSION

11.1 INTRODUCTION

This chapter will draw together the main themes emerging from the local, regional and national perspectives and influences on primary science and in doing so, consider the limitations of the study as well as its implications. A policy trajectory (Bowe et al. 1992) provided a useful framework for structuring the research questions outlined below and for conceptualising primary science within the changing policy to practice context. This has facilitated the 'deconstruction' of primary science by critically analysing the emergence and development of the related themes of curriculum, pedagogy, assessment/accountability, teacher development and subject knowledge from the perspectives of various stakeholders across the policy to practice context.

1. To what extent is primary science a product of conflicting influences, views and perspectives?

2. In what ways have recent policy, policy text and discourse contributed to the debate and development of the primary science curriculum?
3. How do schools, (HTs, SCs and CTs) interpret, reconstruct and implement primary science in practice?

In order to address questions one and two, evidence was collected from elite figures in science education to outline the influence on policy context. Question three was addressed by gathering data from a regional survey which provided an overview of the context of practice and case studies from four contrasting primary schools which illuminated the way teachers interpreted and reconstructed policy in practice.

11.2 KEY FINDINGS FROM LITERATURE

Within the context of policy influence images of primary science emerging from educational and political constructs of curriculum, pedagogy and assessment have changed over time and have evolved from theories of learning and have been influenced by political ideology and discourse closely driven by the notion of market forces in education. In this sense educational issues have been incorporated into wider political debate and used to construct political agenda (Moore and Ozga 1991). It was also apparent that constructivist learning theory had a powerful influence on conceptions of learning science in terms of acknowledging the importance of children’s existing ideas (Ausubel 1968) and the role of teachers in helping pupils to
construct and reconstruct knowledge (Vygotsky 1962, 1978) which
inevitably had implications for teaching.

Evidence from the literature review would suggest that a succession of
science policy initiatives stemming from ERA (DES1988a) have
ultimately shaped current conceptions of primary science curriculum,
pedagogy and assessment in the classroom. Despite the ambitious
proposals of the NCSWP for science, the NC policy texts (DES1989b,
1991b, 1995 and DfEE1999) defined science as a body of knowledge
and reflected only a narrow interpretation of science education
focusing on content knowledge and enquiry (Black 1995). Furthermore,
it largely ignored the wider educational debate on developing
conceptual change in science and the wealth of research evidence
which provided a substantial knowledge base of children as learners in
science (Driver 1983, SPACE research reports 1990-1998). In fact
Millar and Osborne (1998) had claimed that such a centralised
curriculum and assessment system stifled growth and innovation in
science. The increasing focus on assessment and standards in
science reflects the shift from ‘professional to ‘neo-liberal corporate’
accountability, (Ranson 2003).

Longitudinal studies of curriculum implementation and evaluations of
curriculum practice depicted teachers as ‘mediators’ of policy as they
interpret and reconstruct it in their classrooms (Galton 1999, Alexander 1992 and Pollard et al. 1994). In this sense the re-enactment of primary science in classrooms becomes a combination of interpreted policy text mixed with teacher beliefs, knowledge and expertise. These evaluation studies have also documented the tensions experienced by teachers who may be required to teach science in a manner which is often at odds with belief and experience, demanding unfamiliar ‘knowledge’ relating to different expectations of learning.

Within the context of practice the literature provided evidence that teachers needed to draw on a range of science subject and pedagogic content knowledge in order to teach primary science. Evaluation studies funded by DES and NCC provided evidence that teachers had little understanding of how to organise science investigations (Foulds et al. 1992) and that science content knowledge was lacking (Wragg et al. 1989, Bennett et al. 1992, Bennett and Carré 1993, Summers and Kruger 1994, Russell et al. 1995). Further funded studies revealed that primary school teachers also needed support in conducting formative assessment in science (TGAT 1988, Black 1995, Harlen and Qualter 1991). Despite this evidence base there seemed to be little indication that the government adequately addressed all the issues identified in these studies but placed a greater emphasis on science subject knowledge through GEST funded courses (1994 onwards), and
primary ITE programmes (DfEE 1998). In addition greater attention and funding was given to summative rather than formative assessment in science. For example, whilst some exemplary materials were provided to support teacher’s formative assessment in science (SEAC 1990) the majority of money was invested in developing science SATs (Black 1995).

In addition, recent literature has provided evidence that teachers still do not have a clear understanding of the role and purpose of investigations (Watson et al. 1998, Gott and Duggan 2002) Thus although the government had the evidence that teachers needed greater support to implement the PSNC effectively, they chose to focus on ‘objectivist’ conceptions of learning and assessing which Richardson (1997) argued do not sit easily with ‘constructivist’ pedagogies.

Thus it could be argued that without sufficient support and minimal professional development teachers would not be in a position to effectively implement the PSNC within their classrooms (Russell et al. 1995). As a consequence, it is not surprising that there has been little change in teacher’s understanding of primary science and therefore in practice in the classroom.
11.3 LIMITATIONS OF THE STUDY

This study has developed an understanding of the way conceptions of primary science have evolved over time and from competing perspectives. It examined how schools reconstructed and implemented primary science in practice and has shown how this is influenced by external policy and also by participant's beliefs and understanding of particular ideologies and expertise.

Whilst every attempt was made to ensure credibility to the research from the design of the study to the analysis of findings, it has to be acknowledged that the research can only ever be a reinterpretation of events and actions in relation to the reconstruction of primary science through discourse, policy and practice and in this sense can never fully represent reality. Having said this, every effort was made to address issues of reliability, internal and external validity and avoid unwarranted generalisability.

In order to consider issues of trustworthiness and transferability the research adopted a mixed-methods approach and attempted to use both quantitative and qualitative data in order to validate findings (Strauss and Corbin 1998). The use of elite interviews provided a perspective on the policy to practice context whilst the use of a
regional survey facilitated the collection of a large amount of data on primary science across two LEAs. In addition, the use of case study enabled the development of vivid descriptions of practice framed within diverse contexts. Within the case studies questions of internal and external validity were considered, by reporting a number of analytical stories in an attempt to capture the realities of participants' beliefs and practice and their understanding of external policy. In order to do this the study did not just rely on CT's professed views about primary science but also conducted in-depth observations and analysis of their science lessons in order to consider to what extent views were related to practice. Furthermore, in order to validate the views and practices of CTs. This study also considered the extent to which such views were compatible with SCs and HTs and pupils within the case study schools concerned. In addition it provided a regional survey that identified key aspects that were validated by CT views. It drew on national perspectives by figures involved in influencing and writing policy. Thus by using mixed methods this study went beyond an examination of teachers' views of the impact of policy on their practice.

For research to be considered 'trustworthy' it must be credible to the participants. This was achieved through the negotiation of audio-taped interview transcripts not only in terms of what was said but also whether it reflected agreed views by sending the transcripts to
participants for conformation of the statements made. Whilst this may
not be a test of validity (Silverman 2001) it does provide the
opportunity for participants to verify accounts of practice. The extent to
which participant beliefs and practices were affected by the presence
of the researcher cannot be fully determined. Indeed it would not be
possible to completely negate the influence of the researcher on this
study (Strauss and Corbin 1998). It could be argued that pre-arranged
visits to observe science lessons encouraged teachers to modify
normal practice in relation to what they thought the researcher wanted
to see. However observations of three lessons per teacher revealed
surprising consistency in practice in methods and strategies used by
the teacher concerned, strengthening the view that teaching
approaches deviated little from usual practice. Practice which might
have differed from what was anticipated would have been reflected in
pupil reactions.

The sampling of case study schools was theoretical in order to
generate a maximum diversity of contexts and participants, yet remain
manageable within the given time period for study. Furthermore, the
sampling of observed lessons again provided a sub-sample of science
across the four schools. Thus the teachers observed not only worked
in contrasting contexts in terms of urban, rural and mixed localities but
also in terms of recognised national indicators of perforomativity, and
socio economic status. In addition to this, personal histories and experiences provided further diversity and variation. In this sense the researcher does not aim to make generalisations from the case study data but instead provide 'thick descriptions' for others to assess against their own contexts (Strauss and Corbin 1998). Whilst there has been a wealth of data upon which to draw it has been possible to reduce bias and anecdotalism (Silverman 2001) through a systematic and in-depth analysis of data using constant comparison and including negative cases in order to construct emerging themes and relate to broader ones.

As a result, this study does not claim that the dynamic picture of primary science education presented in this research represents reality in all English primary schools, as each school will respond to government policy in its own unique way. Even within the timescale of this study, education policy has moved forward focusing on different aspects of education and leaving schools to adapt practice accordingly. Additionally, the participants in the research will have gained in experience and may have modified their views and practices in response to the daily challenges they face. Likewise it cannot be assumed that views expressed by participants reflected typical practice at the time of the study. Whilst the elite interviews may have helped to map out the wider policy context and explored related themes, the
regional survey provided a broader picture of practice at a particular point in time, enabling continued and deeper analysis of the constructs of primary science and as a basis for an in-depth exploration of interpretation and enactment of primary science at grassroots level through case studies, thus strengthening credibility to the research.

11.4 THE POLICY TO PRACTICE CONTEXT

The following discussion explores the findings from this study in light of the original research questions and then considers its wider implications.

This research would support the claim that primary science is a product of conflicting influences and in particular 'constructivist' approaches to developing conceptual understanding as espoused by the academic community and a political agenda which views 'learning' through 'outcomes' and accountability in terms of raising standards (Ball 1999, Ranson 2003). Furthermore, it would appear that Ball's (1999) assertion that a succession of education policy initiatives have failed to address the fundamental issue of teaching and learning because they focus on performativity and standards, is evident within the findings of this research.
Although primary science has widened in its definition to include physical and material sciences (PSNC DfEE1999), and is taught regularly across all schools in England, there is still an absence of a broader perspective that takes account of the nature and history of science and its social and technological implications which may contribute to a greater public understanding of science (DES 1987, Millar and Osborne 1998, Fensham 1999). Arguably this has led to a narrower knowledge-driven and therefore a possibly ‘impoverished’ conception of the primary science curriculum evidenced by a combination of science policy text and national testing which has focused primary schools on science content rather than enquiry and on summative rather than formative assessment (Black 1995, Harlen 2004).

Thus it could be argued that accountability and high stakes testing in science (Ranson 2003, Black 1995) would seem to have restricted creativity and innovation in science teaching also evidenced by elite and HT interview findings in this study which indicated that some teachers were adopting mostly ‘transmissive’ modes of teaching. This was particularly apparent in two of the case study schools where science SATs results were poor; as it forced a focus on ‘knowledge’ likely to be tested, rather than that which related to progression of ideas and understanding, or was of interest to pupils. Findings from
lesson observations in these schools indicated that only those teachers who were very experienced practitioners and who really had an interest in science education found ways to work creatively within the policy framework. It could be argued that the greater status given to 'knowledge' elements of the primary science curriculum has not only focused attention and debate on teacher's subject knowledge but has possibly reduced opportunities in the classroom for pupils to develop the higher level skills necessary for a global economy (Ball 1999).

Warwick and Stephenson (2002) have suggested that much of the science educational research assumes a 'constructivist' approach to learning as an effective way to develop conceptual understanding (Driver 1983, Driver et al. 1994, Harlen 1993, Watt and Simon 1999, Newton and Newton 2000, Asoko 2002). From this assertion it would seem that good science teaching is based on the claim that learners bring a range of alternative ideas to the classroom and that because these ideas are often unscientific they must be taken into account if teaching for conceptual change is to be effective. Whilst these initial ideas can and should be challenged, guided and extended by the teacher, it is the learner who must actively engage with the learning process in order for new knowledge and ideas to be constructed. It is also necessary for the teacher to listen and diagnose ways in which activities and new ideas are being interpreted by the learner (Driver
Thus the elicitation of existing ideas is important because it allows pupils to 'clarify and articulate their own understanding' and at the same time enables teachers to use formative assessment to decide on the most appropriate teaching and learning strategies (Osborne 1996 p.63). It has been argued that because only the learner actively engages in the construction of knowledge, a range of pedagogic practices which take into account what is to be learned, together with the most appropriate learning style and the resources available, may be appropriate to develop conceptual understanding in science (Driver et al. 1994, Osborne 1996, Windschitl 2002).

Whilst the regional survey revealed teachers held a mixture of 'constructivist' and 'transmissionist' views about learning, with perhaps greater preference for the former (evidenced in the statements selected to represent their views of teaching science); findings from the CT interviews and observed SLG lessons suggested that although some CTs employed a range of strategies, the acknowledgement of pupils' existing ideas was not always evident and where they were, they were not used to diagnose or develop understanding. For example it was common for CTs to quickly recap on what had been covered in the previous science lesson before outlining the aim of the current lesson. Where content had been the focus of the lesson,
mostly in Y6, then factual knowledge was transmitted, and evidence from some pupils, would suggest that although they could list science topics covered they could remember little about them.

Where teachers were able to move pupils forward in their learning there was evidence of a consistent pedagogy that used teacher/pupil ‘talk’ and open-ended questions to elicit children’s existing ideas in order to challenge or extend conceptual understanding (Driver 1983). For example, in CT1B's lesson the discussion at the beginning challenged and extended pupils' understanding of evaporation to plan an investigation for the next lesson. In addition, in some of the SLG lessons CTs appeared to focus more on generic process skills, which had been a key feature of practical science prior to and at the introduction of NC (APU 1988, Foulds et al. 1992). Thus whilst pupils might be 'doing' science there was very little evaluation of evidence in relation to prior knowledge and ideas and consequently little evidence that they were learning anything scientific (Foulds et al. 1992, Goldsworthy in Sherrington 1998).

One conclusion that could be drawn from these findings is that teachers need a greater understanding of science subject knowledge necessary for teaching and of pedagogic content knowledge and curriculum materials in order to support pupil learning. Teaching
strategies will be dependent on the science concepts to be learned and the existing ideas and experiences of pupils (Driver et al. 1994, Osborne 1996). For example some science topics will not have been encountered simply because of their abstract nature and as a consequence pupils are unlikely to have formed alternative ideas. Other topics whose language is also shared with every day meanings for example 'force', 'energy', 'materials' need more attention to misconceptions based on every day language. Teachers therefore need to be aware of the different kinds of science content and that not all 'science' is observable, or may be at odds with every day experience. Each kind of scientific knowledge needs a different kind of teaching approach as prior ideas are either strongly embedded or non existent Osborne (1996). Furthermore Osborne (1996) cited Harré’s three realms of experience as a basis for supporting pupil learning in science and argued that early science should attempt to build on pupils’ experiences of observable macroscopic phenomena in realm one and then introduce children to the descriptive language of the scientific and theoretical frameworks of realms two and three. In this way they learn how to generalise from their experiences to unobservable phenomena and appreciate that these share universal properties (Osborne 1996 p.73).
HT, SC and CT interviews provided evidence that schools were very keen to link science to everyday life contexts, arguably it was these everyday concepts which might be harder to develop and change to scientific ones. Therefore it would seem that it was even more vital for teachers to understand the importance of developing conceptual understanding based on pupils' existing ideas rather than following prescribed learning objectives from the PSSW. Furthermore, an understanding and knowledge of how new technology for example, digital cameras and data logging equipment might support the development of alternative approaches to teaching for conceptual change would also be beneficial (Harlen 1999) as only one teacher consistently made effective use of ICT in his observed lessons.

The findings from observed lessons would suggest there was a need to clarify the role of scientific investigation and provide a clear definition of what is to be taught in scientific enquiry (Gott and Duggan 2002). Early evaluations of investigations have suggested teachers focused mostly on generic process skills (Foulds et al. 1992) and more recent research has provided evidence that the majority of investigations are strongly associated with fair testing with little evidence that pupils engage in other kinds of investigations (Goldsworthy in Sherrington 1998). Gott and Duggan (1996, 2002) have argued that the purpose of science investigation is to develop both conceptual and procedural
understanding in science. Findings from the regional survey indicated that investigative science was perceived as the highest priority for CPD in schools and evidence from the SLG lessons and other observed lessons in this study suggested that teachers employed a broad range of illustrative practical work much of which teachers referred to as 'investigations'. Furthermore in their interviews these SCs and CTs strongly equated 'hands on' experience and practical activity with learning although they also felt obliged to transmit knowledge and prepare pupils for tests.

Harlen (1993) provided a view of investigation as a means to test out pupils' existing ideas in a systematic and scientific way in order to challenge and develop their existing ideas based on evidence collected. Moreover Goldsworthy in Sherrington (1998) and Warwick and Stephenson (2002) felt that pupils need to be actively involved in the decision making in investigations and should have greater opportunity to investigate their own ideas (Harlen 1993). However evidence from the observed SLG lessons would suggest that it was the teacher with support from the PSSW (1998) who determined what was to be investigated and how this would be orchestrated. For example in CT4A's SLG lesson the teacher made the majority of decisions although the pupils carried out the 'investigation'. Much of the evidence from SLG and other observed lessons suggested pupils
engaged in illustrative practical work, strongly directed by the teacher. For example in CT2C's SLG lesson the Y6 teacher spent a great deal of time organising pupils into groups, giving out equipment and explaining how to use it. It could be argued that the predetermined learning objectives and outcomes of PSSW (1998) discouraged CTs from focusing on pupils' existing ideas and using these as a basis for planning investigations. Where investigations were suggested in the PSSW (1998) it was evident that CTs made most of the decisions.

Thus an implication from the findings might be that teachers would benefit from a deeper understanding of the purpose of investigations and to question the extent to which they are able to really develop conceptual understanding, given the amount of time needed to organise investigations with large classes, and whether all scientific concepts are observable and are best experienced through 'investigation'. Instead, it could be argued that more effective conceptual understanding might be achieved through the use of a wide range of innovative strategies to facilitate conceptual change, and which actively encourages the learner to become more mentally (and not necessarily physically) active in the learning process. For example, CTs could take a more central role in promoting learning by 'talking ideas in to existence' (Ogborn et al. 1996, Asoko 2002) or exploring the potential of 'assisted performance' as a framework for conceptual
development (Watt 2002). In addition the use of concept cartoons (Keogh and Naylor 1999), which present differing views about a particular scientific concept, may provide opportunities for focused discussion as well as support pupils to develop their own investigation based on prior discussion.

This would also help to dispel the myth that meaningful learning in science has to be experiential and just because some concepts cannot be taught in this way, then they are inappropriate for primary aged pupils (Sharp and Grace 2004). In addition, it would encourage teachers to consider alternative ways of structuring science lessons and whether the ‘three-part hour lesson for literacy and numeracy was actually an appropriate format for science.

This study would suggest top down educational reform has not acknowledged or addressed the real constraints schools worked within in order to deliver and assess the PSNC effectively (Black 1993, 1995). For example, findings from the elite and HT interviews indicated that science had not been funded in the same way as literacy or numeracy, and as such money for science resources was not readily available. In addition greater time devoted to literacy and numeracy (Boyle and Bragg 2005) had resulted in less time for science. Whilst findings from the regional survey claimed that ‘time’ was the biggest barrier to
teaching, evidence from elite interviews suggested there had never been any clear indication from government ministers as to how much time should be allocated to primary science, although some were doubtful that much could be achieved in science in an hour. In fact in the elite interviews, E3 had stated that in the initial stages of planning the NC a working party had been commissioned to look at the manageability of the core subjects in the primary NC although no report was ever published. CT interviews suggested that as a result of having to devote more time to teaching literacy and numeracy there was insufficient time to ensure pupils had grasped scientific concepts other than in a superficial way.

Furthermore, evidence from CT interviews and observed lessons indicated that the organisation of science into hourly slots, once a week by most of the CTs indicated there was little opportunity to reflect on pupils' prior knowledge in relation to the outcomes of the lesson, and if left to the next lesson the following week, would then be somewhat meaningless. For example the length of time taken for pupils to experience a series of practical activities in one SLG lesson meant there was no time at the end for reflection and discussion. Only one CT in the study had organised science on consecutive afternoons over a week in order to allow continuity and progression of ideas. Findings from the HT interviews implied that one of the inevitable
consequences of covering a large amount of science content as well as maintaining a good position in SATs published 'league' tables had been cramming for science SATs tests particularly in KS2.

Thus Ranson’s (2003) claim that accountability distorts practice was evidenced by all elites in this study who stated that much of current practice in primary science was driven by assessment with Y6 now viewed as a revision year. Despite a wealth of evidence from APU (1988) and TGAT (1988) that the NC should be based on formative assessment, Black (1995) argued the government had never put money into developing formative assessment in the same way funding was made available to develop SATs. Early evaluation of the NC (DES 1989a, 1991a), suggested that a clear link should be made between assessment and learning. However the indication from elite interviews was that teachers still struggled with formative assessment and argued it should have a greater emphasis as it was a crucial way to encourage teachers to work closer with pupils and their existing ideas in science. However findings from SC and CT interviews suggest there was a far greater emphasis and understanding of summative forms of assessment in science. For example one SC explained that teachers in her school found it hard to make formative assessments in science investigations and preferred to use ‘mini’ SATs papers, whilst another CT said he often conducted ‘mini tests and quizzes’ at the end
of the lesson. Furthermore, the emphasis on summative assessment was also evident in some of the pupil interviews across all four schools with indications that the ability to do well in exams and in secondary school was strongly equated learning science at school.

Whilst an in-depth appreciation of the changing complexities of science curriculum, pedagogy and assessment might be familiar debate within science academic community, it cannot be assumed that this formed part of every day conversation and was therefore common knowledge within the case study primary schools. The findings from this study would support the argument that competing debates about science educational research had rarely reached or impacted on science teaching in the classroom, in the way elites and the science education community would like to think (Richardson 1998). Furthermore, Richardson (1997) argued that although much of the discourse about constructivist pedagogy takes place in academia and in the education community, it is then presented to teachers as unproblematic and as an effective way to teach. Teachers are often provided with the curriculum content and resources and expected to know how to use them, much in the same way some teachers think that by providing the activity and letting pupils experience it, somehow they will learn something in science (Foulds et al. 1992).
Thus, it is within the school context that frequent and specific guidance on pedagogic practice is needed not only for teachers to critically reflect on the evidence base (or lack of it) on which their science teaching is based (Ratcliffe et al. 2005) but also to consider ways of teaching and assessment that will develop a wider understanding of conceptual change and inspire and motivate pupils in primary science. Fisher (2002) found that because the NLS failed to provide explicit pedagogical information to teachers on how to use the Literacy Strategy there were a variety of interpretations with some teachers adhering to prescribed structure, forsaking the quality of instruction whilst others abandoned part of the structure as they deemed appropriate. Thus Fisher (2002) concluded that teachers needed more than a list of standard objectives to follow, they needed suggestions for implementing change on a pedagogic level. In a similar way the lack of explicit pedagogical guidance and support for developing conceptual understanding and understanding the role of investigational science has led to teachers interpreting the PSNC in a variety of ways many of which it could be argued from this study reflect a poor grasp of science subject and pedagogical content knowledge and in some cases closely resembled practice prior to NC (DES1989), (Watt and Simon 1999).

Smith and Hardman et al. (2003) have also suggested that despite the NLS and various support materials teachers were still using
transmissive pedagogies rather than engaging in interactive teaching and argued that the Literacy Strategy had failed to address deeper issues around teaching and learning. The evidence from this study would appear to suggest that despite the prescriptive nature of the PSSW, and a notable shift to whole class teaching of primary science since the introduction of the PSNC (ASE 1988, Alexander et al. 1992), interactive teaching was not a prominent feature of many of the observed science lessons.

Findings from the case studies, the regional questionnaire and the elite interviews have shown that the power of informal science policy texts such as PSSW (1998) to define the science curriculum and provide teachers with support cannot be underestimated and have unintentionally been a very effective way of influencing practice. However elites also implied that science policy texts such as the PSNC (DfEE1999) and the PSSW (1998) reflected partial interpretations of research (SPACE 1990-1998) and were a reaction to a need to establish a common curriculum in science for primary schools whilst implementing a national assessment system. Thus, a conclusion that could be drawn from the evidence in this study was that existing practice and expertise in schools and the kind of infrastructure that might be needed to effectively support such implementation needs to be given greater consideration by government ministers, science policy
writers, CPD providers and HTs. For example, the NCSWP’s initial plans for a science NC (DES 1987, Black 1995) failed to take into account that most primary teachers did not have a background knowledge of science concepts (elite interviews) and were unlikely to have experienced scientific investigations first hand (Jenkins 1995, Osborne and Simon 1996) Moreover primary teachers’ lack of experience and knowledge of formative assessment was overlooked by those science educationalists who produced the first science SATS. Despite such gaps between science policy initiatives and practice, teachers and schools are often expected to implement new waves of policy within a short space of time (more recently NNLS 1998, 1999) resulting in the adoption of ‘coping’ strategies in order to manage new ideas and ways of working whilst still trying to maintain existing practice (Harlen and Qualter 1991).

As science policy texts (PSNC, DES1989, 1991, 1995, DfEE1999) have focused on subject knowledge in the curriculum, science educationalists (Harlen 1978, Russell et al. 1992, Feasey in Aubrey 1994, Holroyd and Harlen 1996) have turned their attention to the depth of science subject knowledge required by teachers to deliver the PSNC. Already evidence from this study and indeed from research findings (Watt and Simon 1999, Newton and Newton 2000, Asoko 2002) would suggest that there was still a need to address teacher
subject, pedagogic content knowledge and knowledge of curriculum materials (Shulman 1986, Grossman et al. 1989, Turner-Bissett 1999) in order for teachers to elicit, challenge and extend children’s ideas in science and to understand the role of formative assessment (Bennett and Carré 1993, Carré in Desforges 1995 Harlen 2004). However elites varied in their views about the range and depth of science subject knowledge needed by CTs. For example some elites felt that primary teachers tried to go into too much detail whilst E2 felt strongly that if teachers were expected to teach science then they should be given the opportunity to have a sound understanding and update knowledge and skills. Furthermore, evidence from the regional survey did not suggest that a lack of science subject knowledge was a barrier to teaching science and was a low priority for CPD. Windschitl (2002) argued, teachers needed to experience constructivist pedagogies themselves before they could appreciate implications for subject knowledge and classroom practice, otherwise it is easy for those CTs with only a partial understanding of the importance of pupils’ existing ideas to mistakenly equate pupils engaging in a science ‘activity’ with ‘learning’ and as a result confuse discovery learning and constructivism (Windschitl 2002). Teachers need to be aware they are still learners and play a key role in pupil learning and therefore need the skills not only to develop a sound subject and pedagogic
knowledge but also to critically reflect on and evaluate science research in relation to current practice.

In this study elites suggested that a substantial number of professional development days had been largely devoted to the implementation of NNLS and as a result the opportunities for CPD for SCs and CTs had declined at the same time professional development and funding for NNLS had increased. In fact E5 thought that few CTs would have had support in teaching science since ITE and even then such experience may have been limited and of dubious quality with poor role models of science teaching to observe in school. In one LEA E5 stated there had been no science CPD for seven years.

It could be argued that SCs were more likely to have had science CPD, and were best placed to support science teaching (West 1996), however evidence from SC interviews indicated that they did not know what science teaching strategies were being used in their schools. Furthermore, findings from HT and SC interviews implied that SCs were unlikely to provide professional development by modeling good practice throughout the school as there was a greater pressure by HTs for them to focus on monitoring and assessment, particularly where schools had poor science SATs results. Whilst two SCs had been released from teaching to observe colleagues' science lessons, it
would seem that only one had a clear idea of what to look for in lessons, although she was doubtful as to whether she would have time to provide any feedback to the teachers concerned. Thus, it could be argued that in all four cases study schools there were tensions regarding the role of the SC. On the one hand there was a wish to provide support for teaching and learning; yet on the other there was pressure to monitor teaching with a view to raising standards by supporting teachers in assessment (Webb and Vulliamy 1995, Edwards 1993). Furthermore, it would seem evident that the amount of status and power SCs held within their schools would also seem to determine the manner in which they were able to influence practice. Where SCs had been in the post for a considerable length of time there was some indication of their influence in schools but where SCs were newly appointed, and thus inexperienced teachers, there appeared little understanding of the role. For example, SC3 a NQT appeared to do little more other than audit science resources. Thus it would seem that education reform resulting in shifting definitions of accountability (Ranson 2003) and a content driven curriculum has restricted the widespread development of constructivist pedagogies in science, by providing teachers with few opportunities to update science skills and knowledge.

11.5 IMPLICATIONS
So what can be learned about primary science from this study and what are the implications for science community, educational policy makers, CPD providers and primary schools?

The implications are that top-down linear models of science educational reform which have centred on issues of accountability and performativity (Ball 1999, Ranson 2003), and which ignored the findings of funded research do not have lasting effects and have not led to any long term change or a significant improvement in practice in the classroom. As a result, the impact of policy reforms on science in primary schools, together with a depleted provision of CPD, seems to have resulted in a greater focus on performance against NC levels of attainment and end of KS1&2 SATs and a somewhat fragmented view of science. Consequently, teachers are reluctant to deviate from a pedagogy which they feel will achieve high scores in SATs and there is an indication that they may result to ‘subversive’ practices to achieve this. Moreover, a dearth in science CPD would suggest that few CTs have comprehensive knowledge of the role of science investigations and a range of approaches to teaching for conceptual change and assessing science.

Nevertheless, perhaps there are still lessons to be learned from past evaluations of primary science. It could be argued from the evidence in
this study that if science educational policy had taken into account the existing practice in primary science, together with evidence from large scale funded reports and research (TGAT 1988, Wragg et al. 1989, Foulds et al. 1992, SPACE 1990-1998 and Russell et al. 1995) and used this as a basis for science curriculum reform, there would have been greater evidence of change in practice. A recent evaluation of the NLS (Smith and Hardman et al. 2003) has also concluded that ignoring existing practice in primary schools and imposing change is ineffectual. Therefore the implication would be that science education policy needs to be 'bottom up' if it is to change practice and in the sense that it needs to acknowledge and respond to the evidence from funded research.

Thus, an implication from this study might be that a comprehensive and flexible system of CPD needs to be in place so that SCs and CTs can access a knowledge base in science and update skills. However, there needs to be a recognition that just as pupils are reluctant to let go of their existing ideas and adopt new ones, teachers too, are reluctant to abandon familiar teaching practices. In fact, if they are presented with new ideas which are too different from their existing ones it will take more than short term, intermittent CPD to convince teachers to change them. Instead old practices are likely to predominate, whilst teachers adopt a new approach to use only when necessary for
example, if inspection is imminent. As HT3 explained ‘we do what is necessary to get by, but hold on to what we really believe’. Thus perhaps serious thought needs to be given to how teachers might ‘unlearn’ old practice and embed new ideas emerging from science education research, particularly in light of the rapid succession of government initiatives.

One way this can be done is by providing ‘evidence informed’ CPD (Ratcliffe et al. 2005) that provides teachers with access to teaching materials which are based on research findings in science education. Furthermore, Ratcliffe et al. (2005) argued there needed to be a ‘professional culture’ in schools which was receptive to the exploration of research and changes to practice. CPD needs to be structured so that it works, with and involves CTs to critically reflect on innovative teaching strategies and materials in light of their current practice rather than presenting new pedagogies as unproblematic. If teachers continue to make changes to practice in isolation then this could lead to a very chaotic and confusing learning experience for pupils, and a science curriculum and pedagogy pulling in different directions based on individual beliefs (Richardson 1998). Resistance to change only happens when others enforce it (Richardson 1998, 2003, Smith and Hardman et al. 2003). In this way, teachers are not ‘recycling old practice’ but are subjecting existing practice to new ideas and current
research on teaching and learning within their school context with opportunities to feed back into the wider arena of policy text production and influence. This has yet to be addressed by creating a robust channel of communication between the science education community and civil servants who represent government bodies such as the DES, QCA and TTA, CPD providers and schools.

However this study has also shown that there is a danger for teachers to just conceptualise primary science within the narrow constraints of the PSNC and it is easy to forget that conceptions of science should include knowledge of the ‘stories’ of science, how we have developed and refined scientific explanations over time (Millar and Osborne 1998). Thus a knowledge and understanding of the cultural and historical dimension is important, along with an appreciation of the technological applications of science, past and present (DES 1987, Black 1995). Intrinsically linked to this is a knowledge and understanding of the moral and ethical implications of scientific and technological innovations, which point to the increasing importance of reliable ‘evidence’ to develop a public understanding of science (Millar and Osborne 1998, Fensham 1999) that not only recognises scientific areas of study and the importance of scientific enquiry but locates it in a wider social and global dimension. Although perhaps over ambitious
at the time, the conception of science offered by the NCSWP nearly twenty years ago is still worth contemplating.

*Pupils should be encouraged to study the practical applications of science and the way they are changing the nature of our society. They should be encouraged to explore some of the moral dilemmas that scientific discoveries can cause... have the opportunity to explore the social and historical contexts of scientific discoveries. Through this they can begin to appreciate the tentative nature of scientific truth, the powerful process of refuting theories and the way in which scientific models become refined in the light of new evidence. Most important of all they will be reminded of the excitement of discovery that has been the continual inspiration of all scientists* (NCSWP Interim Report DES 1987, pp.16-17).

Ball (1999) has argued that global issues of performativity now increasingly influence the context of policy. If this is so, then the evidence from this research would suggest there is a need for a broader definition of primary science which takes seriously the need for the public understanding and supports the development of higher skills for a global economy and where knowledge and understanding of social, technological and cultural implications of science are paramount.
However evidence from this study would indicate that we can expect little to change within the context of practice unless a serious consideration is given to how science can be freed from a system of assessment and accountability. Regardless of how much science related CPD might support the development of teaching and learning, primary schools are unable to become innovative and creative within the confines of the science curriculum for fear of dropping down the league tables. A recent evaluation of PNS (Alexander 2004) would suggest that teachers are reluctant to risk their position in 'league tables' by engaging in innovative and creative practice and this may explain why teachers are reluctant to take risks in science. Thus attention needs to be given to the value and purpose of accountability as this is clearly having a negative impact on learning science. Ranson (2003) has argued that accountability is now much more than an aspect of the system but has become the system. The continued focus of national testing on a narrow aspect of the science curriculum has in the past, and will continue in the future, to restrict the development and enjoyment of primary science unless issues of accountability are addressed.
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APPENDICES

4.1 ELITE INTERVIEW SCHEDULE

Introductory questions

1. In what ways do you think views and definitions of primary science education have changed over the last twenty five years?
2. Why in your opinion is there a need for primary aged children to have a basic understanding of science?
3. How would you view the suggestion that science, as a core subject in the Primary National Curriculum, has had relatively less attention than literacy and numeracy?
4. What is your view of the current training requirements for primary science for new entrants to the profession and for experienced staff?

Context of influence

1. What do you think have been major catalysts for change in (primary) science education policy over the last twenty five years?
2. Why do you think these policy changes came about and which groups in particular, influenced them?
3. In your opinion do you think there have been tensions and contradictions within changing policy?

Context of policy text production

1. Given the introduction and subsequent modifications to the national science curriculum over the last fifteen years, what is your opinion of the present primary science national curriculum?
2. What would you say have been the influences upon the development of this current version?
3. What is your view of the QCA science scheme of work?
4. What would you say have been the influences on the development of this document?
Context of practice

1. How in your opinion, have primary school teachers responded to changes in the primary science curriculum over the last twenty five years?
2. What has been the impact of the current national assessment policy on the science curriculum in primary schools?
3. What would you say are the successes in terms of primary science practice over the last twenty five years?
4. What are the challenges (for the future)?
5.1 SURVEY QUESTIONNAIRE

Primary Science Questionnaire

SECTION ONE

Teaching and learning science

Q1 How many classes are there in your school?

<table>
<thead>
<tr>
<th>Less than 7</th>
<th>Between 7 and 14</th>
<th>More than 14</th>
</tr>
</thead>
</table>

Q2 Does your school use the QCA scheme of work for science?

<table>
<thead>
<tr>
<th>Not at all</th>
<th>Some of it</th>
<th>All of it</th>
</tr>
</thead>
</table>

Q3 The following reasons have been given for the assessment of children's science. For each statement, tick one box to show your level of agreement.

<table>
<thead>
<tr>
<th>Reason</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compare performance with other schools</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To monitor standards from year to year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To compare the performance of children in a class</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>To help match teaching materials to children’s needs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To diagnose children’s strengths and weaknesses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To guide future teaching</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q4 Which of the following most closely represents what children in your class do in science lessons. Tick all the methods, which you have used in the last term.
Classifying and grouping activities
past SATs papers, mini tests
Labeling diagrams
concept mapping to find out children’s ideas
Children to draw what they mean or understand
Children using spreadsheets and/or databases
Carrying out surveys to gather data
Using discussion, reporting back to the class
Copying from board or work sheets
Children writing up the whole science investigation

Q5 For each of the following statements about science below, tick one box to indicate how much you agree.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupils learn by being challenged to make links between scientific concepts in order to develop understanding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils learn by being taught existing facts and scientific concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils should be encouraged to use scientific vocabulary whenever possible</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It does not matter if scientific vocabulary is not used, it’s the understanding that’s important</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils misconceptions need to be recognised, made explicit and worked on</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils misconceptions are a result of failure to grasp what is being taught</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A teacher should let pupils plan and carry out their own investigations and draw their own conclusions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils planning and testing out their own ideas is of little importance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A teacher’s main role is to help pupils reject, shape and extend ideas and to justify why they think the way they do.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A teacher should plan pupils practical investigations to prevent aimless activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q6  Rank the following statements with 1 showing the most frequent way you organise science

<table>
<thead>
<tr>
<th>Statement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>One group of children at a time doing practical science</td>
<td></td>
</tr>
<tr>
<td>Children rotating around a 'circus' of related science activities within one lesson</td>
<td></td>
</tr>
<tr>
<td>Whole class involved in the same practical task</td>
<td></td>
</tr>
<tr>
<td>Whole class involved in related practical tasks</td>
<td></td>
</tr>
<tr>
<td>Teacher demonstrating a practical activity to the class</td>
<td></td>
</tr>
</tbody>
</table>

SECTION TWO
Your role as Science Co-ordinator

Q7 How many years teaching experience had you had at the start of this school year?

<table>
<thead>
<tr>
<th>Years</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5 years</td>
<td></td>
</tr>
<tr>
<td>6-10 years</td>
<td></td>
</tr>
<tr>
<td>More than 10 years</td>
<td></td>
</tr>
</tbody>
</table>

Q8 If you passed A levels before your teacher training course, please write in the subjects you passed

........................................................................................................................................

Q9 How long have you been a science co-ordinator in this school?

<table>
<thead>
<tr>
<th>Years</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than a year</td>
<td></td>
</tr>
<tr>
<td>1-5 years</td>
<td></td>
</tr>
<tr>
<td>5-10 years</td>
<td></td>
</tr>
<tr>
<td>Over 10 years</td>
<td></td>
</tr>
</tbody>
</table>

Q10 Other than science co-ordinator, please specify other posts of responsibility you currently hold

........................................................................................................................................

........................................................................................................................................

402
Q11 Tick one box to show how much you agree with each of the following statements.

As science Co-ordinator I need to

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create a climate of positive attitudes to science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensure curriculum coverage and progression for all pupils in science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide guidance on teaching and learning methods in science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyse and interpret national, local and school data and inspection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>evidence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ensure effective development of literacy, numeracy and IT skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>through science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set expectations, establish targets and evaluate pupil progress and</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>achievement in science</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audit training needs of staff for science</td>
<td></td>
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</tr>
<tr>
<td>Evaluate science teaching in school and use this to inform effective</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>practice and areas of improvement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q12 Rank the following in terms of your own needs for professional development, with 1 representing your greatest need.

<table>
<thead>
<tr>
<th>Professional Development Area</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing leadership and management skills</td>
<td></td>
</tr>
<tr>
<td>Science subject knowledge</td>
<td></td>
</tr>
<tr>
<td>Developing a wider range of teaching strategies</td>
<td></td>
</tr>
<tr>
<td>Monitoring, assessing science and setting targets</td>
<td></td>
</tr>
</tbody>
</table>

Q13 Tick three of the following which you feel are barriers to teaching science in your school

<table>
<thead>
<tr>
<th>Barrier</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of time</td>
<td>Lack of staff confidence in science</td>
</tr>
<tr>
<td>Too much paper work</td>
<td>Class size</td>
</tr>
<tr>
<td>Other curriculum pressures</td>
<td>Insufficient science resources</td>
</tr>
</tbody>
</table>
Q14 Tick three of the following.

In our school we would mostly benefit from courses in

<table>
<thead>
<tr>
<th>Science in the early years</th>
<th>ICT and science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessing science</td>
<td>Literacy through science</td>
</tr>
<tr>
<td>Developing investigational skills</td>
<td>Numeracy through science</td>
</tr>
<tr>
<td>Developing subject knowledge</td>
<td>Children recording science</td>
</tr>
</tbody>
</table>
6.1 HEAD TEACHER INTERVIEW SCHEDULE

Learning science
1. What is the link between the science learned at school and children’s everyday lives?
2. What do you consider to be the value of children learning science in the primary school?
3. What would you expect a pupil to know, understand and be able to do by the time they leave this school?

Teaching science
1. What are the main issues for the teaching of science in primary schools today?
2. What criteria would you use to describe a good science teacher in a primary school?
3. How would you describe the way science is taught in this school?

Management of science
1. What are your expectations of your science co-ordinator?
2. Has this expectation changed over time?

Significant changes
1. Since becoming head teacher what significant changes have you noticed in the teaching of primary science, if any?
2. Would you like to see any more changes to the science curriculum at Key Stages one and two?

Issues and influences
1. What do you think the future for science education is in the primary school?
2. What will be the main influences on the science curriculum?
7.1 SCIENCE CO-ORDINATOR INTERVIEW SCHEDULE

Learning science
1. What do you consider to be the value of children learning science in the primary school?
2. What would you expect a pupil to know, understand and be able to do by the time they leave this school?

Teaching science
1. What are the main issues for the teaching of science in primary schools today?
2. What criteria would you use to describe a good science teacher in a primary school?
3. How would you describe the way science is taught in this school?

Planning and assessment
1. How do you plan for science?
2. How is science assessed in your school?
3. What is the purpose of science SATS/teacher assessment?

Managing science
1. Briefly outline why you became a science co-ordinator.
2. What is your role as science co-ordinator?

Significant changes
1. In your view, how has science teaching changed over the last few years?
2. Would you like to see any more changes to the science curriculum at Key Stages one and two?
8.1 CLASS TEACHER INTERVIEW SCHEDULE

Learning science
1. What do you consider to be the value of children learning science in the primary school?
2. What is the link between the science learned at school and children's everyday lives?
3. What would you expect a pupil to know, understand and be able to do by the time they leave this school?

Teaching science
1. How would you describe the way you teach science?
2. How much time do you spend on science?
3. What are your main concerns about teaching science?
4. What criteria would you use to describe a good science teacher in a primary school?

Planning and assessment
1. How do you plan for science?
2. How do you assess science?
3. What is the purpose of SATs assessment?

Significant changes
1. In your view how has science changed over the last few years?
2. Would you like to see any more changes to the science curriculum at Key Stages one and two?
9.1 PUPIL INTERVIEW SCHEDULE

Interest and motivation in science lessons
1. What do you enjoy learning about in school?
2. What kinds of science do you like doing at school?
3. What kinds of science don't you like doing at school?
4. Where else can you learn science?

Defining science
1. What kinds of science have you done at school?
2. What is a science experiment?
3. How would you describe what science is?
4. How is science different from the other subjects?
5. Can anyone do science?

Purpose of science
1. Why should we learn science at school?
2. Why is science important for everyone?
3. What does a scientist do?
4. Can you think of any famous scientists?
### 10.1 OBSERVATION SCHEDULE

<table>
<thead>
<tr>
<th>Focus</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Links with previous work</td>
<td></td>
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<tr>
<td>Relevant and related to everyday life</td>
<td></td>
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<tr>
<td>Suitable resources and equipment</td>
<td></td>
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<tr>
<td>Teacher understanding of science covered</td>
<td></td>
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<tr>
<td>Teacher use of Scientific vocabulary</td>
<td></td>
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<tr>
<td>Teacher involving children in planning</td>
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<tr>
<td>Science process skills</td>
<td></td>
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<tr>
<td>Understanding of fair testing and recording</td>
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<tr>
<td>Use of productive questions</td>
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<tr>
<td>Use of open-ended questions</td>
<td></td>
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<tr>
<td>Scientific responses to questions valued</td>
<td></td>
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<tr>
<td>Children's misconceptions noticed</td>
<td></td>
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<tr>
<td>Children's use of equipment</td>
<td></td>
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<tr>
<td>Children's use of scientific vocabulary</td>
<td></td>
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<tr>
<td>Method of recording science</td>
<td></td>
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<tr>
<td>Evaluate interpret and share findings</td>
<td></td>
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<tr>
<td>Evidence of progress made in scientific knowledge and skills</td>
<td></td>
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<tr>
<td>Achievement of learning outcomes</td>
<td></td>
</tr>
<tr>
<td>Children's interest in science stimulated (scientific attitude)</td>
<td></td>
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</tbody>
</table>
### 10.2 OVERVIEW OF OBSERVED LESSONS

<table>
<thead>
<tr>
<th>SCHOOL 1</th>
<th>SCHOOL 2</th>
<th>SCHOOL 3</th>
<th>SCHOOL 4</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>YR Electricity *</td>
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<td>YR Pets *</td>
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<td></td>
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<td></td>
<td>YR Materials *</td>
</tr>
<tr>
<td>Y1 Ourselves/sight</td>
<td>Y2 Electricity</td>
<td>Y1/2 Growing seeds</td>
<td>Y1/2 Solids/liquids</td>
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<tr>
<td>Y1 Growing plants</td>
<td>Y2 Investigation</td>
<td>Y1/2 Sound vibrations</td>
<td>ice</td>
</tr>
<tr>
<td>Y1 Forces</td>
<td>Y2 Habitats</td>
<td>Y1/2 magnets</td>
<td>Y1/2 Living things/animals</td>
</tr>
<tr>
<td>Y1/2 Growing seeds</td>
<td>Y3 Forces *</td>
<td>Y3/4 Rocks</td>
<td>Y1/2 Waterproof</td>
</tr>
<tr>
<td>Y1/2 Sound vibrations</td>
<td>Y3 Rocks and investigation*</td>
<td>Y3/4 Magnets</td>
<td></td>
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<tr>
<td>Y1/2 magnets</td>
<td>Y3 Plants *</td>
<td>Y3/4 Liquids</td>
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<tr>
<td>Y2 Electricity</td>
<td>Y4 Food chains</td>
<td>Y4/5 Sound</td>
<td></td>
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<tr>
<td>Y4 Thermal conductors*</td>
<td>Y4 Melting</td>
<td>Y4/5 Solids/liquids</td>
<td></td>
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<tr>
<td>Y4 Moving and growing*</td>
<td>Y4 Classification/animals</td>
<td>Y4/5 Forces</td>
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<tr>
<td>Y5 Sound</td>
<td>Y5 Keeping healthy</td>
<td></td>
<td></td>
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<tr>
<td>Y5 Solids, liquids</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Y6 Separating materials</td>
<td>Y6 Magnets (revision)</td>
<td>Y5/6 Habitats *</td>
<td></td>
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<tr>
<td>Y6 Sound the ear (revision)</td>
<td>Y6 Earth in space (revision)</td>
<td>Y5/6 Magnets, (revision) *</td>
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<tr>
<td></td>
<td></td>
<td>Y5/6 Sound insulation *</td>
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</tbody>
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*Science co-ordinator's lessons

Bold denotes SLG lessons reported in chapter ten
10.3 TRANSCRIPTS FROM LESSON OBSERVATIONS

Transcript 10.3.1 CT4A

T I'll explain what we are going to do. Where in the room or near the room would ice melt more quickly?
Ch Near the window because the sun shines through it.
T That's a good idea, where else?
Ch Radiator.
T That would be brilliant in winter, why?
Ch It would melt.
T Yes more quickly where else?
Ch In our hands.
T Yes good idea because we know from before that our hands are warm, but we won't do that today because we need to write, any other suggestions?
Ch On the table.
T Which will melt first?
Ch Window sill.
T Why? Yes because it's hotter. We could try one outside couldn't we and hope it doesn't blow away.
T You're going to work with the person next to you, you will have three paper towels each, put your names on them. Then I will give you ice cubes, one lot keep on the table one lot put on the windowsill and one lot put outside, I will have to think about how to keep it still.

(SLG CT4A)

Transcript 10.3.2 CT1B

T ...remember really focus on evaporation now. I want you to come up with an experiment where we can investigate evaporation. When we do an experiment or investigation we need to make it a fair test. What do I mean by a fair test in science?
Ch Everything has to be the same except what you are testing.
Good, concise answer. Let's say I had a jug of water and how ell if I left them on a window sill, on the patio and in the corner of the room or cupboard, I want to investigate that. So I get a cup and fill it with vinegar and then another cup and fill it with milk and then I've run out of cups so I get a test tube of water. How many things have I changed, have I kept anything the same? I said you have to keep every thing the same except what you are testing, so what am I testing?

Ch Different liquids?

Ch Where will the best place will be?

T Good, not testing different liquids so do not use different liquids so I would use the same liquid e.g. water. So will that be a fair test now? Why not?

Ch Because different amounts of water.

T Yes we have got to have the same amount.

Ch It's got to be in the same place.

T No because that's what I am testing.

Ch Cups.

T Yes, so make all the same containers with the same amount of liquid so now if it evaporates at different rates what does that tell me?

Ch That the different areas make them evaporate.

T If containers were different it could be that. We were talking about puddles earlier in the week, why is it that water in the puddle would evaporate quicker than water in a test tube? It's all to do with how water is arranged, the surface area. The larger the surface area the quicker the water will evaporate. So you're going to learn to devise a fair test (he writes this learning objective on a small white board) we're going to do a test of evaporation. (He then gets out a small bottle of air freshener and sprays it in the air) Listen why is it X can smell it and Y can't, this is revision really.

Ch Because (X) is further away.

T Watch what happens, how it comes out (he sprays it again) it comes out in a big cloud, does it move around like that?, no it disperses (he
gets a bottle of TCP, he lets some smell from the bottle) How do we smell things, when I take the lid off I can smell it, why can I smell it?

Ch Because smell goes up our nose into the brain.

T So there is a thing floating around called a smell? How does it get to my nose when it’s a liquid in a bottle?

Ch Is it air?

Ch It’s giving off gas vapours.

T It evaporates. If I left the lid off and came back in a few weeks it would gradually go down, it would evaporate. It’s a very light gas which goes round the room and that’s what you can smell and that’s how we smell. What causes things to evaporate?

Ch Heat.

Ch Wind.

Ch Air.

Ch How thin it is.

T Well done, how spread out it is. If we spread out a bucket of water over the playground it would evaporate quicker than if the water was left in the bucket. How many help with washing day what’s best for drying washing?

Ch Windy, dry.

T Yes a breezy day

Sharing ideas for investigations at the end of the lesson

Ch A bowl of water, soak three paper towels keep for three weeks and check each day.

T You could do a drawing or take a photo but the important thing is to check at regular intervals.

Ch We would put one out in the playground, one on a hot radiator and one in a corner of the room.

T Think about the paper towels, the way they are positioned, the way they are hung up might have an effect on evaporation.

(SLG CT1B)
Transcript 10.3.3 CT1C

T How are we going to separate the rest? What clue am I giving you with the water? Last week you looked at this in the books.

Ch If we mix water in the pot.

T Will the funnel be any use like that? No. So come and get filter paper

(CT1C also gives out the water and funnel to the children to take back to their tables)

T what is in the pot apart from the water? (She is trying to get them to think about the salt). How are you going to get the sand and sawdust out? How will you get the sawdust off the side of the paper?

Ch Wait for it to dry?

T How will you get the salt out of the water?

Ch You can't.

Ch Stir it?

Ch Filter it?

Ch Sieve it?

There are several suggestions but they are not what the teacher wants.

T It's hot in here.

Ch Evaporate it until the salt evaporates, I think.

T Yes pour off some salt water into a tray and put it on the windowsill for a week to watch.

(SLG CT1C)

Transcript 10.3.4 CT2B

T We are going to do science and I've got a friend who needs some help. He is recording a little video and its being shown tonight on TV. First of all we have a camera and so I need some roving reporters to stand in front of the camera to report. First question, what are solids like? Who thinks they could stand up in front of the camera and say?

Ch They are really hard.

Ch They are not like liquids because you cannot pour solids.
Ch Solids don't change shape.
Ch Some solids can put but all liquids can.
T So lots of ideas some are hard, some can pour or change shape...right who wants a go?

A pupil volunteers
T Right X here is the microphone, ok, off you go.
Ch Some solids you can pour and some you cannot, some are very small like flour. We are testing solids.

Teacher demonstrations during the middle of the lesson

T Now its time to look at the chocolate. We have looked at solids and liquids; can they be both, yes or no?

Hands go up for either answer. The teacher holds up the chocolate
T Is this a solid or a liquid?
Ch Solid.
T If I put it in here and heat it up.
Ch It will melt and change into a liquid.

CT2B puts the chocolate in a pan and heats it on an electric ring
T You can start to smell the chocolate melting, see it melting on the bottom...ok who can describe what it was like before?
Ch It was a solid.
T What did it look like?
Ch Hard, brown.
T Is it bigger than before?
Ch It's a different shape.
T How has it changed?
Ch The hard chunks have melted.
T Is it bigger or smaller?
Ch Its about the same.
T Right sit down with your book and pencil. You have ten minutes to do this, all you do is follow the questions on the board, put the answers in sentences please.

The children write down their answers to the following questions
1. Describe what the material was like before the change
2. Describe what the material was like after the change
3. Describe how the change was made
4. Can the change be reversed?
5. Draw a ‘before’ and ‘after’ picture

The teacher briefly checks their answers and then continues the same process when demonstrating a night light burning and switching on a lava lamp

Discussion at the end of the lesson

T Now we need to finish Eric's TV programme for him. Can things be a solid and liquid? So what do you need to do to change a solid into a liquid?
Ch If the liquid is hard, like chocolate then you have to put it in a pan to heat it
T how do you change a liquid into a solid?
Ch To change a liquid into a solid you have to freeze it.
T You don't always have to freeze it but make it cold. Now I want someone to report on the chocolate, who can be very clear what happened in our chocolate experiment? Try and use some of these important scientific words like liquids and solids.
Ch We got some chocolate and put it in a pan in a small oven and then we let it sizzle and we said it was all sloppy.
T Next one, the reporter has to tell us what happened with the lava lamp.
Ch First you push the button and leave it for a while to heat up and then it breaks into little ones bobbing up to the surface.
T Now someone to report on candies.
Ch First we lit the wick with a match and left it to burn for a while then we blew it out and some of the wax had melted.

(SLG CT2B)
Transcript 10.3.5 CT3B

T What did we do on Monday?
Ch Sorted materials.
T They were all solids in the first group they were all conductors and then you decided that two names for the groups were liquids or solids. How did you know which were solids?
Ch Pour them.
T Yes pour them, but what about rice or flour?
Ch We had a magnifying glass to look at them.
T What did you see?
Ch Cubes.
T Cubes could be a word, but they were grains.

Demonstration of measuring

T Which one is holding more? Is one bigger than the other? Can I have your ideas?
Ch The cylinder has more.
T Let's check which is the cylinder?
Ch That one.
T How do you measure who has more we've got a new word, yes were measuring in ...?
No answer
T We are measuring the volume this is the amount of liquid lets see who can read it?
A child is chosen to come up and read it
T Tell us why you read from kneeling down?
Ch You might get the wrong number.
T Yes your eyes need to be at the same level. Who can read the cylinder?
Another child is chosen
Ch 100 millimeters.
T Yes but we use millilitres for liquids. Look can you see the curve (she draws it on the board), then there's the scale on the side, where should I measure, at the top of the curve or the bottom?

Ch In the middle.

T Yes I should be measuring in the middle. So we will measure volume this afternoon. I have a sheet. Measure 100ml of liquid using the measuring cylinder you will be pouring into different shaped containers. Talk to your group about what shape the water will be?

Ch It's going to be the same shape as the container.

T So put it in and let it drain, why?

No answer

T So we get a true measure. Then draw what you see, measure the final result.

Discussion at the end of the lesson

T So if you have got 100mls in your first container to start with is there any need to re-measure for the next container? Wherever you put the liquid it takes the shape of the container. Did the volume change?

Ch Yes.

Ch No.

T Did it change? If it's measured really accurately, would it stay 100mls if I poured it?

Most of the class say no

T Let me see these sheets, you've all recorded 100ml, well, is that what you saw? What might have spoiled it?

Ch There might have been a little bit of water from the last person.

T Yes may be it did not drain.

Ch People using really small one from the cube, but in the small cylinder it was almost overflowing.

T I have talked to the boys about the fact that the scale is not so spread out on the cube so it cannot be as accurate. On the cylinder there are lots of small marks, you can get more accurate measuring
using a narrow cylinder. Could I measure fairy liquid instead of water?

Ch Yes.

T What would happen if I poured one to one?

Ch It's thicker.

T Yes its sticks to the side. What does volume mean?

Ch The amount of water.

T Or the amount of liquid and that's what we are measuring. Look at this definition of liquid (she sticks a large card sheet on the board with a written definition) Liquids flow they have a fixed volume they take the shape of their container.

(SLG CT3B)

Transcript 10.3.6 CT4B

CT4B provides a work sheet for each pupil containing the following activities and questions

Task 1 — What is the same?

Look closely at the materials on the table. Discuss what is the same about them and make a list

Task 2 — Saturated soil

What do you notice happens to the soil when the water is gently poured onto it? When and why do you think bubbles appeared?

Task 3- Lego bricks in water

What can be seen under some of the Lego bricks?

Task 4- squeezing a sponge under water

What can be seen in the water when the sponge is squeezed? Where do you think they have come from?

Task 5 — Are the containers 'scientifically' empty?
Look at the equipment on the table. How can it be used to show what is in the bottles and cups? Discuss your ideas BEFORE trying them out

**Task 6- Scientists always record what they discover**
Think about the tests you have carried out in Task 3
Record what you did by drawing a diagram and labeling it
Write a short paragraph to explain if your test was successful or not

Once all the activities have been experienced CT10 gets the class to pack up and then has a short time to talk with them. CT10 shows them a porous rock

**The whole class is gathered together for the last five minutes of the lesson**

T  Are these ‘holes’ in the rock ‘scientifically’ empty?
Ch  Yes.
T  How could we prove that?
Ch  We could put water in to see if any bits come out.
Ch  Bubbles.
T  So you think there is something in the holes?

(SLG CT4B)