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THE RELATIONSHIP BETWEEN TEACHERS' UNDERSTANDING OF THE
NATURE OF SCIENCE AND THEIR SCIENCE PRACTICE: FOUR CASE STUDIES
FROM AN URBAN PRIMARY SCHOOL

by

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ABSTRACT
This thesis explores the relationship between a teacher's understanding of the nature of science and her practice. The idea that teachers' understanding of the nature of science is a powerful determinant of their actions in the classroom has a strong intuitive appeal. Research over the last forty years has provided inconclusive results; however, there is a clear implication within recent central policy on teacher education that such knowledge should translate directly into practice. This has led to the identification within teacher training materials of specific expectations regarding understanding of the nature of science (DfEE 1998a).

This thesis presents four case studies of the science teaching of primary teachers. The studies derive from data collected over the course of a year and analyse evidence of the teachers' ideas, both tacit and espoused, about the nature of science against their practice in the classroom. The research employed a methodology unlike other studies in the field. Primary teachers frequently lack experience of reflection on the philosophy of science, and their actions may convey tacit ideas different from those they espouse. In order to ensure that a mechanism existed to facilitate elicitation of the teachers' philosophical understanding, to render possible the identification of any tacit ideas and to enable the inherent dialectical nature of theory and action within practice to be accommodated, the participating teachers were encouraged to engage in action research on their own practice. Data generated by this
personal inquiry then served as evidence for the main research questions. This methodology yields results which are closely derived from the everyday reality of teachers' practice.

The findings indicate that teachers' understanding of the nature of science does not translate directly into predictable approaches to science teaching. Teachers' understanding of the nature of science is seen to be mediated strongly by their pedagogical beliefs and aims and it is these beliefs that assume overriding importance in the derivation of science practice. These findings extend previous research results. They suggest that the development of science practice will need to have regard for factors other than mere extension of knowledge, raising implications for both preservice and inservice teacher education.
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AUTHOR'S DECLARATION

At no time during the registration for the Degree of Doctor of Philosophy has the author been registered for any other University award.

The research was dependent for its data upon the collaborative relationship developed with the participating school and the four teachers involved, but the study itself is the author's own work.

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Signed: ............................................................... 24/11/00
Date: .................................................................
Chapter 1

INTRODUCTION

In the opening chapter of her latest handbook for teachers of primary science, Harlen (2000) makes the following statement:

Although few primary teachers would regard themselves as scientists, we all have a view of what science is and, like it or not, we convey this through our teaching.
(p.6, added emphasis)

This thesis explores the relationship between a teacher’s understanding of the nature of science and her science practice. The nature of science is taken to mean the philosophical issues concerning its methodology and epistemology, covering aspects such as the status and validity of scientific knowledge, the nature of reliable methods for obtaining that knowledge and where science ends and not-science begins (see appendix 1). The first two aspects are of most interest to this study: that is, the thesis concerns itself most with teachers’ understanding of how scientists go about their work and of the nature of scientific knowledge. The study also explores teachers’ science practice. This is taken not only to mean the overt actions of the teacher when engaging her children in science, but also the ideas, beliefs and values which inform that action. The focus of the study is a group of four primary (4 - 11 years) teachers in an urban English school.

The research questions

The research was driven by the following question: Is there a relationship between a teacher’s understanding of the nature of science and the character of her science practice? This question was important to the researcher because of his association with science education and the training of teachers. If a relationship exists, then its nature may be crucial to his work. Chapter 2 highlights the ambiguity of research results in this field. The first question was therefore extended by a further question: If a relationship exists, what is its nature? The researcher entered the inquiry assuming that teachers’ practice is influenced by their understanding of the nature of science.
In order to explore these overriding questions, the research had to reach an understanding of:

*The teachers’ ideas about the nature of science;*

*The character of their science practice.*

The researcher adopted a complex methodology to explore these issues. It is important to acknowledge the argument that the methodology itself contains an implicit assumption that some kind of link between ideas about the nature of science and practice exists. This is discussed in Chapter 6; the time span of the research and the justification for the methodology are discussed at length in Chapters 2 and 3.

**Background**

This is not a new field. There has long been interest in both primary and secondary teachers’ understanding of the nature of science and in whether this understanding has any kind of determining effect on the kind of teaching they carry out (see Chapter 2). Many workers have claimed that a teacher’s understanding of the philosophy of science will determine her practice, providing an implicit, and often explicit, message that this is an area that must be addressed in order to improve science practice in schools. The researcher has a particular interest in this message; he is a university lecturer in science education, involved in the initial training of primary teachers. Furthermore, he is responsible for an element of the university’s undergraduate programme which helps prospective science subject leaders develop an understanding of the nature of science, a programme which he initiated on the very grounds which underpin the message. He explicitly accepted the premise that philosophical understanding would affect practice and he assumed that such understanding would enable students to achieve greater clarity in their teaching and improve their performance.

The improvement of performance is an area replete with problematics, for, like the ‘nature’ of science itself, science education consists of many elements, the relative importance of which is often determined by the perspective from which they are viewed and the purpose of the teaching. However, there is general consensus that, broadly speaking,
science consists of conceptual (the accepted framework of ideas in science) and procedural (methodologies, scientific attitudes and understanding of the need for validity and reliability) elements. These elements are reflected in the structure of the National Curriculum for England and Wales (DES/WO 1989, DfE/WO 1995, DfEE 1999, WO1999) and addressed within the requirements for Initial Teacher Training (DfEE 1998). Student and serving teachers alike need to be aware of these elements in order to achieve Qualified Teacher Status and to fulfil their obligations within school. Recent debate (Millar and Osborne 1998) has questioned the aim and purpose of the National Curriculum for science and the proper balance of the elements within it; how these questions relate to the findings of the study will be addressed in Chapter 7. However, the existing curriculum structure includes the development of children’s procedural understanding as one of only four areas of attainment (Attainment Target 1), and the area is weighted as fifty percent in importance at Key Stage One (5-7 years). There is thus a strong implication within the current curriculum structure that teachers need to have an understanding of methodological and epistemological issues in order to understand what they need to teach.

The research reviewed in Chapter 2 indicates that teachers’ (both primary and secondary) understanding of these issues has historically been weak. This work has been international, with contributions from the UK and Europe, North and South America, Australasia and Africa. Similar patterns appear on the global scale, although Ruggieri et al (1993) argue for some degree of cultural separation. Although strong critiques of curricular structures, for example those of Duschl (1985) and Hodson (1988), have prompted significant changes to science curricula in schools, recent research indicates that the situation regarding teachers’ understanding is changing only slowly. This is also despite Shulman’s (1986) seminal argument that teachers’ pedagogical knowledge in a subject should include a ‘syntactical’ element as a matter of importance. Such an element, Shulman argued, would enable teachers to understand the structure and rules of the subject, allowing them to understand what is important within it, how knowledge is generated and why there should be any faith placed in that knowledge.
If it is reasonable to ask whether a teachers' understanding of the nature of science determines the structure and content of her science practice, then it is also reasonable to ask whether particular aspects might have more significant effects than others. It is further reasonable to discuss what might be the best way of ensuring adequate understanding, should it be found to be necessary. The current demand on initial teacher training in England (DfEE 1988) outlines particular expectations regarding the kind of understanding of science required by newly qualified teachers (Annex E, Section A, p.68, Section C, pp78-79).

These requirements are intended to equip newly qualified teachers with the knowledge and understanding they need. If teachers' understanding of the nature of science is changing only slowly and such an understanding is an important determining factor in their practice, then the requirements need to be addressed effectively. The document does not stipulate teaching methods. The level of demand reflected within the whole of the Initial Teacher Training National Curriculum (ITTNC) is great, creating pressure on the adoption of possibly time consuming teaching methods other than direct transmission and working against the integration of programme elements. The ITTNC includes a huge array of individual statements to be taught; it is important to decide how best to encourage understanding of each. The discussion in Chapter 8 explores the implications of the study's findings for the delivery of the ITTNC.

The study

The research for this thesis took place in a combined first and middle school situated in a medium sized town in the South West of England. Four teachers participated in an extended period of research during 1995 and 1996. Most studies in the field up to the mid-nineties had relied on a range of specific instruments to gain access to teachers' understanding of science, frequently pencil and paper responses to questionnaires, marked against pre-determined scales. However, Lakin and Wellington (1994) have suggested that a majority of teachers are not readily able to articulate their understanding of the nature of science because they are not used to discussing such issues. Importantly, especially when considering the reliability of single instruments, Lakin and Wellington report that the
teachers' views seem frequently to change as they become more involved with the research process (pp. 185-186).

Access to teachers' understanding of the nature of science is not therefore straightforward. Teachers need to be engaged in focused reflection in order to articulate and espouse certain viewpoints and the act of reflection itself encourages these viewpoints to change. The assumption that there is a static reality to be observed becomes a false premise. Furthermore, it may be possible that much of teachers' understanding is not articulated at all, remaining tacit in their practice in the classroom. In addition, just as teachers' ideas are not static, the measuring of teachers' practice has also to allow for change. Practice is not fixed; it is the result of a dialectic between numerous factors, including aims, beliefs, values, theoretical understanding of pedagogical issues and the individual circumstances of children and classrooms.

In order, therefore, to gain access to the dynamics of any relationship that may have existed between the teachers' practice and their understanding of what science is and how it works, this study adopted a methodology which attempted to accommodate the possibility of hidden, tacit understanding and the dialectical propensity for change. In this feature, the research can claim a contribution to the field. The study employed a range of methodological strategies, centred around the use of extended action research by the teachers as a specific research tool. It is this feature particularly which gives the study its distinctive flavour and enables it to address the problems of access and change described. The research addresses the central question of relationship through an exploration of the dynamics of practice and not through simple measurement of it.

Structure of the thesis

Following this introduction, Chapter 2 gives a general review of significant literature relating to teachers' epistemological and methodological understanding in science, and the nature of any link between this understanding and their teaching. It also touches on the possible origins of teachers' ideas and raises important demands for the study to address. Chapter 3 responds to these demands and takes the form of a theoretical discussion of the
methodology adopted, with Chapter 4 providing a comprehensive overview of the methodological strategies used, discussing their implementation and reliability. Chapter 5 is the longest in the thesis, consisting of four sub-chapters. Each of these presents a case study of an individual teacher, preceded by a short portrait of her at work, to help the reader. Chapter 6 deals with an analysis of the studies, revealing a series of findings whose implications are then discussed at length in Chapter 7. Finally, Chapter 8 suggests some recommendations for action in the field of teacher education which derive from this discussion.

Throughout the thesis, the third person is used for the researcher. Although such an action is somewhat counter to the format of most accounts of qualitative research, especially that involving action research, the researcher adopted this format to help him maintain a distance between the competing voices in the account, one of which is inevitably his. It should be taken to imply neither more nor less objectivity than the use of the first person. The researcher's involvement in the research situation is acknowledged and explored where necessary.
Chapter 2

OVERVIEW OF THE FIELD

Introduction

This chapter reviews research into the nature and significance of teachers’ understanding of the nature of science. It begins with a discussion of perspectives on the possible relationship which might exist between such understanding and practice, following which it presents an overview of research findings about the conceptions of science held by teachers. It then includes a discussion of methodological differences within the research and explores the potential significance of the origins of teachers’ understanding. Although primary teachers form the main focus of this study, this review will also consider research into the ideas held by teachers in secondary education. There are two reasons for this. First, there is a much greater wealth of research relating to this phase; the consideration of primary teachers’ ideas is historically relatively recent. Second, it is contended that there is much relevance in a review of the conceptions of secondary teachers; both age phases are involved in what is, at least superficially, the same enterprise of teaching science. The possibility that there are significant factors limited to particular age phases will be discussed further in Chapter 7, in the light of the evidence from the study and this research review. Discussion of teachers’ understanding of the nature of science will inevitably involve the use of ideas and terminology relating to the philosophy of science. Although the focus of this thesis is the relationship between the ideas a teacher holds and her practice, and not the ideas themselves, a general overview of major philosophical positions and their attendant terminology may help the reader. Such an overview is included as appendix 1.

Perspectives on the relationship between teachers’ ideas and their practice

Schwab (1964) differentiated the knowledge inherent within a discipline into two kinds: the ‘substantive’ facts or conceptual structures that comprise the body of knowledge claimed by the discipline and the ‘syntactical’ understanding of the principles that guide knowledge formation within it. When Shulman (1986) wrote his highly influential analysis...
of the essential components of a teacher's knowledge, he incorporated both Schwab's elements within his section entitled subject content knowledge. Research into teachers' understanding has largely been driven by the question of whether syntactical understanding will affect practice, although it must be acknowledged (see Chapter 3) that it is sometimes difficult to differentiate this completely from substantive knowledge.

It may appear quite logical that a teacher's understanding of the nature of science—her understanding of the way the subject works; its purposes and its methods for generating and validating knowledge—will have an influence on the way she teaches the subject in school. Indeed, so intuitively powerful is this conception, that Lederman (1992), in his comprehensive review of the research, claims that until 1985 most studies of teachers' understanding took it as a fundamental, unquestioned premise. Since that date, evidence from a range of studies has encouraged examination of the premise and produced ambiguous results, with the result that it has become—in some eyes at least—a significant element of inquiry in the understanding of a teacher's practice. But although Lederman himself suggested that studies more recent to his review (Duschl and Wright (1989), Lederman and Zeidler (1987), Zeidler and Lederman (1989), amongst others) were rendering the proposition far 'too simplistic' for it to be accepted unquestioningly, its abiding influence can still be seen. For example, Lakin and Wellington (1994) begin their introduction by stating the proposition almost as an article of faith and ignore conflicting studies in their very short literature review. Opening with Salmon's (1988) proposal that teachers convey their knowledge in their teaching, they state that 'it seems that a particular view and belief about the nature of science may have a considerable influence not only on what science is taught but also on how it is taught'(p.175). Recently, however, Murcia and Schibeci (1999, p.1139) have re-emphasised the problematic nature of the area, articulating a range of questions which need to be answered in order to define any possible relationship.

Lederman and Zeidler (1987), however, attempted to analyse directly whether the assumption was likely to be correct. From an examination of teachers' interactions and instructional styles, they identified forty four 'variables' which categorised and discriminated between the teaching behaviours of the eighteen participants. Carrying out a
standard NSKS (Nature of Scientific Knowledge Scale (Rubba 1976)) assessment on the participants, they found that the teachers' understanding of science was related to only one variable with any statistical significance. Whilst not suggesting that understanding of the nature of science was irrelevant, they inferred from their evidence that situational factors perhaps exerted a stronger influence on the teachers' practice. This possibility was supported by Duschl and Wright (1989), who studied a group of American teachers working in conditions which sound not too dissimilar to those operating in England and Wales today: an atmosphere dominated by considerations for ' (a) student development, (b) curriculum guide objectives, and (c) pressures of accountability' (p.493). They found that under those conditions the teachers were preoccupied with 'factors other than those associated with the nature and structure of the subject matter' and that considerations of the nature or structure of science were 'deemed less important or unimportant'.

Lederman's (1992) conclusion from this kind of evidence was that 'the translation of (teachers' understanding of the nature of science) into classroom practice is mediated by a complex set of situational variables' (p.351). At the same time, however, there were still studies which appeared to support the original premise, especially those of Brickhouse (1989, 1990), her collaborators (for example, Brickhouse and Bodner (1992)) and Gallagher (1991). Aguirre et al. (1990) compared student teachers' conceptions of the nature of science with their understandings about teaching and suggested that there could be 'some connection' between the two, going as far as to conjecture from their limited evidence that 'the holding of a positivistic-empiricist view of science by student-teachers may be a significant disposition leading them subsequently to adopt a 'transmissive' approach to teaching' (p.389). In addition, Lantz and Kass (1987) had published the results of a project overlooked by Lederman which clearly suggested that the scientific beliefs and values of three chemistry teachers led them to teach very differently about the nature of science, even though they were using the same curriculum materials. Duschl and Wright also drew attention to Martin's (1972) similar claim that teachers will use different modes of language and approach to laboratory work depending on their conceptions (Duschl and Wright 1989, p.473). But the picture was still complex. Although Brickhouse (1989) claimed her study
supported the main premise, she then admitted (Brickhouse 1990) that for one teacher 'many obstacles prevented (him) from using instructional strategies congruent with his expressed beliefs' (p.60) and went on to admit implicitly that environment must place constraints on teachers' performance.

With this speculation based on studies of teachers in secondary education, some welcome consideration of the position of primary teachers was introduced in the studies of Bloom (1989) and Rowell and Gustafson in Canada (Rowell and Gustafson 1993, Gustafson and Rowell 1995). Bloom saw direct links between the teachers' understanding and some aspects of their practice. Gustafson and Rowell, looking particularly at student and beginning teachers, confirmed the complexity of the position, highlighting 'the interconnectedness of personal beliefs and intentions, the milieu of the classroom and the nature of the institutional program' (Rowell and Gustafson, 1993, p.9). More recently still, however, Laplante (1997) has also worked with teachers of primary age children. He adopts a position which firmly supports the initial idea that a teacher's syntactical understanding is expressed in his or her practice. Drawing on the work of Lyons (1990), which examined the ethical and epistemological dimensions of teachers' work, he acknowledges Lederman's contention that the expression of understanding is mediated. However, his suggestion that the major influence may be the understanding teachers have of themselves and their students as 'knowers in science', seems to sideline the wider situational influences that Lederman and Zeidler (1987) or Duschl and Wright (1989) identify. The teachers he worked with saw themselves as 'consumers' of knowledge - often in part incomprehensible to them - passed on by scientists, with the result that students in their classes saw themselves in the same way. He claims that the effect of these teachers' conceptions of science is that their students' 'rapport' with scientific knowledge is not empowering, with them seeing themselves as 'receptors of knowledge already constructed by others and transmitted by their teachers' (Laplante, 1997, p.290).

Laplante's exploration of Lyons' (1990) conception of student and teacher working within 'nested epistemologies' relates to a further area that has been identified within a number of studies: rather than teacher understanding being formed within the teacher and
then transmitted through his or her practice, it is in a constant state of flux because of the
dialectical character of the teaching situation. Nott and Wellington (1996), referring to Lantz
and Kass' (1987) exploration of the derivation of teachers 'functional paradigms' (the
pedagogical understanding they bring to bear as they teach) suggest that the indications are
'that teachers' knowledge of the nature of science may be as much formed by their teaching
of science as informing their teaching of science' (p.284). They refer to work by Solomon
(1990, 1991) who indicated that teachers actually have little experience of either reflecting
upon or articulating their understanding of the nature of science and that they were 'thinking
on their feet' when answering questions. They point out that the work of Koulaidis and
Ogborn (1989) indicates that such understanding is not static, but will change with time and
context. Brickhouse (1990) also considers this phenomenon of a teacher’s continually
changing philosophy, suggesting other factors that may be relevant to the situation in
England and Wales today:

It is not reasonable to assume that teachers who have been in the classroom for over
a decade...are acting on the same beliefs about science they formed during their
formal education. Their philosophies of science are likely to have been influenced by
their years of teaching science in American institutions that often encourage control
over creativity and emphasise learning facts rather than developing understanding.
(pp.60-61)

Teachers’ understanding of the nature of science

These studies suggest that teachers hold widely varying conceptions of the nature of
science. The preceding section has demonstrated that the notion that a teacher’s
understanding is linked by a straightforward mechanism to her practice is questionable; so,
too, is the idea that teachers’ views of science are predictable and easily categorised.
Summing up this position, Lakin and Wellington (1994) relate their exploration of four
secondary science teachers' understandings of the nature of science to the detailed study
carried out by Koulaidis and Ogborn (1989) and infer that:

it would not be prudent to suggest, on the basis of this study, that teachers are 'naive
inductivists' or to apply any other label. The picture is far more complex than this...
(p.186)

But not all research agrees with their position. The following section charts the variety of
results found within nearly forty years of study.
Discussing the feasibility of making generalisations about teacher ideas, Lakin and Wellington contend that they had shown that 'the only common features (amongst teachers) appear to be a lack of reflection about the nature of science and a feeling of insecurity tinged with traces of elitism' and that such generalisations are impossible. This conclusion - that teachers in general, whether specialist science teachers at secondary level or the generalist in a primary classroom, show a lack of reflection on epistemological matters - confirms a long-running suggestion in a series of research findings. Twenty five years before Lakin and Wellington's study, Carey and Strauss (1968, 1970) had claimed that secondary teachers in the USA had inadequate understanding of the nature of science, with Miller (1963) and Schmidt (1967) showing, somewhat alarmingly, that the understanding of the teachers they studied was often less than their students' (Lederman 1992, p.340).

As Lederman points out, these findings stimulated research in the area. This interest developed into a range of varied studies which raised increasingly complex questions. The strongest area of agreement between these studies was the general sense that teachers' knowledge of the nature of science is inadequate, but apart from this very general agreement, the research findings have shown little overall consistency. Many researchers have striven to locate teachers' or student teachers' understanding within accepted epistemological headings - exemplified strongly by Koulaidis and Ogborn (1989) or Duschl and Wright (1989) - and have reached only limited agreement as to the kind of understanding that teachers hold. The findings can be broadly divided into two categories; those that consider teachers' understanding to be relatively unpredictable, falling into several epistemological positions (for example, Brickhouse (1989), Koulaidis and Ogborn (1989)), and those that found their sample to hold similar ideas within a restricted range (for example, Duschl and Wright (1989), Aguirre et al. (1990) Abell and Smith (1994)).

Duschl and Wright, looking specifically at the relationship between secondary teachers' understanding about science and the decisions they made about tasks and teaching strategies, found that 'none of the teachers hold newer views about the nature of science...Rather, the predominant view...is one that embraces the hypothetico-deductive philosophy of logical positivism' (p.491). Such a claim echoed Duschl's general thesis
(Duschl 1988) that school science teaching in the USA presented science solely as a process of justifying knowledge, rather than helping children explore in addition the contextual base for the generation of the claim. The result, he contended, was that such 'scientistic' understanding of science was widespread in society. The idea that teachers hold such a position about the nature of science, which includes the taking for granted of a non-problematic scientific 'method', is a powerful strand running through those studies which suggest that teachers' understanding generally falls within a restricted range. It is frequently characterised as a 'naive' conception of the subject (Aguirre et al. (1990), Abell and Smith (1994), Laplante (1997)). Aguirre et al. worked with student teachers, as did Abell and Smith, but Laplante also found that this 'naiveté' transferred into the qualified teachers' classroom.

From a sample of 74 secondary students, Aguirre et al. concluded that about thirty three percent held solely this 'naive conception' of the nature of science. Aguirre et al. characterised the conception as 'science as a body of knowledge consisting of a collection of observations and explanations of how and why certain phenomena function in the universe', with 'doing science' meaning 'the providing of plausible explanations for natural phenomena usually based upon observations' (p.384). With a further fifty two percent of the sample holding either what they called an 'experimental-inductive' or 'experimental-falsificationist' conception, they seemed to support Duschl's claim that teachers emphasised experimental procedures within their conceptions, concluding that 'naive' or 'quasi-empiricist' notions could account for the vast majority of the student teachers' understandings. Abell and Smith worked with a sample of 140 elementary students, reaching similar conclusions. Finding that the majority of their students classified science as concerned either with 'discovery' and/or 'knowledge', they asserted strongly that they 'have a view of the nature of science dominated by a naive realist perspective' (Abell and Smith, 1994, p.480). They generalised that students consider science to consist of a body of (true) knowledge, derived from processes which are designed to 'discover' it, defining science itself as 'a process of exploration in which data are gathered to discover truth about the world' (p.480), again echoing Duschl. Their students' conception of scientific process was
inductivist, reflecting a positivist attitude towards the truth or certainty of scientific findings, with science as a discipline taking on 'an almost heroic stature' (p.481) as the way to make sense of the world. Gustafson and Rowell (1995) measured changes in student teachers' understanding over the course of a preservice programme. They support Abell and Smith's findings, claiming that many of their own sample of 27 show an understanding in which 'science was viewed as a body of knowledge, quite separate from us and waiting to be 'discovered' (p.598). Drawing on Abell and Smith and Aguirre et al., they imply that it is consistent to link such a conception with the already described 'naive realism or 'inductivist view of the nature of science' (ibid., p.598).

Also referring to Abell and Smith's work, Laplante (1997) traces this 'naive realist' perspective into the classrooms of two practising primary teachers. He describes a naiveté that is characterised by a trusting image of knowledge in science in which the 'existence (of objects of study) is taken for granted and their nature considered to be self-evident'(p.282). Analysing the nature of the interactions within their teaching, he states:

In both of these activities, the teachers see the objects of study as given, rather than constructed. These objects, whether they are bean seeds or the classification of animals, are seen by the teachers as self-evident or nonproblematic in nature. It is as if the children are expected to see the bean seed as the teacher sees it and classify the animals as the teacher classifies them.

(Laplante, 1997, p.283)

However, despite their contention above, Gustafson and Rowell's (1995) account of elementary student teachers' understanding during their science education course seems to present data which suggest that the situation regarding teachers' understanding may, in fact, be more complex. Although they chose to focus mainly on the responses which seem to emphasise an acceptance of science as a body of knowledge, the results they analyse appear to show that the student teachers may also hold a broader conception. In response to a general request to portray their 'view of the nature of science', approximately 25% of the sample identified the continual 'change of ideas' or the 'process of inquiry' as important (p.596). Gustafson and Rowell suggest that such ideas lie mainly within the same realist conception of knowledge, with 'change' being attributed to the 'uncovering' of more understanding, but their acknowledgement that four of their sample were presenting the
image that science is 'tentative' (p.597), raises the possibility that it might not be wise to
generalise too strongly.

Koulaidis and Ogborn (1989), for example, paint a very different picture. Building
on the work of Koulaidis (1987) and Koulaidis and Ogborn (1988), they analysed student
and newly qualified secondary science teachers' understanding of scientific method,
demarcation criteria, the nature of scientific change and the status of scientific knowledge.
From the assigning of questionnaire answers to pre-determined philosophical positions,
they concluded that 'the commonly received opinion about the naive inductivism of science
teachers may now, even if it was once correct, no longer be a good enough account of their
philosophical assumptions' (p.182). They suggest that there are considerable differences
between teachers' overall responses and also that an individual teacher's understanding is
likely to reveal a degree of incompatibility between the various elements. In addition, they
found that whilst 60% of responses could be assigned to definite positions, a further 40%
gave answers which were inconsistent enough to prevent clear categorisation, labelling such
respondents as 'eclectic'. Attempting some kind of overall grouping within this range of
views, they arrived at a table which supports the idea that individuals may hold theoretically
inconsistent positions (p.181), but they suggest that biology, chemistry and physics
teachers may hold patterns of understanding which are consistent within the subject
grouping, but which differ between disciplines. Despite this wide range, they also find it
possible to identify general trends concerning teachers' understanding within their research.
They relate their findings to what they describe as the 'empirico-inductive' position 'often
described in earlier work' (p.181) and suggest that their results may show that there has
been a 'shift towards views giving rationality a weaker role, to more contextualist positions'
(p.180). Rather disappointingly, they do not reference such 'earlier work' and their
suggestion that teachers' understanding lies on a 'spectrum' is, perhaps, self-evident from
their results. The greater claim, that there has been movement along the spectrum, remains
speculative. Following a later review of methodological approaches (Koulaidis and Ogborn
1995), they repeat their assertions, suggesting 'that future research in this area should avoid
investigations assuming that teachers have one or other completely consistent view of the
nature of science’ (p.280).

Brickhouse (1989, 1990) also gathered evidence which supports this view. Her
small scale study of the relationship of three teachers’ understanding of science to their
practice (Brickhouse 1989) uncovered what she called ‘striking’ differences between their
views of science, particularly the status of scientific theories and their relationship to
scientific processes. Commenting particularly on the positions held by the two experienced
teachers in her sample, she found that the teacher who held a ‘perspective consistent with
earlier philosophies of science such as logical positivism and logical empiricism’,
(Brickhouse 1990, p.54) also viewed theory generation as purely inductive. In contrast, the
other teacher viewed theories as tools to solve problems and considered observation and
experimentation to be driven by them. There is some correspondence in this latter finding
with Koulaidis and Ogborn (1989), for this second teacher studied by Brickhouse had an
M.Sc. in physics. Koulaidis and Ogborn found that the physics teachers in their sample
were both the most definite in their views and appeared to ‘favour a contextualist view much
more than any other group’ (p.176). They speculated that the nature of the discipline itself
may predispose physics students to that kind of understanding, considering that physics has
provided more examples of the change of perspective that informs the contextualist position
than either biology or chemistry.

The above studies concern teachers in the UK, Canada and the USA. Although
Laplante’s (1997) research involved two teachers in French-speaking Quebec, it could be
argued that there were, in general, strong cultural similarities between the participants.
Ruggieri et al. (1993) present findings which expand this cultural overview and which add
to general questions about the origin of teachers’ views. Comparing Italian secondary
school teachers with physics teachers in the Latin American countries of Argentina and
Uruguay, Ruggieri et al. explored their understandings of the definition, evolution and
status of scientific knowledge. Italian teachers were found to exhibit similar views to those
identified above by Abell and Smith (1994) or Aguirre (1990), holding what Ruggieri et al.
termed ‘traditional’ perspectives, showing ‘an inclination to a positivist view of the history
of science' (p. 388). In contrast, those from Latin America held views which took more account of socio-cultural influences in the generation of scientific knowledge. In a brief discussion, the authors suggest, unsurprisingly, that such views may derive from the teachers' past educational experiences in science. They go on to imply, however, that such educational experience could be strongly supported by a culture that holds key figures in the history of science such as Galileo in esteem:

Moreover, Italians seem to believe that, once the scientific methodology had been defined by the birth of modern science (Copernicus, Galileo, Newton), no more changes in methodology and standards of scientific explanation have been needed. This 'new' science grows in linear progress toward a full congruence with reality, certainty and truth. The prejudice of the objectivity of empirical facts is very strong and the relativist-historicist trend of the recent epistemological reflections is refuted (Ruggieri et al. 1993, p. 391)

Cobern (1989) also explored the possibility of cross-cultural differences. A comparison of American and Nigerian student teachers noted that the Africans were more likely to think of the aims of science as being utilitarian, producing useful technology rather than as a search for understanding in its own right. Lederman (1992, p. 344) describes how these findings reflect those of Ogunniyi (1982), who had also studied Nigerian students. However, Bloom (1989), pointed out that such a conception was also prevalent amongst Western teachers, referring to a sample of eighty student elementary teachers who characterised the enterprise of science as being primarily for the service of mankind. Interestingly, Cobern also noted that Nigerians tended to consider scientists to be secretive in their work, raising issues of political and nationalistic influence, rather than international co-operation and collaboration. These cross-cultural findings, though limited, cast light on the character of science education in different countries and it is perhaps surprising that Krugly-Smolska (1995) can characterise the positivist presentation of the science curriculum in Canadian secondary schools as 'acultural'. It would appear that this acultural position may, in fact, be strongly influenced by cultural factors.
Discussion: some central themes

The above review presents a picture of teachers' understanding which, at times, varies widely. With such a lack of agreement within the research, it is difficult to imagine that any one, or group, of studies is presenting a wholly valid picture of the field. One obvious problem in such an overview is that it is difficult to compare like studies with like. For example, there are a range of studies which deal with secondary teachers (e.g. Duschl and Wright 1989, Aguirre et al. 1990, Brickhouse, 1989, 1990), a fewer number which look at primary or elementary teachers (e.g. Laplante 1997), and some which concerned themselves with student teachers (e.g. Cobern 1989 (secondary) and Bloom 1989, Abell and Smith 1994 (primary)). With such a disparity in sample type, it may be difficult to appreciate the contribution that each study can make to the generation of an overall understanding, a reservation that is thrown into even sharper focus when one considers the range of methodologies that have been used. It is, therefore, worth looking in more detail at those methodologies, partly to construct a critique of their applicability to the field, but more importantly because the choice of methodology in this area may illuminate the researchers' standpoints both towards epistemological issues and to their importance in a teacher's practice - the latter issue being the central focus of this thesis.

Methodological considerations:

A variety of methods has been used to attempt to ascertain teachers' understandings of the nature of science. Lederman's (1992) review of the field charts the methods used in early studies and identifies issues which are relevant to the analysis of teachers' conceptions. These issues include the age focus of the teachers, the intended scope of the research instrument and the philosophical position taken by the researchers. In addition, Koulaidis and Ogborn (1995) have also pointed out that the analytic framework used by different researchers varies widely and that this may, in itself, raise difficulties in reaching consistent analysis of teachers' positions.

Most research has relied heavily on some kind of pencil and paper testing, whether informal questionnaire or published instrument. A range of studies in America have used the
Test on Understanding Science (TOUS) (Klopfer and Cooley 1961), described by Koulaidis and Ogborn (1995) as being 'widely considered as amongst the more successful instruments of this type' (p.276). This test consists of a series of multiple choice questions designed to assess understanding about the nature of the scientific enterprise, the way scientists work and the methods and aims of science. Early influential research by Miller (1963) and Schmidt (1967) used this method. Other test scales were also developed around this time, for example the Wisconsin Inventory of Science Processes (WISP) used by Carey and Strauss (1968, 1970) and the field is replete with similar acronyms, such as NOSS (Nature of Science Scale) (Kimball 1968), NOST (Nature of Science Test) (Billeh and Hasan 1975) and the above mentioned NSKS (Nature of Scientific Knowledge Scale) (Rubba 1976). All these scales attempt to inject an element of quantification into analysis.

Other forms of questionnaire, such as those of Aguirre et al. (1990) and Abell and Smith (1994) have adopted a more 'open-ended' approach, with Abell and Smith claiming to use processes of 'analytic induction' (Goetz and LeCompte 1984) in order to identify patterns of understanding within responses. Such approaches have, to a greater or lesser extent, encouraged the participants to give written explanations of their thinking where appropriate. These methods have naturally involved more qualitative analysis than the pre-defined scales and in an attempt to re-introduce an element of quantification into the process whilst still maintaining scope for accommodating what appeared to be the generally eclectic nature of teachers' ideas, Lakin and Wellington (1994) set out to refine the qualitative approach. Basing their work on Kelly's Personal Construct Theory (Kelly, 1955) and drawing heavily on the work of Salmon (1988), they derived a tri-partite methodology in which a preliminary, partly qualitative, elicitation of teacher 'constructs' about the nature of science led to the formation of a general bi-polar repertory grid on which they could score teacher responses.

Lederman (1992, pp.348-349) discusses the findings of Lederman and O'Malley (1990), which seem to indicate that the results of both paper and pencil tests and questionnaires can be significantly enriched by conducting interviews with participants as well. Lederman and O'Malley suggest that interviews provide 'more in depth and valid
assessments of teachers' conceptions and have afforded the researcher a more contextual view of the factors which mediate conceptions (p.352). This view has proved to be influential in a number of studies over the last decade. Nott and Wellington devised a questionnaire which was designed to help teachers construct a personal profile of their understanding of science (Nott and Wellington 1993). Reflecting on Solomon's (1990, 1991) claim that even most science teachers do not seem to have thought much about the nature of science, their primary aim was to produce an instrument that would promote such thinking. As a result, participants were encouraged to discuss their profiles. Nott and Wellington's findings indicated that many teachers who went through the process claimed that the reflection it had produced meant that they would almost certainly complete it differently if asked to do it again. Lakin and Wellington (1994) report that their method had a similar effect, speculating whether it might constitute an effective staff development tool (p. 186). Nott and Wellington subsequently reported how such results 'confirmed (their) suspicions not to place too much faith in paper and pencil tests', agreeing with Lederman that 'research methods that are more qualitative and phenomenological may provide a better understanding of the interaction between teachers' understandings and their classroom actions' (Nott and Wellington 1996 p.285).

Brickhouse (1989, 1990) and Gallagher (1991) went yet further and introduced an element of ethnography within their methodologies. Both these researchers not only involved themselves in the formal or informal interviewing of participants, but carried out detailed observation of teachers' practice, on the premise that a teachers' understanding is conveyed in what she does as well as what she says. Similarly, Laplante (1997) relied heavily on observation, working with teachers in their classrooms for up to twenty five hours. He adopted a range of qualitative research strategies and included negotiation of the veracity of his preliminary analysis with participants.

In a general critique of existing research instruments, Koulaidis and Ogborn (1995, pp. 276-277) point initially to the potential inaccuracy of the older style multiple choice format where a 'correct' answer about epistemological issues may not be possible. Referring specifically to the TOUS, they object that there is no explicit articulation of the
philosophical assumptions behind the questions. Recognising that there are internally consistent but philosophically conflicting models of science, they point out that ‘correctness’ in answers may depend on one’s perspective. They review a range of earlier studies, claiming that most of those prior to 1975 were inexplicit about their basis for analysis of teachers’ responses. In their view, this has led to ‘dubiously informative’ results from these studies. They trace a lack of this kind of rigour through to more recent work, with influential reports such as that of Brickhouse (1989) coming under criticism for being equally inexplicit. They further claim that, even though other studies do take into account more than one philosophical position, they are still not adequate unless the ‘whole spectrum’ of possible views has been covered:

It cannot be right to study whether people adhere, for instance, more to view A or more to view B, when the possibility that most would take view C has not been included.  
(Koulaidis and Ogborn 1995, p.277)

In their overview, only one study, Koulaidis and Ogborn (1988), seems to fit this position. Their work appears to develop logically from that of Koulaidis (1987) in which he gives a detailed analysis of different epistemological and philosophical positions designed, as he puts it, to help clarify ‘the nature of questions about the philosophy of science as it applies to science education’ (p. 43). His overview distinguishes between a range of epistemological systems, which he terms inductivism, hypothetico deductivism, contextualism and relativism, but Koulaidis and Ogborn (1995) also claim that the range of possible topics involved in the analysis of a teachers’ understanding - methodology, criteria of demarcation, patterns of scientific change, the status of scientific knowledge - means that any instrument must be able both to distinguish between the focus of responses in these terms and to accommodate the fact that there may be inconsistencies in terms of the epistemological system ascribed to each one. These issues of analysis and their relevance to the study informing this thesis will be discussed in Chapters 3 and 4.

The origins of teachers' understandings

A methodological analysis appears to raise pertinent issues regarding the nature of the relationship between teachers' espoused understanding, the ideas which appear tacit
within their practice and that practice itself. So too does a consideration of the factors put forward by various authors to explain the origins of teachers' (or student teachers') understanding.

The assumption that a teacher's experiences during formal schooling or in specific courses on their teacher education programme have a profound influence on their understanding of science has a powerful intuitive veracity. It is implicit within Hodson's (1985) analysis of science education in the 1980s, which links unproblematically teachers' attitudes and conceptions of science with the understanding of the subject their pupils develop. Stating that it is 'teachers' inadequate understanding in philosophy of science...that leads them to project an unfavourable image of science and the activities of scientists...'

(p.27), Hodson immediately justifies his position by referring to Rubba et al.'s (1981) then recent study which indicated that children regarded science as revealing 'incontrovertible truths, necessary absolute truths' (p.28). Abell and Smith (1994) appear to support the view that at least when it comes to student primary teachers, their formative experiences at school are of crucial importance in the generation of their conceptions of the nature of science. They contend that the 'naive realist' views they found within their sample were 'constructed over years of formal science instruction' (p.484). Relating their students' understanding to that of seventh graders' in American schools, they see a 'striking' similarity which they consider to have depressing implications:

Overall our students do not have a feel for how science is done, how scientists work together, or how the scientific world-view is unique. According to the SFAA (Science for All Americans) criteria, these students could not be considered scientifically literate. Yet they are to be teachers of science in our elementary schools.

(Abell and Smith, 1994, p.484)

Seeing such little difference in understanding from younger school students, they surmise that such early learning is of profound importance and very difficult to change. Aguirre et al. (1990), who proposed that student teachers' views gave them a significant 'disposition' to teach in a certain way, support the idea. They speculated that the views they encountered arose from experiences in the students' schooling and were again resistant to change. Carey and Strauss (1968) gathered evidence indicating that in-service programmes could change secondary teachers' understanding of the nature of science, but there is little evidence that
shows such programmes are effective by themselves. Gustafson and Rowell (1995), in a study of preservice students in primary education, directly compare the two possible influences of schooling and preservice courses, indicating that of the two the teachers' schooling is probably the most crucial. Their students' understanding of science changed little during a thirteen week preservice course which addressed learning, teaching and the nature of science. If such an idea were right and the paramount influence lies in the ideas generated within general schooling, then it would be consistent to believe that teachers will not vary significantly in their understanding from the rest of the population.

Zeidler and Lederman discuss possible mechanisms for the generation of school students' views about science (Zeidler and Lederman 1989). They suggest influences that appear to close the links between school students' understandings and that of their teachers. Presenting evidence about the influence that a teacher will have on young people of school age, they relate their findings to Munby's (1976) thesis that students will tend to adopt the positions implied within their teacher's use of language. Their discussion then seems to raise the possibility that there exists a non-educative 'closed circle' of teacher to school student, to student teacher and then to new teacher, in which a view of science is introduced, learnt, then passed on to a new generation. If such a circle existed it would be hard to break, especially if, as suggested above, experiences within the crucial training period for student teachers have little effect on the ideas they bring with them from school.

The nature of the understanding that may be transmitted within the 'closed circle' is hinted at by Cross (1997), who explores the ideological pressures at work on teachers' views of science and their practice. His main thesis, which adds further strength to the argument that teachers' views are in large part determined by transmission from the outside, is that all those involved in promoting teachers' or student teachers' understanding are controlled by dominant ideologies. He recognises that a dialectical interplay exists between the curriculum and a teacher's perception of what science is about, but suggests that the dominant ideology of what he calls the 'Institution of Science' is the most important factor in the shaping of the messages science teachers pass on to their students. Because of this, he claims, there is a strong likelihood that science teachers will all pass on similar models of
science, perceiving them as acceptable to the body of science in general. With the 'closed
circle' in operation, such ideological control will mean that powerful and resistant images of
science will be developed during any potential teacher's schooling.

Although Cross points to a basic uniformity of understanding amongst science
teachers from many cultures, there is implicit within his analysis the proposition that science
teachers will transmit the dominant ideological requirement irrespective of whether their
personal views of science are in accordance with it. They become 'gatekeepers' for entry
into the dominant social understanding of the enterprise of science. It is a powerful idea,
suggesting that there is some form of mediation between personal understanding and the
content of teaching. Lakin and Wellington (1994) raise just this point when they discuss
how a teacher's understanding of the expectations children have of science sessions will
have a pronounced effect on the way he or she will teach. Commenting on secondary school
teaching, they suggest that children will expect their sessions to present science as factual
and unproblematic and that knowing this will affect the nature of the teacher's practice. Such
views may also apply to other staff in the school and to the children's parents, originating
from those greater ideological influences on cultural expectations and understanding that
Cross is referring to. The net effect is that a secondary science teacher's action is curtailed
and a strong message is communicated in her teaching whether she likes it or not:

"I don't see science as a body of knowledge. The boss (headteacher) and other staff
hate me to think like this as it makes them feel insecure. I have to transmit it as a
body of facts".

(Lakin and Wellington, 1994, p. 187)

The implication of such an analysis is that a restricted understanding of science will
underpin the 'closed circle' referred to above.

Cross contends that because of this 'ideological hegemony', teachers' understanding
is cross-culturally similar (Cross, 1997, p. 615). Ruggieri et al.'s comparison of Italian and
Latin American teachers (Ruggieri et al. 1993), however, suggests otherwise and, in so
doing, considers in a little more positive light the impact of initial training programmes on
student teachers' views. In discussing the origins of the understanding held by their sample
of teachers, Ruggieri et al. ascribe much importance to educational and cultural factors. In
doing this, they are supporting tacitly the suggestion that teachers' understanding is likely to
be no different from that of their peer group in the same culture, but only if they have not undergone specific education in epistemological issues. Here, they differ from Zeidler and Lederman by holding that such courses are, in fact, likely to be productive. Their sample of Italian teachers, who tended towards positivist views of science, attributed a heroic stature to 'scientific method'. Ruggieri et al. describe the image of Galileo 'struggling' against Aristotelianism as common in Italian textbooks. On the other hand, their Latin American teachers appeared to hold philosophically more 'modern' ideas. As both of the Latin American groups had attended specific courses on epistemological issues within their pre-service training programmes, Ruggieri et al. suggest that the differences with the Italian teachers may be attributable to these courses. Their suggestion that the courses were of influence in the formation of the student teachers' ideas is appealing in its implicit faith in the effectiveness of educational programmes, but is, however, flawed. With no evidence available from prior to the training courses it can be no more than speculation, as it is impossible to tell when the Latin American teachers actually acquired their views. It would be perfectly conceivable that their ideas had originated in school through the same processes of cultural transmission as the authors claim influenced the Italians, with the teaching on their epistemological programme merely reinforcing what had already been taught.

Lantz and Kass (1987) are of the opinion that courses do have an effect, but only as one element of the 'academic history' of the teacher. This also includes a range of other experiences which are potentially individual. These factors, for example the different students a teacher has taught or the syllabuses they have worked with, would imply a dynamic understanding that is difficult to predict. Gustafson and Rowell (1995) explore further the impact of educational programmes themselves, with a study which revealed that little change took place in students' understanding during their participation in a programme dealing with epistemological issues. Gustafson and Rowell's ensuing discussion raises issues to do with cognitive change that will be seen to be of central concern to this thesis. They refer to the work of Hollingsworth (1989), who contended that, although student teachers held 'socially and culturally defined' beliefs which they remained true to, they were capable of simultaneously demonstrating apparent conceptual change (Gustafson and
Rowell, p. 599). In their own work, they suggest that their course members held a ‘core philosophy’ of teaching, learning and science throughout their programme which remained largely untouched by new ideas. They then make a suggestion which appears to complicate the position even further, stating that the course members seemed able to interpret course ideas in different ways, rendering them compatible with their core philosophy (p. 600). This begins to paint an increasingly complex picture of the derivation of teachers’ ideas. If such a process can be shown to occur as these student teachers encounter a range of new ideas on a pre-service programme, can it be said with any certainty that it does not happen earlier, at the more ‘formative’ stage suggested by Cross or Zeidler and Lederman? If it does, it would cast doubt on the extent of the ‘closed circle’ implied by these authors. Constructivist interpretation of children’s learning supports such an idea: the central message of constructivist approaches is that an individual’s prior understanding is most likely to influence the outcome of new experiences - including teacher instruction.

The origin of teachers’ understanding of science appears, therefore, to be difficult to pinpoint. The ‘closed circle’ of Cross or Zeidler and Lederman remains a powerful idea and it would be foolish to dismiss the effect of the tacit or overt messages within a teacher’s lesson on children or students. But Lakin and Wellington suggest that this is not a one-way process, with students’ own perceptions influencing a teacher’s approach. Gustafson and Rowell take this argument one step further, contending that, just as the teacher’s understanding may be mediated by such other factors, as explored by Lederman and Zeidler (1987), the children themselves will also be mediating the content of the teacher’s lesson. To explore the full origin of those children’s ideas, one would have to penetrate into the complex and methodologically impenetrable world of the child’s everyday life. Cross’ ‘ideological hegemony’ may still be a factor, influencing the tacit messages within the child’s everyday socialisation and experience, but it appears to become just one of a range of possible influences. With Brickhouse (1989) and Nott and Wellington (1996) emphasising the degree to which teachers’ own understanding - and thus possibly their ‘message’ - changes over the course of their careers, one is left with an incomplete and problematic understanding that can be at best only highly tentative.
Mediation

A recurring theme within the studies suggests that, if a link exists between teachers’ understanding of science and their practice, it is not linear or necessarily causal. Lederman (1992) points to the situational factors operational at all moments of the teacher’s professional existence. Referring to his earlier work (Lederman and Zeidler 1987), he discusses the strong influence that curriculum constraints, administrative policies and teaching context must have on the translation of teachers’ ideas into their practice. He extracts the simple message that, if science educators are to promote better teaching in schools, their concerns must extend ‘well beyond teachers’ understandings of the nature of science’. Although ‘critically important’, these understandings are not enough in the complex context of the classroom to guarantee effective teaching approaches. Brickhouse (1990), whilst arguing more strongly than Lederman for a causal link between teachers’ conceptions and their practice, also acknowledges that situational factors will mediate teachers ideas and that, given time, will also change them. Of her three teachers, the two experienced ones operated within what she described as a ‘consistent, self-reinforcing belief system’ (p.60). But the newly qualified teacher was ‘unpredictable’ and difficult to analyse. She attributes this phenomenon not only to inconsistencies within his beliefs about science, but also to the ‘impact of institutional constraints’. These, she suggests, can be seen to be in conflict with his aspirations. However, this is no longer the case with the experienced teachers. Such a state of affairs, she surmises, has come into existence because of the long influence of curricular and institutional expectations. The experienced teachers’ beliefs have been moulded.

It is, perhaps, significant that Brickhouse writes of the conflict that the newly qualified teacher experiences, both in his struggle to maintain his professional integrity in the face of such situational pressures and in his experience of the inconsistencies within his beliefs. She injects an air of dialectical complexity into the picture. Lederman’s image, although presenting a complex situation, is fundamentally straightforward, with two players - the teacher and the situation - who have to reach an accommodation. The teacher’s
understanding exists, but it is mediated by external factors. Brickhouse’s analysis suggests otherwise, at least for her inexperienced teacher. She presents a picture of someone who is fumbling from day to day, trying to realise who he is, what his ideas are, what he is supposed to be doing. The fixed understanding does not exist; it and any pedagogical imperatives that may follow from it are continually being constructed and reconstructed in the complex milieu of the classroom and the education system he finds himself in. Many of his ideas to this point are semi-intuitive. If Solomon (1990) or Lakin and Wellington (ibid) are correct, he will not have reflected much about the nature of science before and will be changing his ideas regularly as he begins to ‘know what he knows’.

Cross (1997) introduces a further level of complexity by discussing the ‘dialectical nature of the relationship between beliefs on the one hand and society on the other’ (p.608), but his analysis lacks something of the energy of Brickhouse’s picture. Cross’ image is more one-sided, with his analysis considering those dominant ideologies of science in society that, he claims, will determine a teachers’ understanding. He claims that ‘within the dialectics of science education the teacher is a captive of the curriculum’, but he still highlights the role of external factors, a teacher’s prior experiences and her conception of the purpose of teaching and science itself in the generation of a teacher’s beliefs.

Summary

In summary, therefore, there are issues within the literature that may have relevance for this thesis:

1. It is frequently difficult to compare like studies with like. They vary in particular with regard to:

   i. the nature of the methodology;
   ii. the scope of the methodology in terms of epistemological positions;
   iii. the age phase taught by the teachers.
2. There is little agreement as to the nature of the relationship between teachers’ understanding of science and their practice. All studies assume some kind of relationship, but whether teachers’ understanding has a direct causal influence on practice is the subject of some debate. There are well-supported studies which claim that any influence is mediated by external factors and some, more recent, work suggests that the idea of a ‘fixed’ understanding of science is problematic. The idea that teachers’ conceptions are subject to change because of the dialectical character of the classroom is gaining ground.

3. Analysis of the origins of teachers’ understanding suggests at one extreme that a ‘closed circle’ may exist between teacher and child, thus perpetuating prevalent ideas about science. Other studies suggest, however, that consideration of the dialectical character of the classroom may render this rather stifling idea problematic.

The image of a dialectical complexity underlying a teacher’s practice is one element which underpins the choice of methodology for the present study. Koulaidis and Ogborn (1995), Lederman (1992) and Nott and Wellington (1996) (amongst others) warn that it is important to strive to accommodate the potential range of elements active in the research situation. Lederman claims that the nature of recent qualitative studies allows ‘investigators to avoid the problems created by limiting responses to an apriori set of categories or viewpoints’ (p. 351), implying that inductive processes of analysis allow ‘the wide variety and complexity of perceptions held by both teachers and students’ to be identified. Koulaidis and Ogborn on the one hand dispute whether ill-defined qualitative methods are adequate, but their insistence that methodologies are explicit about the interpretative frameworks they are using can be seen as introducing an element of reflexivity into the process. It is the reflexivity inherent within action research that suggested its suitability as a major part of the methodology of the present study.
This chapter and the next consist of an extended discussion of the methodology adopted for the inquiry. In broad terms, this chapter considers the theoretical justification for the approach adopted, with Chapter 4 exploring the data collection methods used and their reliability. The current chapter is divided into three main sections, each contributing to the overall position taken by the study as regards the validity of the research findings: validity in approach, validity in choice of methods and validity in presentation of the data.

1. Validity in approach

This inquiry adopts an approach which lies within the broad interpretative tradition in the social sciences. The inquiry is concerned with two kinds of phenomena: the nature of four teachers' ideas about an aspect of their experience and cognition (science) and the nature of their teaching of it. It does not attempt to describe, in the manner of some studies referred to in the previous chapter, 'teachers' understanding of the nature of science' as a general category; it is interested in the specific examples of four teachers and the way their understanding related to their teaching. The phenomena of teaching and understanding lie within the social world, hence the need for an interpretative approach (Hammersley and Atkinson 1995, pp. 6-7). The study of social phenomena differs from that of physical phenomena. In the study of physical phenomena, it is assumed that regularities exist which apply to all examples of those phenomena, ensuring predictability and generalisation. Because of this, such study relies heavily - and quite rightly - on quantitative methods and statistical analysis, even though it can still be argued that the researcher's own theoretical framework is instrumental in the generation of evidence and the synthesis of meaning from it (Duhem 1906; Popper 1934). On the other hand, social phenomena relate to the lives and actions of people. Within them, simple causal relationships are unlikely, for people's actions are complex, involving their own intentions,
beliefs and values along with an interpretation, ‘continually under revision as events unfold’ (Hammersley and Atkinson 1993, p. 7), of events around them. Inquiry into aspects of social phenomena is therefore limited in its ability to generalise and predict by virtue of the situated and reflexive nature of those phenomena under study.

The interpretative tradition is ‘broad’. To refer to it as a single tradition may be incorrect, for there is debate about the nature of traditions and the extent to which they can be thought of as determining research approaches. Hamilton (1994) reviews the field lucidly, highlighting the difference in understanding between those who consider traditions to have developed into fixed ‘paradigms’ that represent distinct approaches to social reality (for example Jacob, 1987; Guba and Lincoln, 1994) and those more inclined to think of them in evolutionary terms, melding into each other and changing through history (for example Atkinson et al. 1989). Wolcott (1992, cited in Hamilton, 1994) extends Atkinson et al.’s position, suggesting that each generation of researchers should adopt their own ‘postures’, strategic positions within which they are free ‘to assemble their theoretical assumptions and working practices from a “marketplace of ideas”’ (Hamilton, 1994, p. 61). On the other hand, Guba and Lincoln lay out a fourfold categorisation of current paradigms for social science research. In contrast to Kuhn’s representation of paradigms within the natural sciences (Kuhn 1970), they do not suggest that these paradigms supplant each other in an evolutionary way. Rather, they represent an attempt to define logical relationships within approaches ultimately determined by the interests of the participants, a position related strongly to that of Habermas (Habermas, 1972). The paradigms, they claim, determine positions adopted within research towards questions of ontology, epistemology and methodology:
**Illustration 1 Basic Beliefs (Metaphysics) of Alternative Inquiry Paradigms**

<table>
<thead>
<tr>
<th>Item</th>
<th>Positivism</th>
<th>Postpositivism</th>
<th>Critical Theory et al.</th>
<th>Constructivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ontology</td>
<td>naïve realism- &quot;real&quot; reality but apprehendable</td>
<td>critical realism- &quot;real&quot; reality but only imperfectly and probabilistically apprehendable</td>
<td>historical realism - virtual reality shaped by social, political, cultural, economic, ethnic and gender values; crystallized over time</td>
<td>relativism - local and specific constructed realities</td>
</tr>
<tr>
<td>Epistemology</td>
<td>dualist/objectivist; findings true</td>
<td>modified dualist/objectivist; critical tradition/community; findings probably true</td>
<td>transactional/subjectivist; value-mediated findings</td>
<td>Transactional/subjectivist; created findings</td>
</tr>
<tr>
<td>Methodology</td>
<td>experimental/ manipulative; verification of hypotheses; chiefly quantitative methods</td>
<td>modified experimental/ manipulative; critical multiplicity; falsification of hypotheses; may include qualitative methods</td>
<td>dialogic/dialectical</td>
<td>hermeneutical/ dialectical</td>
</tr>
</tbody>
</table>

Guba and Lincoln (1994, p.109)

Guba and Lincoln (c.f. Kuhn (1970), appendix 1) define a paradigm as a ‘basic belief system or worldview that guides the investigator’ (1994, p. 105) and claim that all research should fit into one of their four examples. The position taken here is that such a claim presumes too much about the investigator’s understanding and provides an unnecessary straightjacket. The categorisations raise useful ideas, but the implication that validity lies within a strict adherence to them as described is not accepted. The categorisations can be criticised in a number of ways. For example, if ‘postpositivists’ adopt a falsificationist methodology, their epistemological position may not be one in which they believe that their findings are ‘probably true’, for the possibility of falsification renders such a claim highly problematic. It can also be argued that to adopt the ontological position that an external reality exists does not mean that one has to negate the influence of values in the research; the acceptance that observation is ‘theory-laden’ can be extended to include an understanding that values might colour interpretation of experience and thus the inevitable ‘theory’ that lies behind any inquiry. The boundaries of the
paradigms appear too restricted, suggesting that the idea of fixed positions is not helpful in understanding the research exercise. On the other hand, Guba and Lincoln's 'questions' are important. Whilst it is contended here that Wolcott's position is a more acceptable reflection of the reality of researchers' actions, any inquiry that does not make clear where it stands on questions of ontology, epistemology and methodology will be flawed. As Erickson (1986, p.120) points out, the fact that there are competing paradigms within research highlight the need for the researcher to indicate at some point the position he or she is taking (cited in Janesick, 1994, p.213).

Within this study, it will be seen that a complex ontological position is adopted. Following Guba and Lincoln's definitions, the inclusion of action research within the inquiry and its implicit epistemological position that knowledge is situated, reflexive and mediated by the participants' values, suggests an attitude towards reality which is close to relativism. Yet this situation lies within an overall approach which is unashamedly realist in its ontology. It is a position of 'critical realism', in that it is acknowledged that the nature of reality cannot ever be fully known, but, for the purposes of the inquiry, the research approach assumes that the teachers' understanding of science and the nature of their practice existed separately from the researcher and the research situation. Epistemologically, the inherent desire for objectivity within such an approach can be seen to be at odds with the inquiry's key research tool of action research, but this difference does not present a conflict. It is possible to view 'results' from one form of inquiry, no matter how situated they may be, as 'evidence' for another. To classify research by presuming that it is possible to specify a researcher's world view is flawed; the important criterion is that the approach adopted is useful in addressing the research question. Of course, questions will be framed according to differing perspectives and in so being they will contain inherent assumptions as to the nature of the research situation. All questions contain assumptions and they must be acknowledged, as far as possible. But the researcher's 'world view' is not definable in these terms; it is quite possible for him or her to work within a variety of perspectives depending upon the nature of the inquiry. Wolcott's call for researchers to adopt
their own ‘posture’ suggests fluidity and change, and it accords with the multilayered nature of people’s lives. Ultimately, though helpful in outlining a range of possible stances, Guba and Lincoln’s categories are flawed because they appear to locate intention in the abstract paradigm rather than with the researchers themselves; an interesting position, as it seems to be at odds with their avowed ‘constructivist’ understanding of reality (p.105).

The position taken here, therefore, is that a research stance is to a large extent determined by the research questions. It is the stance which is most useful at the time in addressing those questions. It is open to critical appraisal and it may become clear during the research that it is inappropriate or unduly limited in its focus. It must be acknowledged that it will give a limited picture of reality and it is possible that research according to one particular view may give rise to deliberation which suggests another. The world view of the researcher is not relevant. This does not mean that every effort must not be taken to identify interests in and assumptions about the research situation; this remains an essential prerequisite of all research.

Following a brief presentation of what were identified as the main imperatives that had to be addressed within the research, the rest of this chapter will deal with the theoretical justification for the research strategies adopted, clarifying how the positions adopted by this inquiry on the questions of ontology, epistemology and methodology are claimed to address the question of validity within the process.

Research Imperatives

There were two main foci for the inquiry, namely: i) the kind of understanding of the nature of science held by the participating teachers and ii) the nature of their practice in the teaching of science. The study of neither is methodologically straightforward.

With regard to teachers’ understanding of science, the review presented in the last chapter traced the development of an array of methods from quantifiable multiple choice questionnaires and scales, for example TOUS (Klopfer and Cooley 1961) and NSKS (Rubba 1976), through qualitative procedures (Aguirre et al. (1990, Abell and Smith, 1994), to some
kind of resolution of the two approaches (Lakin and Wellington 1994). The position taken here is that adherence to a particular understanding of the nature and accessibility of the phenomena under study (ontological and epistemological questions respectively) does not prescribe the methods an inquiry must use. Both quantitative and qualitative methods may be used with any research tradition or paradigm. The use of the term qualitative can, however, lead to some confusion and it needs to be made clear whether it is being used to refer solely to methods or techniques which are non-quantitative in nature or whether it relates to a research approach. Guba and Lincoln, for example, appear to use it in the former way, but others, for example Erickson (1986), consider that qualitative research is a 'matter of substantive focus and intent, rather than of procedure in data collection' (p.120). He uses the term synonymously with interpretative as a standpoint which confers a certain kind of validity on the research, in much the same way as Guba and Lincoln use their paradigms. Erickson agrees that the same techniques can be used for positivist or interpretive ends, but, as methods, they attain meaning for the research within the intentions and actions of the researcher.

In deciding upon an appropriate methodology for this inquiry, there were a number of imperatives which the research had to address if a valid account of the research situation was to be generated. The critiques presented in the last chapter by Lederman (1992), Koulaidis and Ogborn (1995) and Laplante (1997) raised two issues which research in the field has shown to be important:

1. the effectiveness of the methodology in accessing teachers’ ideas (Lederman and O’Malley, 1990; Lederman, 1992);

2. the scope of the methodology and its ability to accommodate a range of possible epistemological positions (Koulaidis and Ogborn, 1995).

In addition to these two imperatives, the need to explore the teachers’ practice in teaching science produced two more requirements:
3. that the methodology can access adequately the nature of teachers' practice;
4. that the methodology has the ability to highlight (if present) potentially significant links between teachers' apparent understanding of science and their actions.

The following discussion will explore the demands placed upon the methodology by these imperatives and the theoretical justification for the approach adopted. In so doing, it will explore the nature of the two kinds of inquiry which ran concurrently through the course of the study, one as a research tool for the other, both potentially, though not necessarily, adopting different ontological and epistemological positions.

2. Validity in choice of methods
i) Theory, practice and some epistemological implications

The methodological imperatives identified above implicitly propose a conception of theory and practice in which teachers' ideas about the nature of science stand outside the practice to which they may be linked and therefore can be accessed separately. There are a number of arguments which suggest that teachers' understanding is more complex than this and that the position is epistemologically unsound. The arguments derive from a) the need for teachers to become conscious of what they know, b) the link between tacit understanding and the nature of a teacher's practice and c) the dialectical relationship between theory and practice. These arguments suggest that an epistemologically rigorous approach must have regard for the character of teachers' teaching of science when trying to ascertain their understanding of the nature of the subject and that the teachers themselves must be fully engaged in reflection on their actions in order for valid results to be obtained.
Lakin and Wellington (1994) contend that a teacher often has to be acclimatised to questions concerning philosophical issues about science. They consider that most teachers do not routinely reflect on the nature of science and that direct questioning about it may well be unproductive. This, however, does not necessarily mean they do not have ideas about the major areas, such as the methods of science, knowledge generation within it or its validity, but simply that they are unused to reflection on the subject. In order to gain access to their understanding, Lakin and Wellington devised a number of activities designed to sensitise teachers to the key issues. Such an approach is reminiscent of Eraut’s suggestion (Eraut 1978) that the process of needs identification in schools has to be embedded in those moments of critical reflection that only occur at certain times of the school year, or that can be engineered by carefully planned intervention. Merely asking a teacher out of the blue what her needs are will provide only superficial and, therefore, highly dubious results.

Working in the field of science education, in which the principles of constructivism have been applied ever more widely over the last two decades to the teaching of science (Driver, 1981; Osborne and Freyberg, 1985; Driver and Bell, 1986; von Glasersfeld, 1989), Lakin and Wellington were perhaps already highly sensitised to the influence of George Kelly’s personal construct theory (Kelly 1955). Kellyan psychology suggests the existence of ‘personal construct systems’ through which we know the world. Lakin and Wellington point to the inherent complexity of these construct systems, suggesting that they ‘encompass much more of what we know than we can describe in words...the more fundamental the knowledge, the less easily accessible it often is to verbalisation’ (Lakin and Wellington, p.178). A process of elicitation is necessary, with the dual purpose of informing an outsider of a subject’s ideas and helping the subject herself know what she knows. Lakin and Wellington highlight this aspect of their research. In discussing the results of their study, they suggest that they had indicated ways in which they could help teachers ‘explore and recognise their own views on the nature of..."
claiming that ‘for many teachers their participation in this study marked the first recognition that they have a “philosophy of science” ‘(p.188).

The possibility that there might exist an understanding that is hidden both from the subject and the observer alike does not in itself necessitate exploration of the subject’s practice. A variety of elicitation strategies could be possible. However, when taken in conjunction with the two following arguments, a rationale develops which suggests that regard for the nature of the subject’s practice might be epistemologically essential.

b) the link between tacit understanding and the nature of a teacher’s practice

Solomon (1991), also found that teachers do not reflect much on the nature of science, but raised the idea that clues to teachers’ understandings of the nature of science can be found within their descriptions of pedagogical activity in their classrooms. This understanding is tacit and not easily articulated, but the discussion of a context within which it is operational may allow access to underlying ideas. However, once this is acknowledged, the issue immediately becomes more complicated. There is an assumption that whatever the teacher suggests in explanation is in fact what she believes. The work of Argyris and Schon (1974) has indicated otherwise. They differentiated between the ‘espoused’ theories (in the current context, ideas or understandings can be substituted for theories) that practitioners may articulate independently of the professional situation - perhaps in a research discussion - and their ‘theories in use’ which only become apparent during the action itself, suggesting that they may well be different. They contended that, whilst teachers might appear to be bringing to bear their espoused ideas in the planning and executing of their teaching, their theories in use may in fact be derived from tacit understandings which are determining their behaviour. Schon (1983) called this ‘tacit knowing-in-action’. Altricher et al. (1993) identify three important characteristics of this action:

- thinking and acting are not separate (skilful, practical activities take place without being planned and prepared intellectually in advance);
- the professional is frequently unaware of the sources of his or her practical knowledge or how it was learnt;
the professional will usually not be able to give a straightforward verbal description of this practical knowledge.  
(Altricher et al. 1993, p.204, emphasis added)

Torff (1999), referring to Sternberg et al. (1996), defines tacit knowledge as "knowledge that is rarely openly expressed or stated" (p.195). He aligns tacit understanding with "intuitive conceptions", claiming that they "exert a great deal of influence on the way...people think and act with respect to education" (p.195). In the context of teaching, he traces the origin of these ideas to a 'folk pedagogy' which has grown out of what Bruner (1990) calls 'folk psychology'. The basic elements of this folk psychology are fundamental to a person's life and powerful determinants of action:

All cultures have as one of their most powerful constitutive instruments a folk psychology, a set of more or less connected, more or less normative descriptions about how human beings 'tick', what our own and other minds are like, what one can expect situated action to be like, what are possible modes of life, how one commits oneself to them, and so on. We learn our culture’s folk psychology early, learn it as we learn to use the very language we acquire and to conduct the interpersonal transactions required in communal life.  

Bruner (1990, p.35)

Torff suggests that the 'folk pedagogy' that derives from this and what he terms our 'theory of mind' 'predisposes individuals to think and teach in particular ways' (Torff, 1999, p. 196). This leads to practice which is driven by assumptions about children's learning, curriculum and knowledge that are hidden from both observer and teacher alike. Strauss (1993, in Torff, p.205) suggests that such understanding may be very persistent, despite the promotion of teachers' reflection on the issues or provision of training programmes. The recent work of Meyer et al. (1999) and, to a lesser extent, Lemberger et al. (1999) provides direct evidence that teachers' practice in the teaching of science can often be in direct conflict with their espoused intentions or understanding of the nature of the subject. Their analyses support the idea of tacit "knowing-in-action", suggesting that a full picture of a teacher's understanding will only be gained by taking into account the beliefs that are simultaneously being promoted through her practice as well as the espoused ideas she may convey through interview or written response. Interestingly, the two studies suggest that the tacit 'starting points' as regards ideas about
science may be different for elementary and secondary teachers, perhaps indicating that the
cultural factors that Bruner describes may differentiate on the micro level.

It is therefore likely that, regardless of what a teacher might communicate in her
espoused ideas, she will also be conveying messages within her practice about her
understanding of the nature of science. Such messages could lie, for example, in her aims for
the session, the way she executes her teaching, her interaction with the children or her class
organisation. The crucial implication from this analysis is that if a researcher wishes to gain a
meaningful picture of this understanding, it is essential to design a methodology which takes
account of these and other indicators of tacit knowledge, for it is possible that i) they may
greatly expand the potentially inarticulate responses to questionnaires or interviews which a
teacher who has not reflected much about the subject might produce and ii) most significantly,
they may indicate understanding which could be in direct conflict with espoused knowledge.

Taking this idea in conjunction with the personal construct approach of Lakin and
Wellington, we have a situation which suggests that a teacher’s practice might be either the
repository or the embodiment of hidden complexities of her understanding. It therefore becomes
essential that the study of this practice becomes an integral part of the methodology, so that both
observer and teacher alike might appreciate more fully what the teacher ‘knows’. This decision,
however, brings one ever deeper into considerations of the nature of that practice, how best to
study it and the kind of knowledge of values, beliefs and intentions that such study might
convey.

c) the dialectical relationship between theory and practice

The logic of including the study of teachers’ practice in the methodology for the
identification of their understanding of science becomes further apparent if one accepts the
contention that all practice is inherently theory laden. Carr and Kemmis (1986) state that:

Teaching....can only be understood by reference to the framework of thought in terms
of which its practitioners make sense of what they are doing. Teachers could not even
begin to 'practise' without some knowledge of the situation in which they are operating and some idea of what it is that needs to be done.

(p.113)

This statement in itself does not imply anything other than a cause-effect relationship between theory and practice, but Carr and Kemmis move quickly to highlight what they see as a crucial reciprocity between the two:

The twin assumptions that all 'theory' is non-practical and all 'practice' is non-theoretical are, therefore, entirely misguided. "Theories" are not bodies of knowledge that can be generated out of a practical vacuum and teaching is not some kind of robot-like mechanical performance that is devoid of any theoretical reflection. Both are practical undertakings whose guiding theory consists of the reflective consciousness of their respective practitioners.

(p.113)

A practitioner's action cannot therefore be considered as simply containing propositions which stand outside that action and direct it. Both proposition and practice may be in a process of mutual construction of each other. As the teacher teaches, she is giving concrete form to ideas (tacit or espoused) which are clarified, extended or contradicted by her practice. Elliott (1989, 1991) suggests that there is a difference between ideas 'about' education and the 'educational' meaning of an idea that can only become clear in action. Such reasoning is close to that of Whitehead (1985, 1989). Pursuing the idea that all practice is driven by the participants' values, whether articulated or not, he considers that their meaning can only be identified through consideration of practice. He claims that to consider them as propositions standing outside practice is pointless.

This intimate relationship between theory and practice is explored in depth by Winter (1987, 1989). Grounding his thinking in Hegel's ontological reflections (Hegel 1977) he suggests that any social practice is constituted by a complex of contradictory elements, which are 'experienced in almost instantaneous succession as a single essence and a plurality of qualities, as universal and specific, as self-defined and as defined-in-relation-to-another' (Winter 1987, p.12). He claims that any attempt to understand practice must be dialectical. The understanding which informs practice is not 'theory', standing outside practice, but a process of 'theorizing' in which meaning resides in the nature of the relationships between the multiplicity
of elements which constitute the practice. Within this perspective, the reality of a teacher’s understanding is impossible to construct in propositional terms, but can only be accessed by appreciating the dialectical interplay of these elements as they exist in the experience of practice. Woods (1996) describes how this appreciation of the multilayered nature of reality has informed methodological discussion in the postmodern era of educational research. Approaching the field particularly from the perspective of ethnography (see Woods, 1986; Hammersley and Atkinson, 1995), he claims that we cannot understand the reality of practice without trying to identify the nature of the competing perspectives which constitute it. It does not exist ‘out there’, but in the continuing interaction between participants and those participants’ intentions, beliefs and values. Methodologically, he focuses specifically on trying to construct through symbolic interactionist analysis (citing, in particular, Mead, 1934; Blumer 1976) the nature of the meanings that the various participants in the social action of teaching bring to it. Such a form of understanding of reality is grounded in the exploration of the inevitable reflexivity that exists within the intelligibility of both propositions and actions; their meaning resides in the identification of the perspectives that both actor and observer bring to their understanding of them. There is thus the likelihood of ambiguity, with no ‘right’ interpretation. Winter summarises this as follows, emphasising the dialogic quality that constitutes reflexive analysis:

...reflexive interpretation is the language of questions: it questions my own interpretation along with others; its extrapolation poses as problematic the origin, the coherence, the grounds, of all perspectives; it is a form of questioning which attempts to speak for not against its interlocutor.....In this way, Heidegger’s notion of ‘thinking’ as reflexive questioning....shifts the criterion of validity from the level of a consensus concerning interpretation to consensus concerning theoretic grounds for a plurality of interpretations.

(Winter, 1987, pp. 128 - 129)

ii) The inclusion of action research and research imperatives 1 and 4

The analysis in the preceding section suggests that the methodology not only had to consider the teachers’ teaching of science, but also had to promote the teachers’ awareness of their practice. Without such enhanced awareness by the teachers, it would have been impossible to engage fully in the analysis of their understanding. External monitoring of the tacit messages
within the teachers’ practice was important, but it was also essential that there was an elicitation process which was effective in ensuring that the teachers knew what they knew so they could communicate their ideas more fully. Furthermore, the process by which the teachers came to know their own practice should ideally have helped to engage them in a dialectical and reflexive analysis of it.

For these reasons, it was decided that the need to accommodate the teachers’ perspective within the overall methodology could best be addressed by engaging them in action research on their own science practice. Action research was chosen because it can be carried out by individuals and because its driving force is the participants’ desire both to understand why their practice is as it is and to see how it can be improved. Ontologically speaking, action research reflects, in Guba and Lincoln’s terms, a ‘historical realist’ perspective, for although the situation within which practice takes place exists, its reality has been shaped by a variety of factors into what it now is. It is not ‘real’, but to the practitioner it can be taken as real. However, such ontological perspectives belong to people, not to words; teachers can participate in the process of action research without necessarily considering such positions. In addition, the identification of a clear methodology for action research is not entirely straightforward. There is much difference of opinion as to its definition and structure.

Reaching a definition of action research

Hollingsworth et al. (1997) begin the concluding chapter of Hollingsworth’s (1997) review of international action research projects with the somewhat alarming statement that:

If there is one single pattern that emerges from these chapters, it is that the forms, purposes, methods and results of action research around the world differ widely.

(Hollingsworth et al., 1997, p.312)

This situation is widely acknowledged. Carr (1989), commenting on the widely differing examples collated in Hustler et al. (1986), pointed to the great diversity of understanding that was developing throughout the eighties, and the position is still similar. Carr suggested at the time that ‘action research now means different things to different people and, as
a result, the action research movement often appears to be held together by little more than a common contempt for academic theorising and a general disenchantment with ‘mainstream’ research.’ (p.85). The criticism is telling, for some theorists, including Carr, have wished to prescribe aims and structures for action research and to dictate the effectiveness of the many ‘forms’ that exist.

Action research did not originate in education, but it has become an influential approach to research in the area over the last twenty five years. It is applicable to practice in any social situation and is about the understanding and improvement of that practice. Its history, however, exemplifies the complexity involved in reaching an agreed definition of its nature. Early work by Lewin with regard to group dynamics (Lewin, 1948) raised the idea that social practices could only be understood and changed by involving the practitioners themselves throughout an inquiry. The aim of the practitioner research, however, was to solve a problem. McKernan suggests that Lewin considered action research to be a form of ‘rational management or social engineering’ (McKernan, 1991, p.18). In common with contemporaries who began to apply action research to education (Corey, 1953; Taba, 1962), Lewin advocated a tightly controlled systematic methodology, based on evidence and evaluation. The aim was social or curriculum improvement, with the process driven by a goal determined at the outset but which could be redefined so that it remained appropriate.

Action research declined in the sixties, when a top-down, research, development and dissemination (RD&D) model pervaded the educational establishment. It reappeared in the seventies and became linked with the idea of ‘teacher as researcher’ advocated by Stenhouse (Stenhouse 1975). The goal of research now could be seen to have moved from the ‘technical’ end of achieving a practice that ‘worked’, to a more general ‘practical’ aim of understanding what made the practice what it was. But with this different perspective, a number of different conceptions of the purpose and nature of the process have appeared, obscuring a clear definition. Some writers, for example Carr and Kemmis (1986) and Elliott (1991) have chosen to represent action research as a number of clearly distinct processes, linked in some kind of
hierarchy of effectiveness. Their justification resides around either the level of collaborative activity involved or the mode of analysis used. Elliott distinguishes between ‘isolated’ and the necessarily collaborative ‘educational’ action research, claiming that when teachers reflect in isolation from each other they are likely to ‘reduce action research to a form of technical rationality aimed at improving their technical skills’ (Elliott 1991, p.55). “Educational’ action research is concerned more with the process of inquiry than its products and is empowering, enabling teachers to ‘critique the curriculum structures which shape their practices and the power to negotiate change within the system that maintains them’ (p.55). In order to understand practice, the hard evidence called for within the Lewinian conception has to soften, accommodating personal interpretations, the problems of communication and the negotiation of meaning. The aim of action research for Elliott is to promote a teacher’s ‘practical wisdom’ (Elliott, 1989) and can be thought of as a ‘moral science’ in which the aim is to realise moral values in practice.

Carr and Kemmis go further and suggest that action research can be differentiated into three clearly distinct types, ‘technical’, ‘practical’ and ‘emancipatory’. They draw parallels between these types and modes of inquiry in the social sciences, claiming that they relate to three ‘general forms that the human and social sciences can take (empirical, interpretive, critical)” (Carr, 1985, p.6, in Whitehead and Lomax (1987) p.178) and that they represent the three ‘knowledge-constitutive’ interests identified by Habermas (Habermas 1972). These interests direct our knowledge formation. The supposed objectivity of the positivist paradigm actually conceals a ‘technical’ need for prediction and control; interpretative social science has the ‘practical’ interest of understanding why a situation is as it is and how effective communication is promoted within it, but it works at the level of subjective understandings; only a reflexive, ‘critical’, stance, which can expose the objective context within which subjective understandings are formed will serve the ‘emancipatory’ interests of people by freeing them from the ‘dictates of compulsions of tradition, precedent, habit, coercion, as well

Carr, Kemmis and Elliott leave little doubt as to which kind of action research they value. But they are not without critics. Focusing particularly on Carr and Kemmis, Whitehead and Lomax (1987) object strongly to the proposal that action research can be ‘subsumed by traditionally competing social science paradigms’ (p.178). They state that ‘educational action research is an educational way of understanding education, with its own distinctive educational values underpinning it. We believe that Carr’s analysis omits the dialectical basis on which action research...has proceeded so far’ (p.178). Whitehead’s conception of action research locates the heart of the process very firmly with the individual, proposing that each participant is involved in the formation of her own ‘living theory’ (Whitehead 1985) out of the dialectical reality of her practice. Collaboration is not essential, except that there is an epistemological necessity to search for another’s point of view to help achieve validity in analysis.

Jennings and Graham (1996) emphasise the individual perspective further by applying a postmodern critique to the framework of technical, practical and empowering action research. They claim that there has been too much focus on procedures and methods, rather than ‘grounding the approach to data analysis in a social perspective.’ They ask: ‘how does a feminist action researcher differ from a phenomenological action researcher?’ (p. 267), claiming that these kinds of perspectives have not been adequately explored. Locating their argument in the work of Foucault (1980) and Lyotard (1984), they reject the notion of emancipation as defined in ‘critical’ action research, suggesting that the postmodern interpretation of the relationship between truth and power means that ‘knowledge is based on nothing more than a number of diverse discourses, each with its own rules and structures, with no discourse being privileged’ (Jennings and Graham, 1996, p. 273). (A similar position regarding science has been proposed by Feyerabend (Feyerabend 1975, 1978), see appendix 1). Jennings and Graham proceed to open up the question of definition further, suggesting that whilst there has
been 'a concern among educators to define action research in more precise terms', it is possible
that 'a static definition is neither feasible nor appropriate in a postmodern world' (p.276).

Hollingsworth et al. (1997) suggest how the minefield of definition might be
sidestepped. They state:

That (the fact that action research varies widely), more than anything, to me, is a point
well worth underlining: Action research has 'multiple' meanings and uses. Its 'potential'
cannot be judged apart from the 'ideological' bases which drive its practices, as well as
the material contexts......What we need to look for is NOT whose version of action
research is THE correct one, but rather, what it is that needs to be done, and how action
research can further those aims.

(Hollingsworth et al., 1997, p. 312.)

Such a calm acceptance of the range of possible action research has not always been the case; in
(1985) raged against what he saw as its hubris and its ironic lack of self-critique, likening the
action research 'movement' to the Salvation Army. Lewis (1987), similarly, was critical of
those who attempted to prescribe to teachers, claiming that he found little evidence of Carr and
Kemmis' 'familiarity with the practical world of teachers and the real problems which teachers
face' (p. 100). A similar criticism of the tendency to compartmentalise action research and thus,
by implication, judge the quality of teachers' research even before it had taken place, was raised
by Somekh (1988). Referring to a range of work then currently going on in schools, she said:

I am advocating that we should abandon narrow academic definitions of action research
which exclude some of the important work going on in schools at present .....most of
those teachers will be unconcerned whether or not we attach the label action research to
their work.

(Somekh, 1988, p. 6)

Zeichner (1993) displayed the same irritation with 'academic definitions':

When I use the term 'action research', I am using it in a very broad sense as a systematic
inquiry by practitioners about their own practices. There has been a lot of debate in the
literature about what is and is not real action research, about the specifics of the action
research spiral, about whether action research must be collaborative or not, about
whether it can or should involve outsiders as well as insiders, and so on....a lot of this
discourse, although highly informative in an academic sense, is essentially irrelevant to
many of those who actually engage in action research....

There are many different cultures of action research and it seems to me that an
awful lot of time and energy is wasted in arguing over who are the 'real' action
researchers and who are the impostors....

(Zeichner, 1993, pp. 200-201)
He stated that he would not adopt the 'now familiar distinction' between the various 'types' of action research, claiming that the classification created 'a hierarchy that devalues practitioners' (p.201).

Unfortunately, Zeichner did not discuss whether there might be a minimum definition of action research, making it hard to know exactly what he would accept as an example of the process. He mentioned that he was committed to what he saw as the 'values and principles' that were associated with action research, highlighting that certain attitudes may perhaps characterise the action research process, but the elements he mentioned ('its commitment to democratise the research process and to give greater voice to the practitioners in determining the course of policies that affect their daily work' (p. 293)) do not necessitate action research for their fulfilment.

Although there are many characterisations of the process of action research, often visually represented (see, for example, Lewin, 1947; Elliott, 1981; Kemmis and McTaggart, 1982; Ebbutt, 1985; McNiff, 1988, McKernan, 1988 - appendix 2), there can be seen to be certain common elements within them. These common elements can be thought of as constituting a 'bottom line' and were adopted as the basis for the teachers’ research in this inquiry.

1. Action research is about teachers striving to understand and to improve their practice. The position taken here is that, at the 'bottom line', this operates at a personal level. It may lead on to collaboration and a critique of the situation in which the practice is carried out, but this does not have to be a fundamental aim.

2. Action research proceeds through a process of planning, action and reflection upon action. This can be thought of as an action-reflection 'cycle':

48
Planning Zý
Reflection
or it can be expressed as a series of statements of intent:
I experience a problem when some of my educational values are negated in my practice.
I imagine a solution to my problem.
I act in the direction of the solution.
I evaluate the outcomes of my actions.
I modify my problems, ideas and actions in the light of my evaluations.
(Whitehead, 1985, p. 98)

3) Action research involves the gathering of evidence about practice;

4) Action research involves teachers trying to see the effects of planned change in their practice;

5) Action research strives to be systematic and rigorous;

6) Analysis and knowledge formation in action research belong to the practitioner.

Definitions of action research are so diverse and the ‘bottom line’ so general, that it may be better to describe it as an approach, not a methodology. In the context of the current inquiry, this approach was seen as being characterised by the teachers conducting an inquiry into their own practice and striving to understand it, researching, from the ‘inside’, questions which were relevant to them. Its focus was personal, though this did not rule out or even discourage collaboration. It was systematic, in that it involved the elements of the action-reflection cycle: an
attempt at focused action by teachers, the gathering of evidence for analysis and reflection and a
process of theorising and re-planning. But it did not follow any particular format or strive to be
thought of as any particular ‘type’ of action research. As Zeichner suggests, any further
stipulation or categorisation of individual participants’ research meets with problems. Progress
through the ‘cycle’ was variable. Some definitions of action research, for example Halsey
(1972), emphasise that a specific action, designed as an ‘intervention’ in normal practice, is the
crucial part of the process, but the identification of such action is frequently difficult. It is
possible to enter the research cycle at any stage and much time can be spent in evaluation and
reflection on existing practice before reaching any plan of revised action. This is particularly true
of classroom research and it is acknowledged that Halsey’s project was not focused on
classroom life. It does, however, highlight the dangers of defining the character of the process
too closely. As McNiff (1988) points out, the classroom is a complex environment and it is
difficult to maintain a ‘pure’ modified action. The idea of intervention in ‘normal’ practice is
naive, for focus upon practice will necessarily change it, no longer making it normal. As the
researcher has discussed previously (Waters-Adams, 1992), the heightening of consciousness
of an element of one’s practice means that action will become ‘tainted’ with reflection as it is
carried out, a process akin to Schon’s ‘knowing-in-action’ (Schon 1983). Action reflected upon
is likely to be modified as it is carried out, especially when that action is driven by the need to
ensure that children are learning.

The result of this conception of the process was that smooth, well-separated cycles of
planning - action - monitoring - analysis and reflection were not anticipated. There is a
seductiveness about more complex representations of action research, as they promise rigour
within a process immersed in the unpredictable nature of practice. But looking for rigour
through the definition of process elements is illusory. Rigour in action research depends upon
the commitment of the participants to act, to search for evidence and to be critical of themselves;
the exact nature or timing of action, the kind or amount of evidence or the style of analysis
cannot be defined. Furthermore, neither can the level of that commitment. Goodson (1991)
suggests that a teacher’s ‘centre of gravity’ is a crucial determinant of a teacher’s action and that
it might not lie in the classroom or even in teaching. Nias (1989) explores the relationship
between a teacher’s ‘situational’ and ‘substantial’ selves, again indicating that overlap between
the two is variable. Such analysis, which allows that teachers vary from those for whom

teaching is their ‘life’ to those for whom it is largely a way of paying the mortgage, suggests
that even ‘commitment’ is indefinable. Both types of teacher may engage in action research for
professional, ‘situational’ reasons, but their levels of engagement, and hence the potential depth
d of their analysis, may vary widely.

It is, however, upon commitment that action research depends. Carr and Kemmis
(1986) liken this commitment to the Aristotelian category of phronesis, the ‘disposition to act
truly and rightly’ (p.34). This ‘disposition’ drives the search for evidence and understanding. It
is unmeasurable, but it must be there. The teachers accepted the need for this commitment and it
was this that characterised their inquiry. It was not uniform, it varied according to immediate
pressures, interests or emotions, but it kept them involved for the length of a year.

Action research and the addressing of research imperatives 1 & 4

The preceding argument indicates why it was considered that involving the participating
teachers in action research would be a powerful method for addressing research imperatives 1
and 4. These were stated as:

1. The need for the methodology to be effective in accessing teachers’ ideas;
4. The potential to highlight significant links between teachers’ ideas and their practice.

Action research addressed these imperatives in the following way:
Imperative 1 - the need to gain access to teachers' ideas

- With regard to gaining access to teachers' espoused ideas about the nature of science, it has been suggested that effective elicitation will not take place unless the teachers have had the opportunity to be focused on the subject. As action research on their science teaching would be challenging them to justify their actions and explore their understanding of the subject, it was considered that it provided an excellent vehicle for promoting such a focus. Shulman's analysis of teachers' knowledge (Shulman 1986) suggests strongly that reaching decisions about pedagogical aims or objectives must involve subject content knowledge (including syntactical understanding). It was anticipated that action research would constantly be stimulating such decision making.

- Action research would also be effective at bringing teachers' tacit understanding of the nature of science to the surface for appraisal. Gaining access to tacit understanding is dependent on there being the opportunity for the researcher to observe and analyse a considerable amount of practice, so that 'theories in use' (Argyris and Schon 1974) can be seen in a variety of contexts. The action research process ensured that there was a much heightened focus on the teachers' science teaching for over a year, giving plenty of opportunity for this to happen. The observation of practice was dependent on the derivation of a research relationship between participant and outside researcher that would not compromise the personal nature of the action research (see point 6, above). This was achieved through involvement of the researcher in observation of the teachers' sessions at their own request, as part of their action research. Negotiation of the focus of the inquiry at the outset of the project ensured that teachers were willing to allow the researcher access to what was, from an action research perspective, their own data. It was acknowledged that the researcher had two roles, facilitator and researcher, and that these were not incompatible (see discussion regarding research imperative 3, below).
Imperative 4 - the potential to highlight significant links between teachers' ideas and their practice

- It has been suggested that a dialectical relationship exists between the nature of teachers' understanding of science and their teaching itself. Winter (1989, pp 46 - 55) provides a lucid overview of the nature of dialectics and dialectical analysis. Dialectics represents both a theory of reality itself and a way of understanding it. Within a dialectical perspective, nothing stands alone; there is no such thing as a simple unity. Any phenomenon, be it an object, a person, a practice or a social situation, is only understood by taking account of the two sets of relationships which comprise it: the relationship between the elements of which the phenomenon is constituted and the relationship between the phenomenon and the context within which it exists. At the heart of this perspective, therefore, lies a contradiction: a phenomenon is a thing, yet it is also many things. The book is a book, yet it is also made up of words, paper, pages and cover and it gains meaning as a book because it is a book amongst other books of the same kind, within the milieu of ideas which inform them. A class is an entity, yet it is made of a teacher and individual children and it lies within a school and the political structures which govern them. Both Winter and Whitehead (1989) trace the perspective to Plato. In the Phaedrus, Socrates says:

> I am myself a great lover of these processes of division and generalisation; they help me to speak and to think. And if I find any man who is able to see a ‘One and Many’ in nature, him I follow and walk in his footsteps as if he were a god. And those who have this art, I have hitherto been in the habit of calling dialecticians...

(Plato, 1871, p.475)

To understand a phenomenon dialectically involves the exploration of these relationships. The elements are interdependent in that they form the unity of the phenomenon, but individually they are different and thus potentially in opposition. The teacher teaches her class in the school, but the children’s interests will be different from hers and her educational values may clash with those of school policy. There are contradictions within the unity of the phenomenon of her teaching. Because of these contradictions, her teaching has the continual potential for change. Analysing her teaching dialectically will help
to highlight those contradictions and suggest from among the great number that can be identified those relationships which might be significant in explaining that change.

McNiff (1988, 1993), along with Winter, suggests that the process of action research can help to promote dialectical analysis. In striving to understand her teaching, the teacher will need to explore the elements which constitute it. Action, reflection and planning proceed through the teacher identifying the contradictory aspects that are preventing her from achieving what she wants to in her teaching. The analysis feeds into new (hopefully improved) teaching and it also feeds into an understanding of why her teaching is as it is. In the context of her teaching of science, theory (her ideas about the nature of science and the way it should be taught) and practice are not separate, they are constitutive elements of the phenomenon of her teaching. Action research should promote analysis which determines whether they are in accord with each other or whether there is contradiction between them.

A propositional representation of theory and practice, as if they exist as separate unities, fails to reflect this essentially dynamic relationship between the two. Theory is practice, for understanding of the nature of science is one element that makes the teacher’s action what it is. Theory also underlies tacit understandings, which may be in contradiction with espoused ideas. In these terms, propositional analysis becomes inadequate. A teacher’s understanding of science may consist of two, possibly contradictory, elements, espoused and tacit, whose meaning, in the context of her teaching, only lies in the reality of her action. The diversity can only be understood by exploring the nature of the unity within which they appear.

Action research depends on such an exploration; focus on the relationship between ideas and practice is the impetus behind the process. It follows that the involvement of the teachers in action research would be an effective way of producing a situation in which significant ‘theory-practice’ relationships might be highlighted.
iii) The overall methodological structure and research imperative 3

Research Imperative 3:

- *That the methodology can access adequately the nature of the teachers’ practice.*

It must be stressed that the overall methodology of the inquiry was not action research and that the epistemological attitudes possible within that form of inquiry were not necessarily those of the inquiry itself. Action research was included as a research tool for the greater inquiry, because it was considered that it constituted a valid way of generating evidence of teachers’ practice and understanding. It was a means to an end; in the final analysis, this knowledge contributed to, but did not constitute, the findings of the inquiry. It was inquiry within an inquiry, the results of one acting as evidence for the other.

The preceding discussion has indicated the potential of action research for gaining access to the reality of teachers’ practice. For a methodology to do this, it must be able to probe the tacit, cognitive and active elements of practice. It has been argued that the inclusion of a dialectical perspective within analysis will enable this generation of understanding; if this understanding can be seen to have transferred from the teachers’ personal inquiries to the main inquiry, then the research imperative should have been adequately addressed. However, the structure of the overall inquiry, in which the action research is seen as a separate action undertaken by the teachers, needs to be justified. It needs to be shown how the action of the researcher in gathering evidence for this overall purpose did not compromise the process of the teachers’ action research and thus the evidence itself.

In the first place, however, the issue of the researcher’s role needs to be clarified. It is a further area of debate within action research methodology. Whitehead (1985, 1989) emphasises strongly the personal nature of action research. Grounding his approach in Polanyi’s contention that any claim to knowledge must involve an awareness by the knower of the fact of knowing and that an individual is responsible for her own knowledge (Polanyi 1958), he derives a characterisation of action research in which the practitioner owns the knowledge formation within it. This characterisation is, however, at odds with those which suggest that action
research can be carried out in partnership between practitioner and outside researcher, for example the GIST project described by Kelly (1985). Within Whitehead’s conception, the practitioner is responsible for the focus of the inquiry, the action undertaken and the knowledge generated in analysis; in Kelly’s, the ‘Project team’ consisted of academics and teachers, with the academics largely responsible for analysis and ideas for action (p. 135). Elliott (1991) describes an intermediate position that he and Adelman adopted in the Ford Teaching Project (Elliott and Adelman 1976), with ‘first-order’ action research (that undertaken by the practitioners themselves, similar to Whitehead’s), and ‘second-order’ research undertaken by a co-ordinating team, designed to facilitate the ‘first-order’ research (Elliott, 1991, pp. 30-31).

The position taken by this inquiry was that of Whitehead. Action research belongs to the teacher, with teachers responsible for knowledge-generation and action planning within it. Analysis is theirs, against their own educational intentions, and so is the choice and gathering of evidence to inform that analysis. It can immediately be seen that the researcher’s role in this inquiry was therefore somewhat problematic. In collecting evidence for his own inquiry, he produced the lesson observations used by the teachers and he was involved in the teachers’ reflection and analysis. This did not, however, compromise the teachers’ action research. The researcher had two, simultaneous, roles, dependent upon the perspective from which he was viewed. The teachers decided that lesson observations would provide useful evidence of their practice and, if they wished, specified their focus; from the perspective of their action research, the fact that the researcher was collecting data from them, and would use them in his analysis for the overall inquiry, was irrelevant. He was simply being used as a tool by the teachers to provide evidence for their reflection, much as a video camera might have been. It would be naive to assume that his own selectivity did not enter into the record (see reliability section, next chapter), but this was acknowledged and a format agreed which attempted to make this selectivity clear where it occurred. The scope and focus of the observation were at all times under the control of the teacher. In the same manner, the researcher adopted a reflective approach to feedback after sessions, clarifying aspects of the observation record rather than
trying to lead analysis. The agenda for discussion still lay with the teacher. In this way, it was felt that the principle of personal knowledge construction by the practitioner within action research was maintained.

If the involvement of the researcher did not compromise the teachers' action research, it is probable that a research situation had been established in which it was extremely likely that valid understanding of the elements of the teachers' practice could be gained by the overall inquiry. This is not to claim that the account presented here of the teachers' practice and understanding is the only one possible; the ontological position of critical realism accepts a problematic relationship between observational evidence and reality. However, the immediacy of the evidence that derived from the teachers' action research and the fact that it dealt with the three central elements of practice - tacit, cognitive and active - mean that, in potential at least, a valid access was possible.

iv) Addressing research imperative 2

Research Imperative 2:

• That the methodology must be able to accommodate a range of possible epistemological positions.

Koulaidis and Ogborn (1995) criticise many studies of teachers' understanding of the nature of science on the grounds that they do not make explicit the philosophical assumptions which underlie their analysis. They state that this 'seems to stem from the fact that most fail to recognise that there are conflicting models of science from a philosophical...standpoint':

It is one thing to propose and/or defend a certain philosophical system, and quite another, when engaging in exploratory work with the purpose of recording somebody else's views, to obscure the fact that conflicting – and sometimes quite incompatible – systems of thought do in fact exist.

(p.277)

The outcome of this oversight, they claim, is that analysis of data must be suspect, for the basis upon which such analysis has taken place has not been identified.
The research stance adopted in this study deals comprehensively with Koulaidis and Ogborn's criticism. It promotes validity through both its methodology and its form of presentation and, in so doing, provides a critique itself of Koulaidis and Ogborn's own work (Koulaidis and Ogborn, 1989), or that of any study which relies solely on quantitative methods for the identification of teachers' conceptions. Following Koulaidis and Ogborn's critique, it can be seen that a valid study needs to ensure two things:

- A clear statement regarding the criteria used to interpret teachers philosophical positions;
- A methodology which allows teachers' positions to be identified.

The first point is addressed in the philosophical overview given in appendix 1. This expresses the researcher's understanding of a range of terms used in the methodology and epistemology of science and presents the basis for analysis within the thesis and — importantly — upon which it took place during the study. From the range of positions identified, the main categories of importance to analysis in this study are: positivism, inductivism, hypothetico-deductivism, falsification, realism, relativism, contextualism and the status of scientific knowledge.

However, the most crucial facet of the study which promotes validity relates to the second point. A methodology must appreciate the dialectical nature of the teachers' understanding, the idea that their understanding of the nature of science may be formed by the activity of their teaching of science (Nott and Wellington, 1996). In addition, it must acknowledge that most teachers (especially primary) are not used to reflection on the nature of science. They are unfamiliar with the terminology and uncomfortable with the expression of their ideas. Direct questioning, whether it be verbal or through a questionnaire (for example, Koulaidis and Ogborn), is unlikely to identify teachers' understanding clearly.

The inclusion of action research addressed these concerns. First, it provided an extended timescale, within which the teachers could become familiar with talking and thinking about their
practice in general and science in particular. This allowed possibly tentative thoughts about
science to be rehearsed and refined, allowing greater accuracy in meaning than a simple
‘snapshot’ would have done. Second, it allowed for the teachers’ conceptions of science to
become apparent in other ways. As will be seen, the teachers frequently conveyed their
epistemological understanding through descriptions and analysis of their practice; they seemed
much more at home talking in this way. The continual reflection promoted by their action
research enabled this kind of data to become available for the wider study. Third, action
research allowed the identification of those dialectical elements inevitably ignored by quantitative
methods. Nott and Wellington’s proposal suggests that the recognition of these elements is
essential in understanding teachers’ conceptions of science and, therefore, in the identification
of the nature of any influence between those conceptions and practice.

Finally, the range of data type collected was also important. Much data for the overall
study derives from that generated within the teachers’ action research; it is also supplemented
from other sources. The next, and final, section of this chapter demonstrates how the choice of
case study presentation for the data enables a further level of validity; it allows the engagement
of the reader in the generation of meaning from the experience of the inquiry.

3. Validity in presentation

The key question to be addressed in this section is that of the relationship between the
account presented here and the reality of its subjects - the phenomena of the teachers’
understanding of the nature of science and their practice. It is not only important that the account
should render a description of that reality which is believable to the reader, but that the
description should be seen to present a picture of that reality which can be thought of as a valid
representation of what happened. A great many accounts could be believable whilst being
merely fictions. This does not mean that the account must be true, for it has already been
accepted that a position of critical realism holds that ultimate access to reality is not possible and
that, as a consequence, no account can be entirely accurate. What the account must demonstrate,
However, is a credibility in analysis and presentation which is grounded in demonstrable connections between itself and its subject.

Case Study and the form of presentation

The products of the inquiry will be presented as four case studies (Stake, 1978) of the teachers. The term is used cautiously, for definitions vary. Borg and Gall (1989) claim that most case studies are based on the supposition that each case presented can convey something that is ‘typical’ of others in the same situation. Stake (1994) disagrees, suggesting that much valid case study consists of study of the single case for its own sake. He terms this intrinsic case study, in which the object is not theory building about a generic issue, but simply interest in the case itself. Reports of such studies are presented without further analysis. Through processes of ‘naturalistic generalisation’ (Stake and Trumbull 1982), the audience ‘comes to know some things told, as if he or she had experienced them’ (Stake, 1994, p.240). Although Stake appreciates that learning from such intrinsic studies ultimately derives from comparison with other cases, this particular approach gains its strength by delaying the process. He claims that comparison works by ‘fixing attention upon the few attributes being compared and obscuring other knowledge about the case’ (p.242) and as such will limit what can be learnt. He contrasts intrinsic studies with instrumental and collective case study, in which the case (or cases) becomes subordinate to the overriding aim of shedding light on a greater issue. Instrumental case study deals with a particular case, chosen because it is expected to promote understanding of the greater issue; collective case study is an extension of this to involve the joint study of a number of cases.

The studies presented here are examples of collective case study, for the overriding aim is to look at the generic question of the relationship between teachers’ understanding of science and their practice. With this aim, the cases sampled must be intended to be representative of cases as a whole, otherwise any generalisation would be meaningless. Yet the assumption is problematic. Such a position implicitly carries a suggestion of researcher bias; how does the
researcher know that they are representative? Furthermore, as Huberman and Miles (1994) suggest, comparison of cases can easily mean that the search for common characteristics results in 'a smooth set of generalisations that may not apply to any single case. This happens more often than we care to remember'. (p.435).

But Stake's categories are not absolute. In reality, he suggests that they are messy, with blurred boundaries and that reports rarely fit neatly into them. It is their heuristic function in illuminating and directing purposes that is important. It is suggested that the studies here are presented as a mix of collective and intrinsic approaches. They serve the instrumental function of potentially shedding light on the research questions, which are formulated in generic terms. The individual cases can be thought of as representative of primary teachers as a whole. At the same time, however, it is recognised that the studies represent the understanding and practice of only four teachers and that, for reasons already discussed, the situated and personal nature of their practice make generalisation difficult. Yet some form of generalisation must be relevant to a research inquiry. This generalisation may be left to the reader, through the application of insights generated by a carefully crafted account, which enables her to experience the subtleties of the research situation vicariously and to apply them to her own experience. On the other hand, the researcher may grasp the nettle and relate his study to the wider world of which it is self-evidently a part. The position taken here is that there is a responsibility for a research account to do the latter. Whilst knowledge construction may be personal and the world may be ultimately unknowable through the cognitive processes available to us, the activity of research itself implies a desire on the part of the researcher to increase human understanding. To state that generalisation is impossible is itself a generalisation. The limitations of generalisation must be acknowledged, but it is important to acknowledge that it is an inevitable part of the research process itself. Hamilton (1981) recognises the situated nature of the evidence that gives rise to generalisation regarding social phenomena and that it exists within a constantly changing, unknowable social reality. But the activity itself is still possible. For Hamilton, generalisation is the offering of ideas, not a claim to truth. 'To generalise', he states, 'is to render a public
account of the past, present or future in a form that can be ‘tested’ through further action and inquiry’ (p.236).

In order to present the data which will lead to this researcher’s offering of speculative generalisations for others to ‘test’ in their own lives and research, a series of four studies will be presented. These rely on a descriptive-narrative approach in which ‘stories’ of the teachers’ inquiries are presented. It is acknowledged that the structure and presentation of the stories is inevitably selective and that on-going analysis is inevitable, but it is hoped that the researcher’s theoretical frameworks are made clear and that analysis is as transparent as possible (see Chapter 4). A story, which allowed space to present the teachers’ words and actions in their original form was deemed to be most important, in order to let the teachers’ individual voices (Goodson 1991) come through. It has already been mentioned that the teachers seemed to be most at home talking about their practice and that it was within this talk that many clues as to their wider understanding of science could be gleaned.

Woods (1996, pp. 56-61) reviews a wide range of current approaches to the question of validity within accounts of qualitative research. He explains his own position as one of a ‘scientific ethnographer’ (p.60), in which a search for objectivity can and should exist alongside a realisation that a ‘thick description’ (Geertz 1973) which tries to paint a picture of the research situation, conveying an idea of the thoughts, feelings and contexts which made the inquiry a process, is also necessary. There is a clear need for evidence to be accessible to the reader and he suggests that Hammersley’s criteria of plausibility and credibility may be useful in judging the validity of an account (Hammersley 1990):

Hammersley (1990, p.61) opts for principles of plausibility (is a claim likely to be true given our existing knowledge?) and credibility (does a claim seem warranted ‘given the nature of the phenomenon concerned, the circumstances of the research, the characteristics of the researcher, etc.’). If neither of these applies, we shall require evidence to be convinced, and this evidence must also be put to the test of plausibility and credibility.

(Woods, 1996, p.57)

These criteria appear important and it is assumed that this account must present itself in such a way that it fulfils them. In the same argument, Woods refers to Altheide and Johnson’s (1994)
suggestion that the ‘categories and ideas used to describe the empirical world’ become ‘part of the phenomena studied empirically and incorporated into the research report’ (p. 489, in Woods, 1996, p.57), a suggestion which reflects the reflexive nature of knowledge construction. This need to represent clearly the frames of understanding brought to the analysis is also taken to be crucial, for, without them, the reader will not be able to reconstruct the research situation adequately and will have to take much of the report at face value. To this end, there is an undertaking within this account to acknowledge and explain the subjective perspectives which the researcher brought to the inquiry. In accordance with Hammersley, the reader needs to have access to key data gathered throughout the inquiry so that the researcher’s analysis of it may be understandable.

The presentation of the account must therefore achieve a descriptive validity. If this is achieved, then further layers of analysis and theoretical speculation within the account have at least a solid foundation. Wolcott (1994) however, debates whether any further search for validity is meaningful. For Wolcott, the inevitability of subjectivity within research means that the idea of striving for a ‘valid’ representation of what is acknowledged to be an impossible, unknowable reality is spurious and unhelpful. Report writing should aim for ‘rigorous subjectivity’, aiming ‘to understand, rather than to convince’ (in Woods, 1996, p.58). An account should be thorough, internally consistent and written with integrity, but it does not have to worry about trying to represent a ‘truth’:

What I seek is something else, a quality that points more to identifying critical elements and wringing plausible interpretations from them, something one can pursue without becoming obsessed with finding the right or ultimate answer, the correct version, the Truth.


Woods suggests that the aim of this approach is ‘not perhaps just understanding, but self-understanding’ (p.59). However, such an extra dimension to this account would not, in Wolcott’s terms, be helpful. As discussed, the ontological position adopted in this account accords broadly with Guba and Lincoln’s (1994) category of critical realism, because the research questions as framed may be best addressed by adopting that stance. The
inconsistencies in positivism and its inapplicability to social research (at least in its ‘naive’ form) are largely accepted; it is therefore possible to consider a research approach as largely a matter of individual choice and belief, bound only by demands upon its internal consistency. (See Guba and Lincoln, or Jacob, 1987, in which ‘paradigms’ are not presented hierarchically but as competing world views.) Therefore, whilst it is acknowledged that there is an inevitable subjectivity within this account, the exploration of that subjectivity will go no further than an attempt to articulate the preconceptions that the researcher has brought to the inquiry. It is not intended to be a reflexive voyage of self discovery.

The account now moves to a description of the research itself and the methods used to gather data within it, considering their reliability and the kinds of analysis that led to the case studies.
Chapter 4

METHODOLOGICAL DISCUSSION 2 – Methods, Reliability and Analysis

Introduction

The purpose of this section is to give a detailed account of the research methods used during the inquiry. It is a long chapter, but its length is necessary. The case studies were built upon data deriving from a wide range of different procedures; it is important that the study establishes the grounds upon which reliable inference is claimed. Moreover, strong theoretical claims have been made for the methodological approach adopted within this inquiry; it is necessary for the account to indicate in detail how the differing procedures meet those claims. This chapter discusses the methods used, their nature and purpose, their administration, their reliability and how the data they generated was analysed. It begins, however, with a brief description of the structure of the research and of the teachers involved.

1. The structure of the research

The four teachers involved in the research were all practising in the same school, a ‘combined’ first and middle school with an intake from Reception (4-5 years) to Year 7 (11-12 years). It was hoped that a balance between Key Stage One and Key Stage Two teachers would be possible and, to this end, five teachers were involved initially, covering Reception (2), Year 2, Year 4 and Year 6. There was an introductory period during the summer term 1995, in order to commence a year’s detailed inquiry through the academic year 1995-1996. However, two teachers - both with Key Stage Two classes - withdrew at the end of the introductory period, (one because she no longer wished to be involved, one because she left to take up another position) and one teacher changed age range for the next academic year. This meant that the three participants left were all to be teaching either Reception or Year One classes during the main research year. Fortunately for the breadth of the inquiry, a new member of staff joined the research in November, working through from January 1996 to December in the 1996-1997 academic year. She taught upper Key Stage Two children,
also changing age focus during her involvement. The overall age foci of the teachers was thus:

Teacher 1 - 'Elizabeth'
Teacher 2 - 'Carol'
Teacher 3 - 'Heather'
Teacher 4 - 'Andrea'

The overall focus of the teachers was therefore still heavily weighted towards children in the early years of schooling. This potential significance of this feature is explored in the Discussion (Chapter 7). The experience of the teachers varied from two years (Carol and Andrea) to twenty two years (Elizabeth). The following table summarises the main points of their training and experience:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Training</th>
<th>First degree( if relevant)</th>
<th>Number of years teaching (at start of project)</th>
<th>Ages taught</th>
<th>Post held during the research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andrea</td>
<td>B.Ed. Primary (Humanities)</td>
<td></td>
<td>Two years</td>
<td>Year Two, Year Five, Year Six</td>
<td>Science Co-ordinator</td>
</tr>
<tr>
<td>Carol</td>
<td>P.G.C.E. Dance/Drama</td>
<td></td>
<td>Two years</td>
<td>Reception</td>
<td>Art Co-ordinator</td>
</tr>
<tr>
<td>Elizabeth</td>
<td>B.Ed. (Early years 4-8; Mathematics) CAPS (mathematics)</td>
<td></td>
<td>Twenty Two years</td>
<td>Reception, Year One, Year Two, Year Three</td>
<td>Key Stage, One team leader</td>
</tr>
<tr>
<td>Heather</td>
<td>P.G.C.E. B.A. Combined Studies (Human Geography)</td>
<td>Five years</td>
<td></td>
<td>Year One, Year Two</td>
<td></td>
</tr>
</tbody>
</table>

With the exception of Elizabeth, it is clear that the teachers were relatively inexperienced. Portraits of the teachers, highlighting characteristic features of their general teaching and their management of the learning environment within the classroom, are included in appendix 9.
General chronology

Teachers worked with the researcher on average once a week, for approximately an hour and a half. Following initial negotiation of access and acclimatisation, there was a general reconnaissance period in which a series of lesson observations and informal discussions took place. In the cases of Elizabeth, Carol and Heather, this lasted from early in the summer half term 1995 until the end of term. With Andrea, this period was a little shorter, comprising about four weeks towards the end of the autumn term 1995-1996. For Elizabeth, Carol and Heather the period culminated in a formal semi-structured interview; for Andrea a more informal discussion fulfilled the same purpose of identifying a preliminary focus for action.

The teachers then worked with the researcher for a further three terms.

Access and ethical considerations

Woods (1996) describes the demand that qualitative research techniques put on the researcher. The list is daunting:

It involves negotiating access, developing rapport, trust and friendship, sociability, inclusion, identification with the others involved, sensitivity to their concerns, and ability to appreciate their feelings as well as cognitive orientations.

(p.61)

Qualitative research derives its name from an understanding that research questions involving human participants cannot be answered meaningfully by the sole use of methods which look for measurable, quantifiable elements of human behaviour. Human behaviour is considered to be such a complex mix of action, intention, understanding (shared or individual, espoused or tacit) and symbolic communication, that reliance on quantification represents a reductionist approach to a research situation which is untenable. Rather, it becomes the job of the researcher to use methods which attempt somehow to access this complexity, methods which allow the researcher to understand something of the 'quality' - the ultimately indefinable mix of all these elements - of the situation within which the behaviour takes place.

As a result of this, however, qualitative research brings with it specific ethical demands. The qualitative researcher is not only looking at people's lives, he or she is
engaging with them. Because qualitative research probes beneath the surface of the easily measurable and opens up participants' beliefs, values, intentions, actions and interactions, the researcher has to ensure that those participants' lives are safeguarded. Confidentiality and trust between participants and researcher is essential. The participants need to feel safe in the researcher's hands. But it is not all one way traffic. Successfully administered ethical procedures, in which participants feel secure, become themselves an important element of the whole research approach, with the quality - and thus the validity - of the data gathered increasing. The more natural a situation feels, the more normally a participant will behave.

At the outset of the research for this thesis, an ethics protocol (appendix 3) based on University of Plymouth guidelines was discussed firstly with the Headteacher of the school, through whom access to the teachers had to be negotiated, and then with those interested in participating. There were no problems involved in reaching agreement regarding the issues it contained. Lack of extended discussion about its content was perhaps a little surprising, but the school was used to working with external university researchers, having a history of close involvement with another local university. The time spent with the Headteacher was useful, as a clear message regarding the research was passed to the staff, along with a strong sense of support, thus considerably easing the initial access.

The content of the ethics protocol is general and could apply to all research, qualitative or quantitative. Certainly consent, honesty, the right to withdraw, confidentiality and the need to ensure children are not put into a position of harm represent a desirable code of behaviour for anyone working in classrooms. However, it is the degree to which some of these aspects gain more importance that distinguishes their place within qualitative research. Finch (1985) makes the point that such ethical questions are not absent in quantitative research, but suggests that the distance a quantitative researcher is able to maintain from his or her 'subjects' renders the questions 'less personally agonising' (p.117). She talks about the way in which a qualitative researcher may be granted 'privileged access to information which is usually private or invisible' (p.117). Interviews may deal with personal details that would not normally find their way into the public arena; lesson observations or reflective commentaries might raise perspectives on a teacher's practice which might be significant.
within the micropolitics of the school. In the face of these possibilities, the degree to which qualitative research needs to be open and honest and needs to maintain confidentiality becomes crucial.

It was essential that all participants felt comfortable with and in control of the research process. Continual discussion of the direction of the research, the ownership by individual teachers of their focus within the action research, the use of open and non-judgemental observation strategies (see below - lesson observations) and the testing of the researcher’s perceptions through strategies such as respondent validation (see below - portraits), all served to maintain a climate of openness and gave confidence to the participating teachers. Confidentiality was maintained throughout the inquiry and is maintained within this account by the use of pseudonyms for all participants, although it is recognised that the provision of personal information such as that included in Table 2 would make identification of the teachers possible, should the name of their school be known. This will need to be addressed when the main findings of the research are disseminated to the teachers and Headteacher.

2. The research methods

General

A range of mainly qualitative procedures was used during the inquiry, generating a variety of data which fed into the analysis. These data can be thought of as consisting of two main elements:

- that which was generated from practice:
  - regular participant and non-participant lesson observations;
  - notes of post-lesson reflective discussions;
  - written evidence of teachers’ aims, planning and reflection.

- that which was generated away from the immediacy of the teachers’ practice:
- regular focused, unstructured interviews;
- teachers’ reflective commentaries;
- researcher’s analytic memos;
- a bi-polar semantic differential scale concerning possible epistemological positions;
- a questionnaire concerning general pedagogical beliefs and values.

The following section will discuss each of these in turn, dealing with four aspects:

i) the administration of the strategy - frequency, dates, participants, etc.

ii) the nature and purpose of the strategy itself;

iii) the reliability of the strategy;

iv) an example of analysis and its contribution to the case studies.

Each method may appear as though it stands on its own. It should be remembered that many of the methods themselves were important constituents of the teachers’ action research and thus were dynamically interrelated within the inquiry itself; in addition, each method gives a different, yet overlapping perspective on the teachers’ practice out of which the general case studies are drawn.

**Methods used to generate evidence within the immediacy of practice**

1) Lesson observations

i) Occurrence

Participants: All teachers.

Frequency: Weekly, as an integral part of the teachers’ action research.

Format: Hand written/video taped.

Researcher role: Generally non-participant.
Nature of evidence: Verbatim record, in a table.

**ii) Nature and purpose**

The lesson observations provided strong evidence of teachers’ tacit understanding of the nature of science. Generally, a non-participant style was adopted and copious observations were made of teachers’ practice. The observations had dual roles. In the first instance, they were a vehicle for teachers to gain evidence of their practice for their own reflection. In a very real sense they were *their* observations, relating to their action research focus. The analysis of the teachers’ understanding of science occurred outside this process. The focus for observation was determined through discussion with the teachers at planning meetings, in which they were encouraged to specify those elements of the forthcoming session about which they would wish to receive feedback. Most observations were hand written, but a few were video-taped.

- Hand written.

It was anticipated that the structure of observations would vary significantly from lesson to lesson, depending on the teacher and her individual focus. In the event, after a few initial pilots, a structure was agreed that was applicable to most situations. The design had to meet the following criteria:

  i) that it was capable of being focused on the teacher’s current interest;

  ii) that it had the scope to record other evidence which might be significant for both the teacher and the overall inquiry;

  iii) that it was relatively objective;

  iv) that it was manageable;

  v) that it was straightforward to analyse.

With the exception of a few with Andrea, all observations therefore were recorded in the following structure. An A4 page in landscape format was divided into two main columns, with a smaller one to the right hand side (see fig. 1).
The main columns gave space to record the teachers’ and children’s actions or words as the lesson progressed. In agreement with the teachers, it was also possible for the researcher to note issues or questions that came to mind as the lesson progressed. These were largely to act as additional ‘prompts’ for teacher reflection. They were not intended to be judgemental (See Reliability). The observation structure did not, normally, include timings; this was not deemed necessary. However, in the case of Elizabeth, the observations were often accompanied by video recording, within which general timings were apparent, if needed. Examples of the format in action can be seen in the appendices, e.g. appendix 4. At the conclusion of the session, both parties had copies of the record. Feedback consisted of discussion of the record to ensure clarity in interpretation and focused questioning designed to help the teacher reflect on her performance and its effects.

- Video taped.

Video taping either accompanied written observations or was the only form of observation within the lesson. The first procedure was used primarily with Elizabeth, to allow her to focus on the interaction between herself and the children more carefully. It also allowed her to relate the researcher’s written observation thoughts to the action of the lesson. The second procedure was used exclusively by Andrea, primarily to give extra evidence of children’s performance. A disadvantage of this procedure was that there was little scope for feedback and reflection immediately post-lesson and the researcher usually did not have the opportunity to view the tape for a week, as the
teacher needed to keep it for her own reflection. Eventually, both parties had copies. There were, however, considerable advantages, including the focused discussion that arose during joint viewing of the tape and the opportunity it gave the teacher to play the tape to her children.

iii) Reliability

- Researcher influence

This is a general issue, but will be dealt with here because a non-participant style of lesson observation presumes that the researcher can separate himself from the lesson under study. Such a presumption is problematic, for researcher influence is unavoidable in any structure, see for example, Adler and Adler (1987) or Hammersley and Atkinson (1995, p.129 et seq.). Some factors may have helped to minimise the inevitable distortion of the research situation caused by the introduction of an outside adult into the classroom.

1) Familiarity:

After the initial introductory period, the researcher became a very familiar person in the school and especially in the participants' classrooms, with visits usually once a week but sometimes more frequently. This meant that he tended to be accepted easily by the children. This is not to say that his presence had no effect on the situation, but this familiarity meant that children behaved naturally with him, thus allowing for near normal interaction with the teacher during the session.

2) Style and Position:

It has already been noted that the format of the hand written observations varied little, both from lesson to lesson and from teacher to teacher. This enabled the researcher to generate a very consistent style of recording. As much of the work, especially with Elizabeth, Carol and Heather, tended to be small group work around a table, the researcher was able to adopt a relatively consistent seating position. The net effect was that, from the children's perspective, he always seemed to be doing the same thing, with
the result that he was predictable and thus relatively uninteresting (see Hopkins (1985), p.87).

- Researcher bias
  1) Lack of common agreement about the nature of phenomena:
  It is easy for researcher bias to affect lesson observations. If an observation schedule is used, it runs the risk of including an idiosyncratic interpretation of the behaviour under study, with a consequent reduction in the objectivity of the record. To cope with this tendency, the schedule must be carefully piloted. This risk was minimised in the observations undertaken in this inquiry. The focus of observations was often general, and records were descriptive, or near-verbatim. Teachers agreed the format of the observation records; they also reported that the records reflected their own subjective experience of the lessons.

  2) The inclusion of the researcher's thoughts or ideas:
  Within personal action research, the practitioner needs objective evidence to help her decide whether her chosen action is working; the addition of the researcher's own thoughts into a lesson observation might compromise that objectivity. However, it must be remembered that the researcher is a university lecturer in science education. The teachers were committed to the process of reflection within their action research, but they inevitably wanted to ask questions. Rather than be continually drawn into open agenda discussion about science teaching which would most certainly have influenced both their teaching and their thinking, the inclusion of thoughts in the immediate context of their own research seemed the best compromise in the circumstances. Researcher influence is impossible to eliminate; this was an attempt to acknowledge its presence and minimise its effect.
With regard to the video taped sessions, the immediate problems raised by the inclusion of the researcher's thoughts in the written observations were eliminated, but replaced, of course, by an inherent selectivity in camera work.

- **Teacher verification**
  Observed lessons sometimes lasted for up to an hour. The observation format adopted was demanding, taking concentration and speed of writing to record the lesson as it progressed, with copious pages of notes being produced. It is inevitable that some information was lost. However, it was remarkable that all four teachers validated the records, considering that they gave an accurate representation of the lessons as they had perceived them, particularly with reference to pacing and the recording of key interactions with the children.

iv) **Analysis**

The lesson observations gave strong indications of the teachers' understandings of the nature of science, both espoused and tacit. Careful analysis of the content of lessons showed that as the teachers' approaches to teaching science changed, there was frequently conflict between espoused positions and tacit messages in their action. Lesson observations were perhaps the most powerful vehicle within the inquiry for drawing the teachers' attention to the existence of conflicting elements in their practice and they were instrumental in maintaining the dialectical challenge of the teachers' own research. As with all the evidence, it is important to emphasise that the lesson observations do not stand alone, but in terms of direct analysis, three main elements of the observations have been taken to give evidence of the teachers' attitudes towards science:

* their statements within the lessons;
* their interactions with the children;
* the overall structure and progress of the lessons themselves.
The following examples are intended to give a flavour of how analysis of these elements can generate understanding.

1) **teachers' statements within the lessons:**

It was found that teachers very rarely communicated directly to the children what they considered science to be about. This may have been because of a reluctance to commit themselves in front of the researcher, but as the phenomenon was common to all four teachers, this is unlikely. The most direct statements about science communicated to the children tended to be an exhortation to 'act like scientists'. Such communication could, however, be taken to represent an understanding of science by the teacher. Take, for example, the introduction to Carol's session on 13.6.96. The class is preparing to go outdoors to do some observational work. She says:

Put on your scientist’s hats and become really good investigators.

Where will you see lots of trees?
Look and see how many kinds of trees you see.
Put your scientist’s eyes in.

Shut your eyes and feel your hand
What does it feel like?
Is it smooth all over? (I can feel bumpy bits on mine)
What about your nails - are they the same as your skin?
Some parts might be squidy
Are there any pointy bits?

I find when I shut my eyes it helps me know more what I’m feeling.
(Extract, lesson observation, Carol, 13.6.96, appendix 12)

There are strong messages here for the children that science is about using the senses to gain information. An investigation is ‘finding out’ something by exploration. There is no hint in this representation of science that testing and ideas have a strong place in the way it works. From an epistemological point of view, this suggests that Carol might be taking an inductive stance towards science at this point. Andrea, on the other hand, in her science lessons during June, 1996 conveys a strongly hypothetico-deductive image, in which the work of scientists is very clearly about the testing of ideas. Her planning notes reflect this, as do the instructions she gives to the children. In her session on 18.6.96 there is a strong message for the children that science knowledge is fixed and that process in science consists of
testing in order to show that it is right. She begins the session by talking about the National Curriculum then, having encouraged the children to turn a statement from the curriculum into a question that can be investigated, she talks through what she has written on the board:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Plan investigation</td>
<td>Estimate</td>
</tr>
<tr>
<td>What materials do you need?</td>
<td>Predict</td>
</tr>
<tr>
<td>What will you do?</td>
<td></td>
</tr>
<tr>
<td>How record results?</td>
<td></td>
</tr>
<tr>
<td>What will you need?</td>
<td></td>
</tr>
<tr>
<td>There's one thing left out, near the beginning.</td>
<td></td>
</tr>
<tr>
<td>No, it begins with a P</td>
<td></td>
</tr>
<tr>
<td>Then what? Listen carefully, Write down what you already Know.</td>
<td></td>
</tr>
</tbody>
</table>

(Extract, lesson observation, Andrea, 18.6.99)

The evidence may be thin, but the overall flavour of the session is hypothetico-deductive. The testing is to demonstrate something and so is not falsificationist.

2) teachers' interaction with the children

Clues to the teachers' understanding of science can be found in the detail of their interaction with the children during the lesson. Once caught up in the action, the questions the teacher asks or the manner of her response to children's comments and questions may give strong indications of an understanding of science which is driving her at that moment. Further analysis may show whether this is espoused or tacit understanding or indicate how conflicts between positions are beginning to be resolved. Consider this extract from Elizabeth's session on 24.1.96. The focus is forces. There are eight children around a table, looking at toys:
Within this session, Elizabeth can be seen not only to be encouraging the children to develop their observation *skills*, she can very clearly be seen to be showing them how they can start to use the evidence of their own senses to help them organise their experience. This carries on during the rest of the session. The promotion of observation becomes a central part of her science teaching to Reception children and the evidence that comes from sessions such as this suggests that her epistemological position might be inductivist. With all four teachers it was frequently difficult to distinguish between their understanding of science and
their understanding of science teaching; the significance of this will be considered in Chapters 6 and 7.

At other times, the indication of the teacher's understanding came more from how she ignored the children rather than what she tried to encourage them to do. In this section from Heather's lesson on 10.5.96, she appears to be ignoring the observations that the children are bringing to the discussion, whilst promoting the idea that there is a right answer somewhere. Such action is linked with a naïve realist position regarding scientific knowledge. The children are trying to find out which material will make a good window:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now G. (Takes the white paper) Can you see through?</td>
<td>Yes (!) Yes</td>
<td>Whose ideas? Implication of a right answer?</td>
</tr>
<tr>
<td>Are you sure? I can't. You must have a good imagination I think you saw a shadow E. (Takes the brown paper) Do you think it will be any good? I don't. N. (Takes the tissue paper. Draws attention to the effects where it overlaps) Can you see inside? Yes, but you can't see the real colours and shapes</td>
<td>I can see a shadow I can.... (Children think)</td>
<td></td>
</tr>
<tr>
<td>Which is the best so far? I'll tell you what, none of them were very good.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Extract, lesson observation, Heather, 10.5.96)

The extract hints at a tacit understanding of science or science teaching that is controlling her interactions. There may have been other factors that were affecting her teaching that day, but this is where the lesson has to be seen in context with the rest of the data and her development. The content of this session was important. It highlighted a significant conflict that was emerging between her understanding and her practice.
3) the overall structure and progress of the lessons themselves

Analysis of the lesson as a whole, or comparison of their content over time, would also generate evidence of either the teachers' understanding of science or of emerging issues in their practice. Elizabeth's session on 8.11.95 (appendix 5) acts as an indicator of conflicts in her understanding of science. She espouses an inductivist position with regard to the teaching, but the evidence of the lesson observation itself suggests that she also wants the children to have specific ideas. The observations she encourages them to make are useful for skill development, but seem not to have much purpose, neither for idea-generation (inductivism) nor as a challenge to the children's existing ideas (hypothetico-deductivism). Although she describes it as 'about right today', there is little sense of what she means by right.

The epistemological conflict between an initial naïve realist position regarding science and a constructivist approach to children's learning, apparent in the above lesson (10.5.96) and visible throughout Heather's involvement in the study, is discernible early in the autumn term 1995. The session on 4.10.95 (appendix 4) appears to show someone concerned primarily with children's conceptual development and the promotion of cognitive conflict. However, the reality was that Heather wanted specific knowledge learned (heavy things sink); her questioning was a semi-intuitive aspect of her practice, linked to her general understanding about what makes good interaction in the classroom (see Portrait, appendix 9) and not specifically to science objectives. The cognitive conflict is used to demonstrate an already existing idea, rather than to help the child explore phenomena in an open way. Comparison of the lessons across the study brings this epistemological conflict into sharp focus.

2) Notes of post-lesson reflective discussions

i) Occurrence

Participants: All teachers

Frequency: Regularly, after observed lessons
These were not the detailed records of situations commonly associated with field notes (see Hammersley and Atkinson, 1995, pp. 175-186). The term field notes is used here to denote brief records or comments made by the researcher, either as an aide memoire for specific actions or points raised by the teachers, or as a note of significant ideas that occurred to him. They were frequent, but brief and often in note form. They record decisions taken as regards the process of the inquiry or raise issues for future reflection.

Post-lesson reflective discussions took place immediately after an observed lesson, using the observation record as a stimulus. They served two main purposes. Primarily, they were to help the teachers reflect on the content of the lesson and to help them analyse and focus in terms of their own action research. In addition, they provided complementary evidence regarding the teachers' understanding of science, either through clarificatory remarks or explanations for actions. There was no set format. Most discussions were recorded as notes of key points, trying to record verbatim comments or phrases where appropriate and possible, often incorporating arrows to indicate relationships within the comments, with underlining to indicate emphasis. For example, this extract records some of Elizabeth's thoughts on her session on 18.10.95:

(It) Felt a bit "woolly" - (she) tried to focus systematically. "Hard to find a real purpose for the science". Hard finding the activities with a purpose. Wants activities to be related.

Doing more science
Enjoying teaching science
Feeling more relaxed about science - "more an attitude thing" rather than education

because smaller focus - observation rather than knowledge, not covering all the knowledge/ More aware of possibilities - recognising in the playground - more focused.

Much more high profile.

(Elizabeth, post-lesson reflective discussion 18.10.95)
Most notes were of this kind. However, the post-lesson discussions after two of Heather’s sessions (15.11.95 and 12.6.96) were audio-taped, resulting in a transcript which was handled in a similar way to those from the formal interviews.

### iii) Reliability

Although the notes from the discussions present an obvious potential for researcher bias, with its inherent selectivity, it is considered that the records still provide evidence of sufficient reliability. This is for two reasons:

1) The notes were made in full view of the teachers. Recording of the discussions was negotiated prior to the beginning of each, with the teacher having the power to refuse permission. None did so, but this negotiation drew attention to the process and the discussion was often punctuated by the researcher scribbling notes. Teachers would sometimes question what was being recorded. This gave a chance for clarification of intended meanings. Assent to the whole process thus strongly indicated teacher agreement that the notes had some representative content.

2) The notes were only one element of the overall data. However, they provided evidence which achieved an apparent reliability because it ‘fitted’ with the picture coming from other sources. This does not rule out researcher bias in analysis, but all data is subject to this.

### iv) Analysis

1) As the prime focus of the discussions was to help the teachers with reflection in their action research, it was unlikely that clear statements relating to an understanding of the nature of science would emerge through them. Comments were pedagogical in focus. These, however, would not be without significance, for they, too, could give evidence of the teachers’ epistemological and methodological assumptions. For example, in the extract given above, there are two elements which may indicate this kind of understanding:
i) Elizabeth reports that the session 'felt a bit “woolly”', but that she 'tried to focus systematically'. This is limited, but it conveys an understanding that she considers that her science sessions should be tightly focused and involve systematic action. Central to the analysis presented in this thesis is the assumption that teachers' comments about the nature of science teaching may convey understandings of science itself. If so, the wish for systematic action within her teaching may suggest an understanding that science itself is also systematic in character.

ii) Elizabeth then discusses more general aspects of her teaching and indicates a developing understanding of effective science practice:

because smaller focus - observation rather than knowledge, not covering all the knowledge.

If she is considering that her science teaching should focus primarily on the development of children's observation, there is tentative support for an inductive position. It is one element of an emerging picture.

2) Evidence from these discussions also helps indicate the levels of confidence the teachers feel about their science teaching. Such evidence is crucial, for the relationship between what the teachers do and what they feel about it reveals much about the link between their understanding and their practice. Within this example, small indications can be noted, particularly where Elizabeth comments she is 'feeling more relaxed about science', it is 'more an attitude thing'. She then immediately relates this sense of new confidence to her developing understanding about observation, hinting at deeper relationships between practice and values which will be discussed later.

A further example, showing analysis:

Heather 18.10.95:

Feels more confident.
Says: Still worried about content of science - seems to take over so that she finds it hard to concentrate on the ‘other’ aspects.
Project is helping. Good to have someone to talk with her to help her focus and analyse the sessions.

Started with a focus on her questions, seems to have given her more info. re. the amount she plans for and a realistic focus for the session. Messages about the way in which children can learn and understand concepts.

(Heather, post-lesson reflective discussion 18.10.95)

This short record provides evidence of her developing confidence. It suggests an explanation for that confidence: the presence of someone to help her focus and the understanding that is coming from her own research. But it also points to conflict in her practice, raising the possibility of contradiction between her aims (to focus more on procedural aspects of science?) and her action (taken over by the content). This raises questions. What does she mean by taken over? How does it relate to her understanding of what science is? Is there a strong tacit acceptance that it is a body of knowledge to be transmitted? These questions feed into the developing picture of Heather’s overall understanding.

3) Written evidence of teachers’ aims and planning

i) Occurrence

Participants: All teachers
Frequency: Weekly, accompanying observed lessons; half termly, outlining medium term aims
Format: Teachers written notes/school planning documents
Researcher role: Not applicable
Nature of evidence: Written short and medium term plans, indicating aims and intentions

ii) Nature and purpose

These were the teachers’ normal planning records. With no formalised lesson planning structure in place within the school at the time of the inquiry, they were variable in both format and content. The three examples below (Elizabeth 14.9.95, Carol 22.11.95 and Andrea 12.11.96) illustrate the range of detail they included.
Elizabeth 14.9.95:

Exploring fruit and vegetables.
My focus: finding out where the children are:
- what are they seeing?
- what are they saying?
- what is focused, what isn’t, what is the germ of an idea?

Record the session to listen to again later.
Also, to take notes.

Introduction:
“I’ve brought some lovely things to show you today.
I’m going to put them all on the table.
Have a look at them as I put them out, but don’t say anything.
Think about which one you might like to look at first.
I want you to look very carefully at whatever you have chosen.
I want you to find out as many interesting things as you can about it.
When we stop looking I would like you to tell everybody what you found out”.

.....See what happens.
Possible opportunity for continuing:
“You have found out some really interesting things about your....
“I want us to think how we could sort these things.
Are there some we could put together, because they belong together in some way?

Go with the children’s ideas.
Model if necessary.
Use set rings.

Carol 22.11.95:

Exploring materials:

This activity has been generated in response to last week’s work on ‘making a post bag’.

Aims:
*Systematic Enquiry: To give opportunities to use focused exploration and investigation to acquire scientific knowledge, understanding and skills..(i.e. observation).
*Communication: Use scientific vocabulary to name and describe things. Present information in a number of ways.

Initial Activity

Resources (Group)
A variety of materials (natural and manufactured)
‘set’ rings
small palettes for sorting
pencils and paper for recording purposes

*Play ‘one word’ - a game where the children have to find one word to describe the object etc. in their hand.
*Focus in on the descriptive vocabulary associated with the object.
*Repeat with a contrasting object.
*Brainstorm descriptive words
*Use senses to explore and recognise the similarities and differences between materials.
*Sort (and match) materials into groups - using set rings. Do any fall into more than one category?
*Use pre-set ideas sheet or the children's own ideas to gather information.

Andrea 12.11.96:

**Aims 12.11.96**
Complete simple plan (Begun 11.11.96).
Carry out practical task and record the results.
Talk about what they have found out.

Detail was thus very varied. Furthermore, it varied not only between different teachers, but also between different sessions by the same teacher. There was little consistency. Sometimes, as with Carol's example, the teachers would include reference to previous sessions, sometimes indicating the derivation of the new session. Although the researcher encouraged them to include such information (in an attempt to ensure the coherence and prominence of the deliberations within their action research), the lack of consistency in detail reflected fluctuating levels of pressure felt by the teachers, both within school and outside.

**iii) Reliability**

Discussion of the reliability of the plans is largely irrelevant. The researcher was not involved in their production. However, given the fluctuation in content and detail indicated above, it must be acknowledged that they might provide only a limited indication of the teachers' thoughts before a lesson.

**iv) Analysis**

The plans provided data which related to teachers' understanding of science pedagogy and which could be related to their wider understanding of science, both espoused and tacit. The plans were seldom analysed separately from their accompanying lesson, as the nature of the relationship between them was a key question. Plans such as Andrea's on 12.11.96 gave little evidence by themselves, but when considered in conjunction with the lesson (appendix 6), it can be seen that the lack of detail was possibly indicative of a lack of
overall pedagogical clarity. Elizabeth’s (from very early in the inquiry) also shows a lack of clarity, with no aims that relate to science itself. However, in contrast to Andrea’s, there is a strong indication of an intended pedagogical process, with an emphasis on observation. The exploration of the relationship between this approach to the teaching of Reception children and her understanding of science became an important part of the inquiry. Carol’s example gives a much stronger picture of understanding. It is mostly of the pedagogical aims for her science teaching, but the use of terminology such as ‘systematic inquiry’ and the associated lists of intended coverage might relate to a wider understanding of scientific processes. Again, these aspects became crucially important in building an overall picture of her development.

Methods used to generate evidence away from the immediacy of teachers’ practice.

1) Focused, semi-structured interviews

i) Occurrence

Participants: All teachers
Frequency: Generally once per term, towards the end
Format: semi-structured, 45 minutes to 1 hour
Researcher role: Interviewer
Nature of evidence: Audio tape/transcript

ii) Nature and purpose

The interviews provided useful evidence of teachers’ espoused understanding of the nature of science, but were also strong indicators of tacit ideas. Furthermore, they provided a forum within which the teachers could analyse their thinking. As such, they constituted an important element of the teachers’ action research process. The result of this was that consolidation or change in understanding often occurred within the interview itself. A semi-
structured interview format was adopted in order to give more scope to the exploration of
the teachers' ideas and because the teachers' own research reflections made their content
individual and impossible to predict. This is not to say, however, that they were not
planned. Borg and Gall (1989) in fact describe this kind of interview as 'unstructured'
(p.453), but the term semi-structured is considered to describe the process more accurately.
An example of the 'general plan' for one of the interviews is given below. This was early in
the inquiry and the intention was to draw the teachers into talking about the nature of science
through a discussion of their science teaching.


• Introduction
• How is the science work going in your classroom?
• Thoughts on the current changes in science - new curriculum etc.
  Any particular problems/concerns?
• Focusing on aspects for the inquiry.
• What do you think science is?
  How would you characterise it?
  Is it unique? Follow up.
• Do you think you can teach science in the classroom?
  What are your aims in the teaching of science?
  (From notes for forthcoming interview, 3.7.95)

iii) Reliability

Issues of reliability in the use of interview material as evidence fall into two areas,
those of administration and those of recording.

1) Administration:

It could be considered that interview material is inherently reliable in that it is a verbatim
record of a participant's thoughts. But this is too simplistic a representation. Clandinin and
Connelly (1994) highlight the complex relationship between the interviewer's actions and
the kinds of response that will be forthcoming from the interviewee. They point out that 'the
way an interviewer acts, questions, and responds in an interview shapes the relationship
and, therefore, the ways particular participants respond and give accounts of their
experience’ (p.420). People conduct conversations in many different ways. Some talk quickly, others slowly, with many pauses. If a researcher fills the gaps too readily, he may be intervening before the interviewee’s thoughts are complete, potentially changing the meaning of the response. The body language between interviewer and interviewee or the tone of voice used by the interviewer may also have a crucial bearing on the nature of the interviewee’s responses. If she feels threatened, she may strive to give what she feels to be the ‘right’ answer, rather than her own ideas.

The researcher strove to reduce these possibilities. In the first instance, the interviews were conducted in a venue chosen by the interviewees, where they might feel comfortable. Secondly, the decision to conduct a semi-structured interview gave a greater likelihood that full responses could be obtained. Rather than expecting tightly focused answers to questions, the more open format allowed the interviewees to explore questions more fully and allowed the interviewer to probe and to clarify. In the following extract from an interview with Carol, the researcher has the space to probe Carol’s understanding of how she ought to be teaching science. Not only can Carol explain herself in great detail, evidence also emerges about her understanding of science itself, with some clear statements of epistemological understanding:

SWA: So what do you think you should be doing? In a general approach...?
Carol: I’m really thinking here...I really need to know how much and what I need to be teaching and that’s not just got to come from me, it’s got to come from the whole skills map of the school...
SWA: And is that in terms of conceptual areas or is that in terms of...?
Carol: Just skills, yeah.
SWA: Observation, communication?
Carol: All those sorts of things, yeah. But in terms of understanding, which is a different ball game, isn’t it? No, it isn’t really, because observation...that’s your major one...
SWA: So what would you say would characterise the important things about science work in your classroom now and in your planning?
Carol: I know what science is to me and what perhaps would be a better name for it in Reception - it’s general knowledge. I think it would be a better title, it wouldn’t scare people so much. I did have an investigation station at one point...but just general knowledge, looking at the world around you, you know, incorporating the nature table or the sand or whatever, you know, general knowledge - it gives you a nice feel of starting to look beyond just their own lives, the waking up, getting to school...Feeds into their natural curiosity.
SWA: Sort of what happens and why?
Carol: Yeah. Making their own explanations and maybe needing guidance at some times, needing to find out and needing to know that there are reasons and sometimes to need to know that there aren’t. That maybe the grown ups
haven't got it all sewn up either, that they're still finding out too...I think that's an important part of it, I mean that's a deeper concept, isn't it?

SWA: So you're saying that now you're feeling quite a bit happier?

Carol: Yes. I've not come full circle, but I'm almost there. Because I have to say to myself this is science whatever level it is, because I was beginning to think that I should be teaching them, leading them, showing them and a lot of it ended up with quite sort of didactic, me telling them about things...For example, the temptation is, you know, Oh, snow! and magnifying glasses looking at the crystals...But they're not interested, they're interested in that it's cold and that it's happened cos it's cold and it doesn't need to be any more does it? It's really broken down my thought processes so I am thinking more clearly that it's okay not to try to teach everything - I mean observation skills are, you know, is your starting point, you have to start by looking and by looking you can find out.

SWA: Would you say that was one of the key things you're trying to encourage?

Carol: Yeah. That's the skill I think from Reception that you are teaching them, just to look...

(Carol, interview, 8.12.95)

This kind of interview takes time. It thus needs careful organisation. In order to elicit meaningful data, the interviewee needs to be able to relax and not feel pressured. Because responses can be so exploratory, both interviewer and interviewee may lose sight of the main question, but that is where the interviewer needs the general plan. Its function is not to dictate questions, but to be a reminder of the key points to be covered. The strength of the semi-structured interview is that it allows aspects of the questions to emerge which the interviewer had not considered, but which might be valuable.

2) Recording

Verbal communication seldom occurs by itself. It is frequently accompanied by a range of facial or hand expressions which add meaning to the words. Such expressions are part of the richness of communication that passes between people involved in a conversation and, as such, will be an integral part of an interview. They are, however, the first things to be lost when the interview is recorded for use as data. Video taping will provide a primary record of such expressions, but video tapes are inconvenient to handle and video cameras are potentially intrusive and intimidating. Audio taping is more common. But if audio taping is used, as it was for the interviews for this inquiry, there is then also the question of transcribing the record. More is lost here. Tone of voice, pacing, emphasis and inflection all disappear as the tape is transferred to the written word. These are major obstacles to
reliability. The richness of interaction between two people in the human relationship of the interview is frozen into an unvarying and much diminished paper record.

Little can be done, however, except to acknowledge these limitations. Cohen and Manion (1989) suggest that summaries of responses or note taking within the interview might help the interviewer, but they also point out that such action is likely to break continuity and thus present its own problems (p.320). Importantly, the researcher transcribed all the tapes himself. In doing this, he opened himself to the possible accusation of bias and it is upon his word that the transcripts referred to are taken as accurate records of the interviews. The original tapes are available for inspection should they be required. The researcher claims that his own transcription of the audio tapes was actually an important factor in the reliability of the data presented. It has already been mentioned how much is lost between interview and transcript. If a third party transcribes the tapes, all subtlety still present is lost for ever. When the researcher himself does the transcribing, there is more likelihood that the immediacy of the interview situation of which he was a part will be brought to mind again. He will be aware of the variations, the asides, the inflections in the interviewee’s responses. There is more chance that his resulting understanding will be closer to the subtleties of the original situation, although his transcripts should not themselves vary from those produced by a third party. Because of this, in the inevitable selectivity which takes place in the presentation of an account, it is more likely that a greater degree of accuracy in the representation of the research situation will be ensured. Researcher-transcription becomes, paradoxically, an instrument for reliability.

iv) Analysis

Analysis of the interview material was not straightforward. Whilst teachers would occasionally make direct statements about the nature of science, this was, on the whole, rare. In addition, teachers frequently found it difficult to articulate their thoughts directly, suggesting they neither had the vocabulary nor the confidence with syntactical understanding of science to do so. In the following response, Elizabeth, although a
thoroughly articulate person when describing her practice, struggles to make her thoughts clear in justification for her recent science teaching:

‘Elizabeth: We’ve had this quite strong focus on observation, haven’t we, and that seems to be this sort of key issue; it seems to be very important if they are going to be competent in science later on; it seems to be very critical that they are good observers.

SWA: Do you think that’s right?

Elizabeth: I do actually, yes.

SWA: Why?

Elizabeth: Because I think I’m beginning to come to an understanding more about what science is, you know it’s beginning to have an understanding about the world in which they live and beginning to, you know, er...build up ideas. I suppose concepts about...about...about the natural world.’

(Elizabeth, interview, 16.7.96)

Even though supposedly describing an understanding of science, this response suggests little apart from a possible idea that ‘knowledge’ of some description underlies the subject.

Analysis of the interview material, therefore, became a matter of careful sifting and interpretation.

In contrast to this inability to talk directly about the nature of science, the teachers all seemed to display a tendency to convey their understanding of science through description of their practice or through stories about the children in their classes. Teachers would almost immediately turn a direct question into a description of a particular incident, or recount philosophical aims through reference to pedagogy. It was as if they needed the security of their familiar context in order for their thinking to proceed. These responses became potentially significant in providing evidence of the teachers’ tacit understanding. This sequence from Heather’s interview on 16.7.96, is an example. She is considering the responses she has made to the bi-polar semantic differential scale (see below). She describes her own philosophical conceptions by referring to her children and her pedagogical approach:

‘SWA: I think the only places that you’ve changed are on the subjective - objective one. There may be very little significance at all, you moved it a notch towards objective. Can you think of any reason why you did that or do you think that just is...?

Heather: (Long pause) I think it is to do with them being wrong more of the time, you know, and giving them a bit of leeway for there to be not necessarily right or wrong answers, but for the children their thinking might be different to mine. I think it’s more to do with really, rather than there’s always a right answer....It’s somewhere in the middle, playing safe!

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And the discovered - constructed, you've moved into the middle from being over on the discovered side. Is that anything, do you think?

Heather: I think that was to do with them formulating their ideas and building on them a bit more.’

(Heather, interview, 16.7.96)

Carol also frequently gives the same kind of response. In the extract within the Reliability section she continually mixes understanding of science with understanding of science teaching and conveys epistemological perceptions through examples of how she relates to the children. For example:

‘I know what science is to me and what perhaps would be a better name for it in Reception - it's general knowledge. I think it would be a better title, it wouldn't scare people so much. I did have an investigation station at one point...but just general knowledge, looking at the world around you, you know, incorporating the nature table or the sand or whatever, you know, general knowledge.’

or:

‘That maybe the grown ups haven’t got it all sewn up either, that they’re still finding out too...’

There is a strong sense of metaphor and story within Carol’s normal conversation. This comes through strongly in the interview material and many examples can be found in her case study.

Analysis of the interview material was therefore made difficult by the complexity of the responses within it. The assignment of categories of understanding to clearly identified philosophical positions was not possible. It was important to look at the whole picture emerging from the interview and to remember the teachers’ focus. The interviews provided a forum for discussion and re-focusing within the teachers’ action research and as such had an educational function for them. The interviews were not solely situations in which the teachers might recount their understanding; frequently, they were involved in the active generation of it during the discussion.

2) Teachers’ reflective commentary

i) Occurrence:

Participants: All teachers, but variable.

Frequency: Variable, often in short bursts according to
commitment to own research.

Format: Hand written/word processed
Researcher role: Not applicable
Nature of evidence: Written record.

j) Nature and purpose

The reflective commentaries were produced over the course of the inquiry, both spontaneously by teachers and in response to requests by the researcher. Three of the four participants (Carol, Heather and Andrea) had not used writing as a reflective tool before. Elizabeth was used to the approach. Hammersley and Atkinson (1995, pp.163-164) review the potential of accounts written by participants in the research situation, claiming they 'are especially useful ways of eliciting information about the personal and the private' (p.164). They can give access to information often withheld in interviews. These accounts are often referred to as diaries or journals, but such titles are problematic when considering the action of the teachers in this inquiry. They imply regular, systematic entries. This was not the case. The teachers were encouraged to keep a reflective journal, but it was emphasised at the outset that it was not essential. In the event, due to increasing pressures on time (for example, during the inquiry the school was preparing for their first Ofsted inspection), irregular loose leaf sheets were all that were kept. Whatever the nature of the record, however, it proved valuable for both the teachers and the researcher. Primarily, the teachers used it as a reflective medium for their own thinking and as a focus for discussion with the researcher. These reflections provided evidence of their developing thinking and understanding of science. They also gave a valuable insight into the processes of change the teachers were experiencing within the complexity of their action research.

iii) Reliability

The complexity and length of the commentaries varied widely. Some were word processed (especially Carol's), others hand written, but including significant reflections and analyses of teaching (particularly Elizabeth's and Andrea's). Heather's tended to be short,
sometimes only hurried notes on scraps of paper. All need to be taken at face value and it is
unsafe to assume that the apparent length of time taken to complete them may be an indicator
of reliability.

iv) Analysis

The commentaries produced a range of potential evidence for the inquiry, sometimes
giving insights into personal change and development. Take, for instance, these reflections
by Elizabeth:

Participating in the Action Research has been really stimulating for me. It feels like
the best kind of in-service, because it is about children learning and about me getting
better at helping children to learn science. It’s about me changing my practice, but
understanding why and how I am changing, so it’s the best kind of learning for me.
There is quite a lot of struggle involved because sometimes I’m not quite sure what
to do; I still find planning science difficult and challenging. It is even quite hard to
articulate what I have learnt so far.

(Elizabeth, reflective commentary, 23.10.95)

More commonly, the commentaries would show focused reflection on practice, conveying
the sense of review and modification characteristic of action research. Sometimes they were
short, reflecting a pressure on time and revealing little except a general sense of speculation
on action:

I feel I know (sic) have more faith in myself to let the lesson go where it leads - i.e.
the children’s questions and answers often tell me how far to take the lesson.

Catering for mixed ability still a problem - perhaps I could use challenges for D, J etc. to free me to talk to the quieter ones

(Heather, reflective commentary, 15.11.95)

Others were much more detailed, often providing evidence of the teachers’ understanding of
science. In the following example, Andrea finds it difficult to arrive at sufficiently focused
action. She is concerned with the need to ensure children meet knowledge targets, but
specifically wants to improve her children’s ability to plan investigative work. She writes:

I felt that the recapping part and the questions which the children came up
with was ‘real’ science because they were trying to establish what they knew from
previous investigations and then try to see what the next unknown step was which it
was possible to find out.

I want to build on ‘what they know’ or think they know and therefore make
it easier to identify what they don’t know or challenge the conclusions which they
draw.

Very few of them make links between things in any subject - it seems a hard
skill to acquire - and science seems the ideal vehicle to make this process part of
‘normal’ thinking. I’m not convinced I can teach this particular class now to get into
the habit of making links but at the very least it is a start.

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The investigations were relatively simple to plan, not many variables to control, but I feel it gave those who find this difficult a measure of success. This leads me on to wonder whether I (we) make things too complicated and therefore the focus is not on making links or drawing conclusions or asking questions but just on understanding and coping with the task in hand. It makes me feel that I should be much clearer about my objectives and what I actually want them to learn.  
(Andrea, reflective commentary, 11.6.96)

This is detailed reflection. It conveys very powerfully the intellectual demand that the inquiry process was making (her main reason for wanting to be involved in the inquiry was that she thought it would help her focus on the demands of her new job) and it shows the struggle of honest analysis with the identification of conflicting elements of her practice and aims. In addition, it gives evidence of her understanding of the nature of science. The last paragraph may be concerned mainly with her exploration of the implications of her analysis for her practice, but the first three contain suggestions about a general understanding. ‘Real’ science for her seems to be something that is built up by applying knowledge from one situation to another; she wants to help the children build on what they know. She is also interested in helping them ‘challenge the conclusions which they draw’. This appears to reflect a hypothetico-deductive conception. Her wish to help the children ‘make links’, implies that she holds a conception of a unified body of scientific knowledge.

3) Analytic memo

i) Occurrence

Participant: The researcher  
Frequency: At intervals, between phases or at key points  
Format: Hand written, note form or extended prose  
Researcher role: Originator  
Nature of evidence: Written record

ii) Nature and purpose

This was a detailed record of thoughts and feelings relating to the progress of the inquiry and to the meaning of specific events. It served as a focus for the preliminary
analysis of data or events. The completion of memo entries was not scheduled, but arose out of a response to the on-going research situation. They thus clustered around important points in the process, such as June and October 1995, when initial reconnaissance and focusing were coming to an end for Elizabeth, Carol and Heather, or further review and focusing times such as January, March and June 1996. The entries were kept as loose leaf sheets.

iii) Reliability

The reliability of analytic memo entries can be judged by reference to data gathered by other techniques. The entries give a record of the development of the researcher’s understanding of the research situation, but they are already two steps removed from the primary data. Woods (1996), referring to the keeping of diaries, suggests that they are a way of ensuring that the researcher’s voice is acknowledged in the overall analysis. He claims that ‘the researcher’s feelings are important, not only as context for the message of the research, but as part of the message itself’ (p. 87). This may be so, but it is important that the researcher’s conclusions from the data are transparent; his voice must not obscure data from other sources. Analytic memo entries can be seen to be reliable when the picture they present triangulates with that emerging from other sources. Woods also points out that the compilation of memo entries provides an insurance that the immediate impact of an event is not lost between data collection and writing up (p. 87).

iv) Analysis

The following examples give an idea of the kind of content in the entries. They are measured reflections, completed away from the immediacy of the research situation. They represent different styles of entry, some note form, some extended prose. They show how different the entries might be in content, from deeply personal, confidential reflections on individuals to more analytical considerations of data. From the point of view of analysis, they represent a filtering and synthesis from the experience of the inquiry to date, for example:
1) Memo entry, 15.11.95

Finally a seemingly productive session with Carol. I'm sure she feels that there was more focus to today's session, although she also feels the others were coherent scientifically. Planning for the sessions obviously gives her considerable stress and she commented on this again. Production of aims and plan is very positive - still needs focusing down onto objectives for session (from my point of view as the researcher/observer for feedback, also from A/R point of view). Can honestly say we have reached the end of reconnaissance.

A/R, or me, or project etc. is useful to her (she says) because it is forcing her to focus. Whether this is A/R specifically is impossible to say. She confided about the problems in the school today - tensions, lack of consultation - which have come to a head. (Art advisor). She felt insulted and ignored, especially after the amount of work she had put in and she needed someone to talk to. I feel she now trusts me. The confidant angle raises its head again - confidentiality and security are so important! Why do people do this to each other? Shows that no matter what one cannot ignore the personal 'lives' in interpreting teachers' actions. The location of self and self esteem are everything.

This reflection was completed soon after the incident referred to. It is not, however, solely informed by that incident; the first paragraph, particularly, relates to the whole of Carol's involvement in the inquiry to that date. There is a strong sense of her development and commitment to the action research, even though it is causing stress.

The second example is very different. It shows an interim analysis of Carol's development to that date, highlighting how the different kinds of data were starting to provide evidence and how they might contribute to overall understanding. The data relate to her understanding of science and her general beliefs about pedagogy. The memo is in note form, listing points of analysis. There is the occasional comment on possible implications, but there is no synthesis. Similar entries occur for all four teachers. This is a short extract from the whole.

2) Memo entry 28.3.96

Carol - Science practice (Extract)

July: Wants independence, holism etc. (Portrait)
Thinks children are very naturally scientific
Own lack of science knowledge

- Started with group in 'science area' - 'Interesting things' collection.
Children encouraged to go and 'discover'/change selection each week.
- Holistic / not told / experienced
- Ideas for follow up later. /Within PDR

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My notes (8.11)
- Unsure of focus
- Feels may be too much demand. Wants observation
- Reluctant to plan firmly for science sessions. Writes up afterwards
- Agrees has a problem with focus / 'going with children’s ideas'
- Very anxious about sessions - focusing on something she is unsure of

* - To organise science session in PDR / not just 'corner'

Plans (15.11)
- Shows first strong evidence of planning:
  - Investigative / Bags / Materials?

Feedback in observation includes reflection on amount in session

4) The bi-polar semantic differential scale (Appendix 7)

i) Occurrence
Participants: All teachers
Frequency: Twice, near beginning of teacher involvement and at end
Format: Bi-polar scale
Researcher role: Devising scale, administration
Nature of evidence: Completed scales for comparative purposes

ii) Nature and Purpose
The bi-polar scale was a minor element of the range of data gathering techniques, devised to give a ‘snapshot’ of teachers’ understanding at the beginning and end of the inquiry period. It was the only procedure to include a small measure of quantification. Deriving its structure very loosely from Kelly’s Personal Construct Theory (Kelly 1955), it was designed for two purposes:

• to give supplementary information of teachers’ understanding of aspects of the nature of science, for triangulation purposes;

• to provide evidence from across the period of the inquiry that could be compared and discussed at the final interview.
Its prime purpose was the latter. It was to provide a useful stimulus for discussion and give evidence of any change in teachers' understanding.

The instrument consisted of fourteen bi-polar attributes, located on a five point semantic differential scale. In common with Kelly's approach, it was intended that the constructs included on the scale were to be based on the teachers' own. These, however, had to be a collation of shared ideas; separate attribute lists were not generated for each teacher. In the event, because of the staggered entry of one participant to the inquiry, only three of the four teachers were involved in the generation of the scale. Information gleaned from the initial interview and field notes from the introductory phase led to the production of a list of key ideas that the teachers associated with the nature of science. These were then collated and extrapolated into what were seen as key attributes about science and located on a semantic differential. The attributes generated by this method were:

- Explanatory - Descriptive
- Certain - Provisional
- Systematic - Unsystematic
- Cohesive - Unconnected
- Rigorous - Laissez faire
- Exploratory - Lacking exploration
- Verified - Unconfirmed
- Imprecise - Precise
- Discovered - Constructed
- Questioning - Unquestioning

On analysis of these attributes, the researcher decided to depart from Kelly's principle that constructs should be provided solely by the teachers, by including four more. He did this in an attempt to ensure that the instrument itself allowed for as wide a survey of possible stances on the nature of science (cf. research imperative 2). The four bi-polar attributes added were:

- Sure - Tentative
<table>
<thead>
<tr>
<th>Public</th>
<th>Personal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing</td>
<td>Unchanging</td>
</tr>
<tr>
<td>Subjective</td>
<td>Objective</td>
</tr>
</tbody>
</table>

Teachers were asked to complete the scale twice during the inquiry. For Elizabeth, Carol and Heather, this occurred in October 1995 and July 1996. The results were discussed at their final interview in July 1996. For Andrea, the scale was completed in March 1996 and again in December 1996, immediately prior to her final interview.

### iii) Reliability

The instrument was acknowledged to have limited reliability if used as a measure of teachers' understanding of science. This was not its prime function. Completion of the same instrument at the beginning and end of the inquiry was designed to raise issues for discussion with the teachers rather than derive reliable results. However, this is not to say that the responses themselves did not signify some kind of understanding; when they were triangulated with the rest of the data, they could be seen to have value in themselves.

Measures of internal consistency existed within the scale, but they had little function within the instrument itself, except that they served to help the researcher focus on questions at interview. Apparently random responses would also have yielded important information for discussion. However, it was assumed that similar responses would be obtained to:

- Systematic - Unsystematic
- Rigorous - Laissez faire
- Sure - Tentative
- Certain - Provisional
- Verified - Unconfirmed
- Exploratory - Lacking exploration
- Questioning - Unquestioning
In order to ensure that potential differences in the teachers' understanding were reflected in their responses to the scale, the researcher kept all copies of the responses to the first scale.

iv) Analysis

Responses to the separate attributes were assumed to relate to different aspects of the nature of science. The scale was not precise or detailed enough to allow specific predictions of teachers' understandings to be made from their responses, but it could indicate general methodological, epistemological or ontological positions. In broad terms, the differentials were thought to relate to the following areas. Some occur in more than one:

**Methodological**
- Exploratory - Lacking exploration
- Questioning - Unquestioning
- Rigorous - Laissez faire
- Imprecise - Precise
- Systematic - Unsystematic

**Epistemological**
- Discovered - Constructed
- Exploratory - Lacking exploration
- Certain - Provisional
- Verified - Unconfirmed
- Explanatory - Descriptive

**Ontological**
- Certain - Provisional
- Discovered - Constructed
- Explanatory - Descriptive
- Cohesive - Unconnected
A look at the comparison of Carol's results (appendix 7) shows how the analysis worked. The most important focus was change (or lack of it) over time. In Carol's case the most change occurred in the Subjective – Objective differential. This triggered some important reflection in her interview on 16.7.96, in which she expanded on the implicit epistemological deliberations which had given rise to the change, suggesting that knowledge formation in science was strongly socially and personally constructed. Her responses are important in putting together the picture of her understanding at the end of the inquiry.

5) The questionnaire (Appendix 8)

i) Occurrence

Participants: Elizabeth, Carol, Heather (not completed by Andrea)
Frequency: Once - May 1996
Format: Open-ended, five questions
Researcher role: Originator
Nature of evidence: Written responses

ii) Nature and purpose

The questionnaire arose as a result of a perceived need to explore the teachers' pedagogical beliefs and values more closely. It is the nature of qualitative research that methods can be anticipated, but close prescription is not possible. For the research to retain validity, it must be responsive to the changing interests of the participants and the messages coming out of on-going analysis. It must continually seek to follow up strands which might potentially shed light on the central research questions. Woods (1996) refers to the 'chief research instrument' being the researcher (p.51), stating that it is necessary to develop research skills in situ' (p.52) The questionnaire arose out of reflections in the researcher's analytic memo. As evidence was emerging about the nature of the teachers' tacit knowledge-in-action, it became apparent that wider influences than an understanding of science might also be significant. Evidence regarding those influences was already being collected through
observation of practice, post-lesson reflective discussion and interview, but the researcher considered that an open questionnaire might yield further useful data. Therefore, as it was becoming increasingly clear in the inquiry that the teachers seemed most comfortable discussing theoretical ideas or personal feelings through the medium of a reflection on their own teaching, five questions were designed to focus on the teachers' interests, their motivation and their sense of engagement with the role. In the event, Elizabeth, Carol and Heather completed their questionnaires; Andrea did not. She was, in May 1996, at a very different point from the others in her inquiry. Her class had just finished SATs and she had not generated the focus that became a feature of her engagement in the autumn term. It is possible that she lacked the confidence to divulge the personal information that the questionnaire requested. It was not repeated.

iii) Reliability

The research was not intended to be carried out by questionnaire and the small number of questions and the lack of piloting procedures meant that the potential reliability of this questionnaire was low. The instrument was more like a series of open-ended interview questions than a traditional questionnaire. On the other hand, the questions yielded a range of data, some of it potentially very significant, with Elizabeth and particularly Carol completing them very thoroughly. Cohen and Manion (1989, p.320) point out that a researcher cannot guarantee that respondents will understand the questions in the same way and the depth of content of the responses did vary between the teachers, though whether it was for this reason is impossible to say. Some measure of the reliability of the responses can be ascertained by comparing them with previously elicited espoused positions or emerging indications of tacit understanding. The close similarities that emerge here suggest that the rest of the responses to the questions should yield useful data. For example:
1) Agreement with espoused ideas:

Carol had what she described as a strongly ‘holistic’ approach to teaching (see her ‘Portrait’, Chapter 5). In response to question 1 - ‘What would you say motivates your teaching?’ - she wrote:

I am fascinated with their (children’s) fascination. I am motivated by their motivation, I am enthused by their enthusiasm. Watching young children with their hands immersed in clay...you see how in touch with the world they are...in that they are fully absorbed in the experience.

2) Agreement with emerging indicators of tacit understanding:

It had become clear through lesson observation (for example 4.10.95, appendix 4) that Heather seemed to have a strong intuitive ability to promote investigative work in the classroom. Her response to question 2- ‘What do you see as the main characteristics of your best teaching?’ - was:

Holding the children’s interests - being able to keep the majority focused and interested. Using questions to keep children’s thoughts moving without demanding ‘set’ answers.

iv) Analysis

The purpose of the questionnaire was to gain further information about the teachers’ pedagogical beliefs and values. The kind of analysis possible can be illustrated by looking briefly at some of Elizabeth’s responses.

When asked to describe the characteristics of her best teaching, Elizabeth’s first responses were:

- respect for the children’s ideas;
- valuing what they do;
- that children have needs and interests which they bring to each learning situation and that what I plan must take account of this;
- the quality of the relationship between the children and myself (and their families)...

Child centredness would be too vague a categorisation of these values; the words speak eloquently of a deep human respect that could be seen to characterise her whole approach to her teaching. These values underpin her aims. Education is immensely important to her. She
speaks of wanting children to experience the same kind of learning as she herself experiences when she teaches well:

In the same way, it feels good to be instrumental in making these things happen for children. I feel education can be instrumental in changing peoples’ lives; how good to be involved in being part of this process.

She describes her approach to teaching as being that of a ‘facilitator’:

I don’t feel like a controlling kind of teacher, more a facilitating kind of teacher; someone who is responsible for creating the best kind of environment, and interacting with the children in the best possible way for learning to take place.

These responses added much to the general understanding of Elizabeth’s approach to teaching and did much to help the production of a rounded picture of her development through the inquiry. The other teachers, especially Carol, also produced responses to the questions which contributed to understanding in a similar way.

**Summary: the contribution of each method**

At the beginning of this overview, it was pointed out that the methods were not applied singly within the inquiry. Furthermore, analysis took place both during the inquiry itself and in the production of the case studies. In neither case were the methods analysed in isolation. The purpose of analysis within the inquiry was i) to aid the teachers’ action research and ii) to aid the researcher in monitoring the direction and emerging messages from the inquiry. Subsequent analysis for the case studies, therefore, was informed by the analysis which had already taken place within the inquiry; inference from each method was not discrete. This is an important point. Although this is, ultimately, a study of teachers, the multifaceted and changing nature of their practice rendered it essential that the researcher did not approach it with preconceived ideas (or as few as is possible). An important aspect of validity rested on the researcher’s ability to make judgements during the research as to whether modifications of the chosen research strategies would yield important data. Such decisions could only be made on the basis of on-going analysis.

It has been shown throughout the chapter how each method triangulated with others; the brief summary below highlights how each contributes elements of analysis which interrelate in the production of the case studies: 

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**Lesson observations:**

include verbal statements, teacher-child interactions, lesson structures; give data relating to teachers’ understanding of the nature of science, especially tacit; contribute to an understanding of the dynamics in the teachers’ action and its possible relationship with practice; yield evidence of teachers’ beliefs about pedagogy; their meaning is enhanced considerably by relating them to post lesson reflective discussions and reflective commentaries;

**Post lesson reflective discussions:**

of particular importance for the teacher in their evaluation and planning within their action research; gives evidence of teachers’ understanding of science, both espoused and tacit; also raise evidence of the teachers pedagogical beliefs and assumptions; of particular importance when related to lesson observations;

**Teachers’ planning:**

provides evidence of teachers’ understanding of science, especially tacit; to be considered in conjunction with accompanying lesson observations and post lesson reflective discussions;

**Interviews:**

important from the perspective of teachers’ action research – help reflection and planning; relate to teachers’ understanding of science, both directly and also through description of their practice – metaphor and story – thus can give evidence of both tacit and espoused ideas about science;
**reflective commentary:**

charts teachers' change and development across the inquiry; may give evidence of their developing espoused understanding of science; provides a window onto their pedagogical beliefs;

**bi-polar scale:**

provides evidence of espoused understanding of science, for discussion; at beginning and end of inquiry, therefore an indicator of change, rather than complete accuracy;

**questionnaire:**

provides evidence about teachers' beliefs about pedagogy, what is important in teaching and the values which underpin their practice;

**analytic memo:**

used by the researcher to aid his developing analysis of the progress of the inquiry;

This account now proceeds to a presentation of the case studies. In these, the analysis of the data generated by the above elements is brought together to form a description of each teachers' practice in the teaching of science over the course of the inquiry and how it related to their understanding of the nature of the subject. Short portraits of the teachers to highlight key facets of their general practice and their attitude and approach to teaching are included in appendix 9. These portraits present images of the teachers which add contextual depth to the case studies.
Chapter 5 - CASE STUDIES

STUDY 1 - Elizabeth

1) Initial period - to July 1995

As Elizabeth enters the inquiry, she is very insecure about her science teaching. Her insecurity translates itself into what she describes as 'safe' activities for the children. This compounds her situation, for such activities are in direct contradiction to her pedagogical aims, in which she wishes to generate children's inquiry and independence; they produce an area of her teaching in which she imagines the children may be bored. She is very unhappy about this and wants to improve. However, the researcher's analytic memo entry for 27.5.95 indicates that there are tensions within her practice which will make the resolution of such a wish far from straightforward. Most obviously, her teaching indicates a conflict between her desire to promote inquiry and the fact that, at this stage, she seems to be primarily concerned with the transmission of a body of knowledge in her science teaching:

Elizabeth:
• Wants to take risks in her teaching, less inclined to do so in science;
• Thinks she might teach something wrongly, put the wrong idea in children's heads;
• She wants to have the ability to know where things are going;
• She wants to have background knowledge;
• She wants/needs to be well-planned. Science takes the longest at the moment.

(Analytic memo entry, 27.5.95)

Elizabeth's general philosophy advocates a constructivist approach to teaching and learning, based on the development of children's thinking and independence. When asked to commit herself to an understanding of science, she can be seen to espouse an understanding which broadly reflects this, leaning towards a hypothetico-deductive conceptualisation of scientific method. During the end of term interview this understanding is common in her comments. There is a range of remarks about science within this interview:

1. It's a way of finding out about the world, a method actually, particularly through the use of the senses, especially sight.
2. I think of it as a process for testing ideas as well so, while you're finding out about the world, you're perhaps generating questions and then you use opportunities to test those out with other people, you know, refine your ideas...

3. SWA: What would it be that a scientist does that would enable you to characterise that activity as science?
Elizabeth: I think it's the testing aspect, isn't it? You're actually able to set up an experiment that will measure, aren't you?...rather than just an idea, it's an idea that can be tested.

4. I provide quite a lot of opportunities for thinking, you know I think thinking is very valuable and has been seriously neglected in teaching in the past...and science gives that opportunity, it's that sort of subject.

5. I want them to have a lot of process in their science. I want them to behave like scientists, if you like; you know, I don't want to feel that I'm just telling them things...I want to get that balance right...

6. (my philosophy) does translate quite well into my classroom. I think I provide quite a lot of opportunities for raising questions, then asking for their own ideas before starting activities, trying to find out what their own thoughts are...

7. SWA: Do you see anything different in the kinds of thinking that you're encouraging the children to do in science and a lot of the general things you're trying to do in Reception?”
Elizabeth: I think the same kinds of behaviours can be seen right the way through, right the way through from early childhood, right the way the kind of questioning and testing approach is a good one to nurture.....If you can start it young, if we can develop that in our schools I think that would be a very good thing to be able to do...

(all interview, 7.95)

These comments are supplemented by additional indications of her understanding recorded in her reflective commentary entry for 10.7.95:

8. Science is a way of finding out about the world, especially through the use of the senses. It is a process also, whereby one thinks about the nature of things, then tests that view to either confirm or challenge the original thought/view.

9. I believe children are constructing their view of the world and science can enhance this understanding.

10. Also, the opportunity to explore through spoken language what is happening - to describe, predict, explain and to have one's ideas challenged through discussion and the observation and participation of others

11. What do I want my science teaching to demonstrate about science and scientific investigation?
   - that we can explore together
that it is good to ask questions and challenge one another
- it is important to think about things first
- that we might be left with more questions
- that we can test our ideas
(all reflective commentary, 10.7.95)

These comments give insight into Elizabeth’s espoused understanding of science at this time. The procedural nature of science is represented strongly. All but number 9 mention it directly, and this response does so implicitly, suggesting a link between the process of construction and the nature of science. A strong characterisation of a hypothetico-deductive method is apparent, in which the purpose of science is thinking or exploration in order to give rise to ideas which can then be tested (see 2,3,6,7,8,10,11). The kind of knowledge produced by this method seems to be expanded in 8 and 10, with statements which hint at a falsificationist understanding, in which the role of tests or experiments is not to prove the validity of an idea, but to challenge it. Statement 1 suggests Elizabeth also recognises inductive processes, stressing the empirical basis of science and giving particular emphasis to the role of observation as a starting point for the method. She also seems to understand that scientific knowledge is provisional (see 2,3,10 & 11). Statements 1 and 2 suggest that Elizabeth conceives the overall purpose of science to be one of finding out about the world. This might suggest a realist epistemology.

References to Elizabeth’s attitude and approach to the teaching of science highlight the importance she places on the development of thinking and how she wants her science work to reflect this. The comments suggest that she wants to use a hypothetico-deductive approach within her teaching, with response 7, particularly, indicating how centrally her pedagogical philosophy is related to her conception of a person’s development throughout life.

The evidence coming from her practice is somewhat contradictory, identifying a tension between her espoused idea that science is primarily about epistemological processes and a tacit preoccupation with knowledge elements, in both her planning and teaching. Although procedures to encourage thinking and the generation of ideas are present within the sessions, these seem to be affected by an apparent desire to push through particular knowledge, often leading to confusion.
The plans for the three sessions on 12.5.95, 19.6.95 and 26.6.95 (appendix 10) contain procedures which appear to have the potential for generating the kind of thinking that she wants (see for example, the first part of 19.6.95 in which the children are encouraged to speculate and predict from their own ideas), but are in practice the sessions are strongly focused on the learning of specific knowledge. The planning targets for the half term, listed on 12.5.95, are very general, representing little more than elements taken straight from the National Curriculum. They are broad in range for Reception children, with little sense of how they are to be achieved or their relevance. As such, they are indicative of a lack of understanding or confidence with the demands of the curriculum.

The researcher's reflections from this period highlight this tension. For example, with regard to the session on 26.6.95, in which Elizabeth’s espoused aims for the session were to encourage the children to raise ideas about and predict what might be found in a forest or school environment, they indicate that her style is less open and tolerant of children's ideas and speculations than she would have wanted. The following analytic memo entry reflects an emphasis on learning specific knowledge:

- Questioning: focus? and is it dictating (certain) answers?
- Sorting: Venn diagram - she would not accept certain ideas, e.g. 'hats' in 'living'. Imposition of own ideas?
- Showing problems concerning the knowledge (she wants to put across) and uncertainty about alternative answers;
- She wants to encourage process base and has strategies (for it). But, pressure/conflict/tension (?) with knowledge, or more deep seated 'feel' about science nature and/or the nature and content of the curriculum?
- How happy is she if the children come up with alternative ideas?
- re. her statement that she 'wants to take risks with her practice and that she is less inclined to do so in science): If she wants to take risks, it would include - going with alternative ideas, not clamping down on them, providing experiences to challenge thinking, as she espouses.

(analytic memo, 26.6.95)

and Elizabeth herself is certainly not unaware of the tensions in her practice. It is well articulated in this comment:

I want them to have a lot of process in their science - I want them to behave like scientists, if you like; you know I don't want to feel that I'm just telling them things...I want to get that balance right....I could feel I was doing it this afternoon, you know, when I was saying what do we call it when you put the seed in and I wanted to use the word plant and there's a point when you have to give language; it's just sort of knowing that balance.

(interview, 7.95)
The introductory period has thus enabled her to realise something of the nature of her practice and the tensions within it. Within her reflective commentary for 10.7.95 she states that her aim for the project is to make her science ‘more procedural, not knowledge based’, indicating the direction her own research is to take.

2) Autumn term 1995

The evidence from 9.95 to 12.95 shows Elizabeth engaging strongly with her own inquiry. The process of questioning her practice is not easy for her, throwing her immediately into some confusion and self doubt:

She feels at a ‘struggle’ stage. Says she suddenly doesn't know what to do. Thinks it could be a good thing - learning about conflict. Says she is a bit lost with planning at the moment.

(analytic memo entry, 4.10.95)

Elizabeth focuses at first on the content of her science sessions. She makes a conscious effort to change her emphasis and tries to promote process elements within her teaching. The result is that the sessions become heavily weighted towards the development of children's observation skills. The decision to focus on observation comes early in the term, with her planning notes for 9.9.95 reading:

My focus: trying to make my science work more procedural, not knowledge based.

Exploration (procedural):
Start with making sure that the children have opportunities to observe.
Focus on children observing/then talking.
When planning make sure the children are observing.
My focus: [develop children's observation]...
SWA will give me focused feedback on that.

Me: write this up - just the observation. Things which worked, things which didn't.

(planning notes, 9.9.95)

The focus is maintained the next week and by the week after, 20.9.95, she is beginning to analyse the children's responses and discuss how best to use them. There is a movement towards an inductive approach within her general aims, as she seems to want the children to generate ideas from their observations:
Science: Exploring fruit and vegetables (2)
My focus: To continue with my observations of the children observing:
- what are they seeing?
- what are they saying?
- what is focused, what isn't?

I found I was beginning to make judgements about this last week, but I did find it difficult to pick out what was a 'germ of an idea' amongst all the talk and then support in the best way.

(planning notes, added emphasis, 20.9.95)

The session consists of the cutting up of various fruits and a discussion of what is found. The researcher's notes indicate that there appeared to be 'little real focusing, allowing the children to play with the cut fruit'. There are a few interventions, such as questions of the form "Is it sticky? What do you think is going to be in there?", but, in general, there is a sense of 'going with the flow' of the children's observations and comments. Elizabeth collects three pages of children's observation statements.

The session on 11.10.95 is again very explicit in its focus on observation. The researchers' observation record shows another very free exploration, largely consisting of the children's observation of jelly cubes. This is mostly undirected and, despite her intentions on 20.9.95, few of the children's ideas are followed up. Much of the session seems to rely on the value of children's observations, per se, as the following extract shows. Although she attempts to follow up one child's idea (the fridge), there is little development of, or from, their observations and even the obvious excitement of one child's discovery of the effect of light shining through the jelly is largely ignored:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>How are we going to change it?</td>
<td>A - Put it into water and put it into the fridge A - You need boiling water</td>
<td>- It's got bigger - The water went up the sides - It sank A - You have to wait till tomorrow for it to set. You put it in the fridge. A - It's cold R - I can smell it. M - It's lime....Lemon, lemon.</td>
</tr>
<tr>
<td>Let's try A's idea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Put the jelly into water.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What's happened?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Prompts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What's special about the fridge?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Pours water on)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Why might stirring help?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Passes it round the table for stirring)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A - The water's green now.</td>
<td>C - It's gone smaller.</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------------------</td>
<td></td>
</tr>
<tr>
<td>R - All the juice is coming into the water.</td>
<td>A - Hey! There's a light on the bottom of the bowl!</td>
<td></td>
</tr>
</tbody>
</table>

**What's happening to the jelly?**

I can notice something - it's disappearing. (Focuses on the fact that A can now cut it easily. Just now C. couldn't.)

What's happening to the jelly?

I can see it reflected on the table. Can you see it?

Can you see bubbles? It's disappearing. It's taking quite a long time.

Those hairy bits look interesting. Can you see them?

How has it changed?

(C - Lifts spoonful to nose. Smells it.)

How do you anticipate children's responses and what will be noticed in a session like this?

<table>
<thead>
<tr>
<th>C - Lifts spoonful to nose. Smells it.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - It's gone into water.</td>
</tr>
<tr>
<td>J - I can see sort of hairy, sort of jelly stuff round the edge of the jelly.</td>
</tr>
<tr>
<td>Ri - It's chopped in half and it's in the water.</td>
</tr>
<tr>
<td>M - It's all melted.</td>
</tr>
</tbody>
</table>

(Dissolving strands?)

The session ends with the children reporting a series of observations they have made about the jelly. These are not explored, but allowed to stand at face value. There is a sense that she is making a huge effort to curtail her tendency to try to transmit knowledge directly to the children and that this is making her hold back from most intervention. This is again evident in the session on 18.10.95.

In her written reflections of 23.10.95, she considers her practice over the preceding half term and she tries to justify her actions. She conveys very powerfully how the process of her own research is helping her to analyse her practice, confirming that she is making a strong effort to be aware of the tacit messages within it. She recognises her passivity in handling the children's responses, but contrary to the evidence of the sessions, she feels she is moving away from it. She feels the tension with her deep-seated concern to transmit a body of scientific knowledge. Her understanding is definitely in flux:

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Participating in the Action Research has been really stimulating for me. It feels like the best kind of in-service, because it is about children learning, and about me getting better at helping children to learn science. It's about me changing
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my practice, but understanding why and how I am changing, so it's the best kind of learning for me.

I think I have begun to sort out which kind of teacher support is helpful to the children in developing their observation skills. Initially, I was so conscious of needing to get away from the knowledge-based mode of teaching I was in, I became too passive during the sessions. I wanted to listen to the children, but I think I've found out that providing interesting resources is only partly helpful in encouraging observation.

... Me asking focused questions during the children's sessions is helping them to be more objective when they are observing. At times, however, I have felt myself slipping back into a didactic role, so perhaps this is the next step for me - sorting out my role, thinking about the kinds of questions I am asking or the enabling phrases I am using to focus the children's attention....

(Reflective commentary 23.10.95)

Change is evident within the next session (8.11.95). Her planning is more focused in its objectives, with an intention to help the children 'begin to notice similarities and differences in a variety of objects; to sort objects according to their own criteria'. There are also specific learning objectives in terms of scientific knowledge - 'to raise awareness of the materials around them'. The apparent link between the two is tacitly inductivist. The structure of the session itself involves the children sorting a variety of objects according to their own criteria and then classifying other objects around the room in terms of the material they are made of. The materials focus is a little unclear (as it does not arise spontaneously with all the children) and Elizabeth again shows a reticence when it comes to intervention with the children's ideas for classification. Epistemologically, therefore, the purpose of the observation is obscure, for the challenge to the children's ideas that would have been needed to describe it as hypothetico-deductive is not present, nor is any real idea-generation in an inductive sense. The children are asked to identify the basis of their sorting, but are not challenged by the other children, nor are their criteria discussed. Elizabeth describes it in the post lesson reflective discussion as feeling 'about right today'.

Elizabeth's confidence increases markedly during the second half of the term and by Christmas she is beginning to enjoy her science teaching. Part of this confidence she attributes to her ability now to be able to identify developmental implications within the children's actions. She is beginning to reconcile the development of conceptual understanding with her wish to promote the children's thinking ability. She considers that concepts should develop through what she describes as experiences. This is exemplified by the hypothetico-deductive instance in this extract from her interview and is also
consistent with her move to include more of an inductive approach, the experience itself being the basis of knowledge formation:

And then things started happening in the classroom... where the children were showing me what to do next, because the things they were doing were kind of like feeding into their conceptual development on materials. ..... There was this lovely day when R made a post bag very quickly, stapled card together, put a handle on; he was very pleased with it, you know - put two parcels in, great, put the third in and it snapped, but he kept on, it was great... I thought this is a great lead into this work on materials... and I'm thinking, I wasn't observing this happening before, you know, so I then started trying to write down how these experiences were feeding into the children's own development..... So I'm thinking all these experiences are all sort of feeding in - well I don't know if it's the right sort of, 'cos I'm always very concerned about getting it right you know. (interview 6.12.95)

This pedagogical understanding is also reflected in her ideas about science itself:

SWA: You've said that you feel it's more right now because you're seeing science in a different way; in what way are you seeing it differently?

Elizabeth: I think I'm seeing it much broader; I'm getting much better at being able to observe the children and see what they're doing and link that in with some sort of conceptual development that they're having to do with their making sense of the world in a scientific way - the experiences that they're having and they're telling me about. (interview 6.12.95)

She adds at the end of the interview that she finds it quite exciting that she has not done any experimental science in the sense of a 'fair test' this term. This has characterised her practice before and is, in primary schools, a very commonly used method. It is strongly hypothetico-deductive in character.

Elizabeth’s new enthusiasm for science suggests that she feels she knows more about what she should be teaching. In the same way that she identified certain skills and processes as being common to all people at all stages of life, she excitedly draws a parallel between the nature of her own learning and that which children must experience:

I'm feeling really good about the project actually, because it seems all to have come to a good point over the work with materials. Suddenly, as I was preparing over the last few sessions, I didn't have this problem of not knowing what to do, which I've been having a problem with earlier on in the term. I feel I do now, actually; I feel very positive about the science work that's going on - different things that were happening suddenly started to feed into my own development and I thought this is a real case of learning actually, this is what must happen to children... It's what happens to all of us, but somehow I could see it happening, I could feel it happening - I hope this doesn't sound too sloppy! (interview 6.12.95)
The confidence in what she is now doing is accompanied by a sense of ‘rightness’ that was not there before:

SWA: You said that somehow it feels more right than it did and you were quite concerned about getting it right - now you feel you are getting it right...'

Elizabeth: Somehow, something's going on inside my mind where all these things are slotting in together and it just feels easier; I seem to know what to do. Whereas I used to have to make a really conscious effort to go to the document and look things up and think what am I going to do, you know, and it was just like an isolated bolt on kind of thing - I don't think I was doing it in an unconstructed way...but it was all rather sort of isolated, but now it's become more holistic.

(interview 6.12.96)

Elizabeth also indicates that her science teaching and the rest of her practice have become more closely aligned. Not only does it fit more easily with her general pedagogical philosophy, the approach she is developing towards her science may now be exerting an influence elsewhere. She describes how it is helping her to justify the Plan Do Review session she organises for each afternoon:

I've always found it difficult to know what they are actually doing, actually achieving, because when we have this time which is about free choice, then I think it is very important for me to justify it in educational terms, you know, - I think I could. I think it's had a really good knock on effect actually; I'm really pleased to be involved in the project; I feel quite excited about going on next term...

(both interview 6.12.95)

3) Spring term 1996

The sense of excitement and change within Elizabeth’s practice continues across this term. Her sessions become more purposive and this is reflected in her planning. She is clearer in what she intends to do and, by the end of the term, there is evidence that she is beginning to blend greater expectations of knowledge development back into her sessions.

The term is dominated, however, by her exploration of the potential of children’s observation and this is frequently referred to in her planning notes. She begins the term with a strongly inductivist approach, reflected in her preparation for the session on 10.1.96. In this, she specifically identifies aspects of the National Curriculum concerned with the development of observation skills:

Sc1: 1,1b - Use focused exploration and investigation to acquire scientific knowledge, understanding and skills;
Sc1: 2.2a - To explore using appropriate senses;
Sc1: 3.1a - To use their sense to explore and recognise the similarities and
differences between materials

and there is a recognition within her detailed intentions for the session that this
observation has a purpose:

Aim:
- To introduce the idea that things can be put together because they share
  common properties and that we call this sorting;
- To introduce the idea that we can find out about things using more than one
  sense;

(planning notes, 10.1.96)

Within the sessions themselves, she can be seen to focus increasingly on the use of
observation as a tool for the development of children's scientific knowledge. She starts to
intervene with suggestions and questions much more frequently. Unlike the sessions
before Christmas, she is much less content to leave the children's observations
unexplored. This approach develops slowly, with the lesson observation for 10.1.96
indicating merely a collation of the children's ideas. However, she does try to encourage
the children to explore the thinking behind the sets they have created:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
</table>
| Have you got an idea? | 8 - lorry  
| | robot  
| | ball  
| | (canoe)  
| | car  
| | 4 - It's a line  
| Can you tell us about your set? | 4 - book  
| I thought it was cars or vehicles, then he put this person in.  
| | camera  
| | puzzle  
| | 4 - cos they're both flat and these are both hard  
| Why? | 119 Challenge and progression  
| So if we put those together in a set you've got 2 sets. If you were making a set of hard things, then are there more on this table? Can you find them? | Challenge and progression  
| | Application?  
| (Gets rope) I'm going to put it in a ring to show they go together. A set |  
| 5? | - wobbly man  
| | - boat  
| | - car  
| | - ball  

119
What is 5 thinking of?
I thought she was thinking of shiny things, but.....
(Sorts for 5)

5 - Angel
- ball
- book
- reindeer
- puzzle
- bear

Learning from others?

5's ideas?
Whose thinking?

(lesson observation, 10.1.96)

There is an increase in her use of focused questions to direct the children's observations during the session on 24.1.96 as she tries to encourage the children to generate understanding from what they are seeing. At the same time, however, she supplements this inductiveist approach with an attempt to engage the children in the testing of ideas. She makes three attempts at this in response to their suggestions as to what the wind might be able to move. She gives up when she gets no response that she feels she can pursue:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>What made the ball move across the table?</td>
<td>Breath</td>
<td></td>
</tr>
<tr>
<td>We're going to think about a windy day.</td>
<td>8 - (blows pen across)</td>
<td></td>
</tr>
<tr>
<td>Oh look... All of you have a go.... I want you to think about what the wind might move on a windy day.</td>
<td>Kite Pictures</td>
<td></td>
</tr>
<tr>
<td>Like when taking home a piece of paper?</td>
<td>Balls Balloons Dog (8 disagrees) Kites Grass Rubbish Flowers, trees, hats Balloons Paper Doors blowing Boxes</td>
<td>This vast range of examples must surely indicate an understanding of something. What?</td>
</tr>
<tr>
<td>What sort?</td>
<td>With wheels on. River and the sand Plastic plates Waves Boats</td>
<td></td>
</tr>
<tr>
<td>Boats on the sea...</td>
<td></td>
<td>More exploration of ideas?</td>
</tr>
</tbody>
</table>
This kind of structure - direct observation of objects, moving to recall of experiences, new experiences and application of understanding to new situations - is starting to become established as characteristic of her practice. Interestingly, it is allowing her both to re-locate the learning of scientific knowledge in her teaching and to have the processes of induction and hypothetico-deduction proceeding alongside each other. The question 'how could you find out if your idea is right' does not suggest a falsificationist approach, but much science education literature characterises the pedagogical process in this way. Elizabeth was, for example, reading Harlen and Jelly (1989) at the time, a text which advocates this questioning style. Harlen and Jelly are not, however, putting forward an epistemological position; it is a pedagogical suggestion, designed as a teaching aid for the encouragement of children’s conceptual understanding. This kind of difficulty in analysis is a good example of the complexity involved in trying to identify fixed philosophical positions within the lives and actions of teachers whose prime focus is the education of the children in their care, not philosophical debate.

Elizabeth’s general approach has strengthened by 29.2.96 (appendix 11). Here the lesson is clearly structured, with intervention questions designed to focus children’s observations. There are attempts to encourage the children to apply their understanding - either from what they have just observed or from their past experience - by generating predictions.

The complexity of Elizabeth’s emerging position regarding the nature of science is reflected in the end of term interview. When challenged to say whether or not she thinks her understanding has changed, she gives a rather ambiguous answer which, nonetheless, suggests that it has. It also highlights her continuing concern with the place and status of
knowledge in science and whether answers can be right, indicating a move towards resolution. She is much clearer about provisionality in scientific understanding, identifying an importance in skills and procedures. This is allowing her to establish links with her other teaching:

SWA: Do you feel that your understanding of what science is, has changed since we started?
Elizabeth: I don't know if it has or not, really. It's become sort of much more complex I think, yes. I'm still asking myself what it is exactly, you know. I've still got a slightly academic view of it, you know, because of school science...

SWA: Because what you said to begin with was that you were worried about the right answers.
Elizabeth: Yes, I'm not worried about that now, no that's definitely changed
SWA: Why not?
Elizabeth: Well, it seems that there isn't really a right answer, you know...that people are still struggling towards a right answer and once they've got a right answer then something else happens which challenges that, really...I suppose there are certain things that people are sure about, but when you start thinking about it, then it's not so sure, so I think, yes, I don't think there are right answers now and I'm quite happy for children to sort of go through that process as well. It's very interesting in how it relates to other subjects, isn't it, cos like with maths it's a very abstract world, isn't it, and there are right answers. But with science it's different, you know. With literature, with literacy it's different...So I'm not worried about the children having right answers now, I feel much more the important thing is the process and the skills actually than the end product, which I suppose is what I sort of believe about my other work as well, you know...
(interview 26.3.96)

The accord between science and her general pedagogical philosophy is continuing to increase. She sees the importance of discussion and social construction in knowledge formation, emphasising how she wants children to interact in their search for understanding:

I feel completely committed towards the kind of process approach for the children to go through. So, I mean I found the little structure I made for myself to be quite a useful way of planning and I think when I plan the next sequence of work, which is about living things, I think I'll use that again, although obviously it will need change. I also think the kind of attitudes I'm promoting in the children are very important, so I think I will stick to that - the fact that they can argue with each other and try to justify things, you know, or justify what they've done, I think that's good.

(interview 26.3.96)
Her confidence is evident throughout the interview. The excitement apparent in her 6.12.95 interview has matured, but the positive attitude she has to her science practice is tempered by a realisation of what still has to be done. For example:

SWA: How do you feel about the project now and do you feel you are still changing?

Elizabeth: Yes, I do, actually, I do feel I'm still changing. I'm still feeling positive about the project and still enjoying doing it - I wish I could give more time to it, one feels one is being pulled in all different directions. But during the Easter holiday I am going to have the opportunity of writing something up; I am going to write something down because I think it's good just to write something down about where I think I am now. I haven’t really marshalled thoughts together, you know?........

I feel I want to change my style, you know, how I'm running the small group times after the holiday.

(interview 26.3.96)

One of the results of her new found interest in teaching science is that she has become more interested in scientific ideas herself. She first alluded to this in the 6.12.96 interview, attributing it to the demands of her inquiry. It has made her question herself and search for justification for her practice:

Do you remember I was saying to you last time that I've suddenly become very interested in science?...I'm still going on with that, I'm still reading about things. I know there's been quite an awareness of it outside, in the wider world, hasn't there, but I still feel quite interested about doing more myself at my own level, and I don't think that would have happened, I think that's possibly to do with the process of being in the action research, because it's just making you think about it all the time, isn't it, because you're asking questions like, what does science look like for five year olds....so I'm puzzled by that myself; I'm interested by that myself. But I think that ultimately it will have a good effect on what I'm doing with children....I think anything where you're thinking about something is bound to be helpful and I've found myself talking about it to my friends outside school and asking them what do they think science is.

I had a hang up about science which I think is going, you know, has gone really...I want to read the Stephen Hawking book - my sister's got it and she's bringing it home for Easter. When you start thinking about time having a beginning, you know, it's all very exciting, isn't it? And it wasn't a while ago.

(both interview 26.3.96)

4) Summer term 1996

This term sees further change. Elizabeth continues to explore the balance between procedural and knowledge elements in her teaching and her planning notes for the term indicate that she now sees procedures as a means to an end.
The three sessions observed to 6.6.96 reflect this trend. From the focus on inductive procedural elements seen earlier in the year (c.f. planning notes, 10.1.96), there is once more an emphasis on knowledge outcomes in her planning. For example, there is almost no mention of procedural or observational objectives in the proposed intentions for the session on 10.5.96, save for the word 'explore'. The aims for this session read:

- to explore the idea of what a plant is
- to begin to come to an understanding that there is a wide variety of living things called plants
- to come to their own definition of what a plant is.

(Planning sheet 10.5.96)

In the continuing change of prominence between inductive and hypothetico-deductive processes within her teaching, the record of this session shows a complex mixture of the two. There is definitely a hypothetico-deductive feel to the initial format, in which the children are encouraged to see a 'picture of a plant in their heads' which they then use to sort a collection of objects into plants or not-plants. The subsequent exhortation to observe closely the characteristics of their plants suggests they are testing their original ideas for validity. There is a firm structure to the session, with many examples of teacher questioning to focus observations or challenge ideas. However, there is a suggestion that Elizabeth wants to ensure that certain facts are known. This appears most overtly towards the end of the session, where the researcher comments: 'pushing?'

The session is worth close consideration, for it demonstrates how the various elements of her understanding and pedagogical style are becoming increasingly intertwined:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
</table>
| (Has a collection of objects under a cloth). See a picture of a plant in your head. Ask each other what you can see. We'll listen to each other. | L - Daffodil  
H - Tulip  
Th. - Red red rose  
To. - Yellow flower  
M - Sunflower seed. It was a seed then it grew.  
B - An orange | |
I saw a tree.
(Takes off cloth - Russian doll, bluebells, cabbage, tree leaves, seeds, pineapple, bark, cress plants, pepper, avocado, sprouting twig, mug with picture of plants, stone, scissors, pencil, leek, book, plant in pot.)
Have a look at them. Play with them for a while.

Put them all back.
We're going to think now. I want us to think about what a plant is.
(Recaps the children's choices).
Is there anything not a plant here?

Let's make a not set.

Anything else?

Is everyone happy?
Let's look at these (the plants).
One each.

Now we'll have a new game. All these are in the plants. Look and try to tell me why it is a plant.

Anyone help?

L ?
Anything else? What are the green bits?

It's got buds.
I think mine is a plant (leek).

Anything else for that set?

(Children play, look, make the Russian doll, lots of smelling).
M - Guess what, my seeds are growing

L - cabbage
Leaves....
M - mug
B - bark
L - stone
MM - stone
H - Russian dolls
Th - cabbage
To - pepper

Pineapple
Pencil
Seeds (H - those are plants)
Scissors
M - these seeds can grow into plants

(H chooses leek from the other set)

Th - (pot plant) It grows.
M - cos when you plant it and water it it grows and grows and grows until it is big.
B - (shakes head).
L - cos it's got leaves
Th - it's got green leaves
To - Sticks off a tree
L - cos it's got petals (bluebells)

M - stem
L - buds

L - it's a vegetable. We should have a vegetable set.
Pineapple/cabbage/avocado/pepper/leek
Are vegetables plants?

(Breaks off a leaf) What is it? So this has leaves just like the plant. Anything else in the vegetable set a plant?

Is it a vegetable? It's not a vegetable. It's a... It's got leaves.

Anything else?

Why is this a plant, To. ? Do you think these are leaves? Do you think there can be different kinds of leaves? H - why is yours a plant? It's from a tree, its got bark, leaves... Tho.? Why is yours a plant?

What can you see underneath?

And it's got leaves? So there are lots of different kinds of leaves? Put them back - we'll finish with one more thing.

(Writes on paper - what is special about plants?) We're going to pretend that we're trying to tell people what plants are. Maybe they've never seen plants before. They're not from our planet. What's special about plants?

Would you say trees are plants, To.?

What's special, B?

If there are living things called people, are plants different kinds of living things?

Do plants have legs? So shall we say plants have roots? Anything about the place you find plants?

No...
H - well, they are sorts of plants.
M - If we plant seeds they grow into cabbage
A leaf.

M - (pineapple). This, cos it's from a seed.

Fruit.
L - pepper
M - (avocado) I know this had a stalk. It's from a tree
To. - cos it's got leaves.
M - No....

H - it's from a tree. Its got leaves.

Th. Cos it came from out of a seed and it's green.

M - roots

What are leaves?

Opportunity for more observation/comparison of leaves?

H - they've got leaves
To - they've got leaves in space.
M - seeds - they grow - we could tell them about seeds.

To - trees grow
B - (no response)
Th. - cress has little tiny leaves, it grows in twos.

Specific/general

Different concept?

Pushing?
What happens in a shop?
Is there anything special about plants needing water?

M - in your garden
- in a shop
They put seeds and water
They need it or they may die.
If you don't give them water they'll go (bends plant over).

(lesson observation, 10.5.96)

There is a long, taped post-lesson reflective discussion following the session on 6.6.96. Elizabeth's confidence is very high. Process and knowledge are mutually important in her developing view that scientific knowledge for the children is that which has been generated scientifically. She feels that she is now 'doing it right', indicating that she has acquired the confidence to organise the curriculum in her own way. She sees it as important that she does not slavishly follow either National Curriculum structures or the school planning, for that might not enable her to pursue the full potential for knowledge generation which her conception of process is giving her:

SWA: So where do you want to take this then?
Elizabeth: What, the leaf bit? I've been thinking about sort of like long term what I'm going to do. I feel like I'm really behind, but it doesn't matter about that because I feel I'm really quite interested in exploring the idea of plants and leaves with the children, from the process point of view that's important..... I think it's about getting the children to observe and getting them to talk and getting them to explore, so I'm not worried about the knowledge any more, you know I'm more concerned about the way they're behaving and so I don't feel worried about being far behind, you know...

SWA: So you feel far behind. But, so why do you feel far behind?
Elizabeth: It's whether you give them lots of experience or whether you do something in depth.....I only feel far behind in terms of it's not so cut and dried now, like this week doing plants, next week we're doing birds...I know Carol has explored a lot of work on flight. I haven't done anything like that, I've just kept right off that and gone on with this and I feel happy about that.

SWA: Why do you feel happy about that?
Elizabeth: I don't know why I feel happy - I've changed! I've changed! Because I'm enjoying what I'm doing and I feel satisfied with the way I'm teaching and I feel they're getting a lot out of it as well in terms of learning, you know? Yes, so that's it, I feel...I don't feel there's any conflict really...I mean, will it matter that they haven't covered that bit about birds in terms of knowledge - I think the rewards are greater for seeing this through actually, pursuing it and doing it more in depth and
if they're ending up with a more process based curriculum, if you like, rather than just skimming the surface, having lots of experiences, I think I feel alright about that, I think I do...

SWA: So you're prepared to sacrifice facts, knowledge...?
Elizabeth: Yes, yes, for the way that we were this morning because I think they were behaving in quite a scientific sort of way. I feel they're getting the right kind of attitudes, you know, I feel they're talking, I feel they're looking...I think their observational skills are improving...
(post lesson reflective discussion, 6.6.96)

There is a strong sense of validation here. It derives from a mixture of educational criteria and those connected with her understanding of the nature of the scientific enterprise. Those based on educational aspirations appear to be the final arbiters. Her attitude and approach to teaching science are ultimately justified because they help to give children life skills, recalling strongly the emphasis she had placed on the relationship between child and adult learning in the previous two interviews:

SWA: And you think your aim is justified, do you?
Elizabeth: Yes I do, yes...
SWA: Why?
Elizabeth: Em...because I think I believe that is much better for the learner as a developing, changing being, you know, with a life skill, rather than ending up with a body of knowledge which I think will probably be forgotten. ...It's how you approach things...
SWA: So that is not just to do with science, then?
Elizabeth: No, I think it is to do with other things as well, but I think in science it's very tempting to focus on the knowledge and not to give that other bit the importance that it needs...I think the knowledge is much easier to assimilate probably as a learner if you've got all the other things in place really, so if you're laying those good foundations - that's what I feel I suppose - then it's going to make it easier later on.
(post lesson reflective discussion, 6.6.96)

Her responses to the questionnaire (appendix 8) indicate how closely her personal and professional lives merge in her commitment to teaching. Passionate concern for children's well-being and intellectual development is characteristic of all her responses, leaving no doubt as to the centrality of her professional role in her life. It is a source of deep fulfilment. In describing what her best teaching feels like when it's happening (Question 3), she portrays a mixture of emotional and intellectual engagement which recalls the characteristics of a Maslovian 'peak experience' (Maslow, 1954, 1971):

Wonderful! Stimulating and totally absorbing. It has a kind of momentum to it; one thing leads to another and it feels really exciting, especially when something is sparked off that perhaps I hadn’t planned for. It's totally rewarding too, although it
The pivotal role of her affective experience in the both the validation of her practice and her motivation to engage in continual professional development, is reiterated during the post lesson discussion when she discusses the questionnaire responses. But she also adds an element of external approval from parents and colleagues to her overall position. The result is a complex mixture, suggesting dialectical conflicts which explain her commitment to examination of her practice and her propensity for change:

Elizabeth: It is linked with knowing what you're doing is right, but that's the sort of person I am, you know; I've got to feel I'm doing it right. I have got quite a sense of my own sort of philosophy, my own aims for education and at the moment they don't seem to conflict too much with what's generally accepted with what's good practice, or whatever...but I think there is a certain sort of inner sense that you get when things are going really well...it's like a sort of engagement of mind and that's a really stimulating thing, but yes, it is linked with what you're doing is right, but at the moment I feel that what I am doing is right because I can see the children change. I sort of get feedback from them and I get feedback from parents and colleagues...

SWA: So a lot of the justification could actually come from those elements rather than you saying I know this is right because I've sort of analysed the subject? But it's the feedback you're getting from parents, it's the look in the child's eye, its...

Elizabeth: Yes, it's all those things as well. I think it is that, isn't it? It doesn't seem to happen just on its own, you know?

SWA: So could you imagine a situation where you were teaching something because you thought it was right, could you imagine still thinking it was right in a sort of philosophical way, a justificatory way, if you kept getting poor feedback from the parents?

Elizabeth: I don't think so, not at all, not in a negative way, no. It's very much to do with relationships and, you know, being in a community. No I just don't think I could. If I had any sense that it wasn't right - externally right - then I think I wouldn't do it....

(post lesson reflective discussion, 6.6.96)

Elizabeth's confidence remains high for the rest of the term. However, her struggle with understanding goes on. She still has uncertainties. The discussion after the session on 25.6.96 shows her trying to gather the elements of science into a coherent conception of its nature. She is ostensibly talking about her teaching, but her thoughts about her
practice and her own epistemological ideas are intertwined. A month later, during the final interview, she is reaching a resolution of these tensions. She is enthusiastic about the effects of the inquiry and looking forward to the coming year. She has a clear sense of what she wants in her science teaching and how to achieve it:

I think it’s been a very good year. I’ve really enjoyed it. Actually, I’m sorry it’s come to an end, but I’m determined to keep up the momentum and the interest, you know, and this weekend when I did my planning for the next year I felt, you know, sort of inspired by what we’ve been doing and I felt I had a clear picture of where I wanted to go, what I wanted to do.

(interview, 16.7.96)

This ‘clear picture’ has enabled her to be confident that she can interpret children’s activity in terms of their scientific learning. She recognises the change she has undergone over the year, considering that her struggle has brought her to a position upon which she can now build. She explains that she has developed a framework which enables her to make sense in science education terms of the children’s actions:

So that when they come up to me and they say all those little things that they constantly come up and tell me all through the day, I’m beginning to slot it into an understanding of their scientific development. I think, you know.....that’s building towards scientific understanding, scientific ideas, and I felt pleased I could do that; I don’t know whether I could a year ago. They seem to be doing something good, it seems to be a good learning experience they’re going through, but I seem to be able to slot it and I think I’m at the beginning of that process and I think that’s actually going to carry on now. I don’t think it’s fully there...

(interview, 16.7.96)

There are some significant responses regarding her espoused understanding of the nature of science. She begins the interview with a reaffirmation of the position that scientific understanding begins with observation, but this leads into an interesting ambivalence when she tries, rather inarticulately, to define the subject:

SWA: Do you think that's right?
Elizabeth: I do actually, yes.
SWA: Why?
Elizabeth: Because I think I’m beginning to come to an understanding more about what science is, you know, it's beginning to have an understanding about the world in which they live and beginning to, you know, er...build up ideas. I suppose concepts about...about...about the natural world.

(interview, 16.7.96)

There emerges the possibility that her exploration of science over the year has brought her back to a position where its aim can again be viewed as knowledge. Initially,
This meant knowledge transmission, seen tacitly within her practice. Now the position of knowledge can be legitimated; science is about knowledge formation. The processes and skills she has explored and now espouses are significant because they are educational, enabling children to generate that knowledge. The fact that she can link this new conception to her philosophy of the development of children's life skills is empowering for her; she has found within her understanding of the nature of science something which brings her science teaching into the rest of her practice. Now scientific knowledge can quite legitimately be the aim of her teaching. As a teacher, her job is to find the best way of helping children generate it. The interview continues:

SWA: Do you think that understanding you've got about science has changed?
Elizabeth: I think, yeah, I think it has. I think it has become much more process based, I'm sure....I've always felt that I've wanted to offer a process based curriculum, but I've found it difficult to know what that was in science; I'm beginning to know that now...It has changed. I think I've moved away from feeling that I've got to offer a knowledge based curriculum..... I think that because you're enabling the child through developing processes, then I think that leads naturally into them wanting to increase their knowledge, do you see? It seems that the process comes first and then the knowledge...alright I suppose they all kind of fit together in a puzzle, but...you've got skills too and they all fit together...but I definitely feel more confident about my science teaching. I think I'm a better teacher of science than I was. It's been a great experience. I don't think it's going to stop actually...
(interview 16.7.96)

Her discussion of the two bi-polar scales reveals significant evidence of the change that has occurred in her understanding of the nature of knowledge formation in science. They are ostensibly very similar, but as she engages with the comparison she recognises how differently she now views science. She gives a verbal confirmation that her original conception was of fixed, objective knowledge and that the experience of her action research has raised epistemological considerations which make her challenge that view. She sees provisionality in scientific knowledge; this understanding appears to stem from a realisation that human beings are inevitably involved in the generation of scientific knowledge and that, consequently, all that she understands about personal knowledge formation will be present in it. The sense that she is slowly drawing the process of scientific knowledge formation into the general constructivist understanding of learning.
which underpins her teaching philosophy is strong. Her initial realism is now tempered by an epistemology which casts doubt on whether truth is ultimately knowable.

The discussion of the results enables her to crystallise these views, as the following lengthy extract shows. The discussion also helps her explore what she at first sees as an inconsistency between this epistemological understanding and the nature of the methodology her responses indicate. The resolution is powerful. She develops an understanding that a rigorous methodology is still necessary, even though knowledge formation may be provisional and subjective. Importantly, she can link this understanding to her teaching:

SWA: So, do you feel that your actual understanding of what science is about has changed?
Elizabeth: I don't know if I had a very clear understanding of what it was...I still struggle a bit...em...
SWA: It's very interesting as regards the two (differential sheets); basically they're almost identical. It's quite fantastic...there are only a couple of differences, slight differences...
Elizabeth: More to rigorous is interesting, isn't it?
SWA: You've gone more to rigorous and the subjective objective has gone a step towards being more subjective and the certain-provisional you've gone a step towards being more provisional. Does that mean anything?
Elizabeth: Em...yes, I think I have gone more to the provisional, because it seems that the more you discover new things, it leads to more kinds of questions, so yeah, I think I have, I have moved there...whether it's right or not, I don't know! Yes, I thought about that a lot and found that quite hard actually because it always is certain at a certain point in time, but then it's...by that very nature it's always provisional because there must always be more to learn about something or...you can break it into smaller and smaller parts...
SWA: So does that contradict a feeling that you might have had at the start?
Elizabeth: Perhaps I thought that it was more certain...
SWA: What about the subjective-objective one?
Elizabeth: Em...I think that's a bit like the certain-provisional idea. I think that ties in with that, that it's objective to a certain point, but because of the way you're viewing, the way I'm viewing it at that time, then there's a subjective element in it, so it's always going to have that kind of personal element in it as well, which makes it subjective...I think that's what I was thinking about, whereas it was always totally objective - I think I did think of science more as a 'discipline', you know, that was objective - but because of the work, I suppose, I've come to challenge that now, so I think I have changed...
SWA: The other one you've changed is the systematic and the rigorous. You've put the systematic and the rigorous right in the ones now.
Elizabeth: I've put the rigorous in the ones...yes that's right - that's
SWA: Is it contradictory?
Elizabeth: Em...I've got the rigorous in the ones and the systematic in the ones, oh yes, that's right....what did I have before? In the twos....
SWA: You had it in the twos....
Elizabeth: That's interesting....(pause)....No, I don't think that's contradictory, actually, no, I think it is systematic...It can still be subjective and provisional, but still be systematic and rigorous...yes...Yes, I did find the whole quite difficult, quite hard, quite challenging, which is why I've got lots in the threes, cos, you know, it seemed to fall into both categories....Yes, I feel it has to be rigorous still....
SWA: It's a feeling that you still need rigour?
Elizabeth: Mmm and a system, yes, even though I might not be thinking about it as a...as a...Perhaps it means that okay it might be systematic and rigorous, but it's raised more questions for me about what it actually is, do you see? So one is implying a way of working and one is implying what science is - it's very questioning and can be uncertain and it's always changing...
SWA: So you don't feel there is a tension and a conflict between being strongly disciplined and the uncertainty of what you're finding out?
Elizabeth: Yes, that's right. And I think it's alright to promote that idea in children, you know, it's good that they work to a high standard and they're not going to accept any old results; it's okay to be uncertain but to tackle it in a very ...(tape indistinct)...way...Yes, I feel happy about it!
(interview, 16.7.96)

This last comment hints at mutual support between her new understanding of science and her teaching philosophy. In the same way that she can now accommodate science within her wish for process and skills based education, her epistemological realisations can be applied generally. The two are intertwined.

Her inquiry has transformed her from someone who was very reticent and insecure about the teaching of science to someone who now has the confidence to challenge the conceptions of others, something which she considers to be very out of character for her. She recounts how she felt ‘awful’ when she realised she was judging a colleague’s planning, but that this did not stop her from thinking she was right. She has a sense of equanimity and belief in her practice now that would be hard to change:

Elizabeth: If somebody said you’ve got to teach all this knowledge, I think I’d find that extremely difficult. I’d think this isn’t a good way of learning; this is a waste of time, because in six months time the children are not going to retain this knowledge. But I think with the way I’m teaching at the moment, they are. They’re building up a kind of internal structure, if you like, that will enable them to be able to learn
knowledge as and when it’s appropriate, do you see?
So it would have to be someone like an Ofsted inspector to say something like you’re just not covering enough of the knowledge, you’ve got to put in more...I think it would be a very narrow view, it would only be a part and not the whole thing. It would be like I think about maths, if someone said you’ve got to go back to teaching standard algorithms all the time - that’s a very impoverished learning style. I’d do it, but I’d try and be subversive. I’d have to try and do both.

SWA: You’d have to?
Elizabeth: I’d have to, I think...unless I was threatened with dismissal or something I think I’d have to try and compromise. I’d have to try and introduce different ways of understanding as well...because you can’t actually teach something well that you don’t believe in, can you really, I don’t think...

(interview 16.7.96)
Chapter 5 - Case Studies

STUDY 2 - Carol

1) Initial period - to July 1995

At the start of the inquiry, Carol conveys a general lack of confidence towards science and the teaching of science. Her ideas about the nature of science are articulate but there appear to be significant tensions between them and her practice. Preliminary evidence presents a picture of someone who considers that her role within her science teaching is to plan open-ended activities for children in which they will be encouraged to learn for themselves. Within the post lesson reflective discussion, 10.7.95, she explains that she sees the teacher's role as rather superfluous once the children are engaged and that she doesn't want to 'interfere' with their explanations. Her image is of well-motivated, confident children exploring their environment and constructing their own understanding from experience.

This apparently coherent position does not, however, carry through into confident science practice. On the contrary, there appears to be uncertainty and contradiction. A lesson observation on 10.6.95 suggests that although she may espouse an open-ended, process based approach within her science work, her manner with the children contains a tacit message that she considers science actually to be about 'right' answers. Although she may be encouraging the children to generate ideas, these ideas are not significant in her conceptual objectives for the session. She is aware of this tension. In the post lesson reflective discussion from 10.7.95, she comments that she is unsure of the purpose or direction of science work and that she feels a conflict between her 'holistic' philosophy and the need to identify science work that specifies knowledge. In commenting on a preliminary portrait of herself by the researcher, she expands on this tension a little, giving a clue as to its possible origins. She identifies a personal lack of scientific knowledge as a major concern, indicating how it makes it difficult for her to support children's learning effectively. She then goes on to comment:
My dad is a well known scientist and three of my four brothers have science led degrees. (Hence deep seated insecurities or what!!)

(Respondent validation comments, preliminary portrait - July 1995)

Clearly, such a statement has a potential significance in the understanding of Carol’s attitude and approach to science and the way it develops over the course of the inquiry. It suggests that an element of her professional attitude and practice may well be determined by factors which are powerfully influential in the determination of her self image, but which have little connection with her professional life (c.f. Goodson, 1991).

Evidence of Carol’s understanding of the nature of science at this early stage of the inquiry is beginning to emerge through lesson observations and post lesson discussions. Further evidence can be found in an interview conducted in July 1995. Within this interview, Carol makes the following statements, all of which can be seen to relate to her conception of science:

1. I ask what do scientists do and hopefully the reply comes out "we are investigators, we find out about things". I don't know if we ever really look for answers or reasons, we just look to find out.

2. SWA: Is finding out about finding answers? Carol: Yes, but given that there are lots of answers there never seems to be one reason for any one thing; you might find out part of an answer - I don't think you ever get the whole picture.

3. SWA: So scientists don't get the whole picture? Carol: No, I don't think they do.

4. It's a process of exploration. (Scientists) are searching and researching and continually investigating.

5. SWA: What is it that adult scientists do that actually characterises what they're doing as science? Carol: I'm not entirely sure that it's very much different from what we do with Reception children in that you are still trying to find things out, you are still looking for reasons, you're testing out your ideas, I mean we go round and round with all these ideas and things and nobody really knows.

6. You take on the wider scale the whole thing about measles vaccine. This is how I personally perceive scientists. There they are, oh yes, they've got all this sussed out and then, oh my goodness me, in ten years time they've all changed their minds. Oh that wasn't right, so what do they do, they're only doing what we're doing - they have ideas about things, they try them out, they see if they work and if they work well all to the good and if they don't, they try another way...
I think part of human nature is partly the quest for reasons and we look for patterns - patterns in almost everything...

So you have a healthy scepticism about the truth of scientific knowledge?

Yes

There are so many questions and there are so many answers and I just don't believe that anyone ever finds them...

When we're actually looking and teaching science I mean it's actually teaching them to look, to actually notice, to observe around them and when they're actually observing they're gaining their own sort of understanding and they're making their own questions - you know they make their own statements and assumptions about things which you can challenge and they challenge for themselves and so it goes on...

(All interview, 7.95)

This evidence conveys a passionately held understanding that a quest for meaning in the world is a fundamental part of human nature (5,7,9) and a conviction that the scientific enterprise is severely limited in its ability to provide answers to that search (2,3,5,6,8,9).

Science is characterised as a process of exploration and inquiry which could generally be described as hypothetico-deductive (5,6,10), in which the driving force seems to be an exploration and testing of ideas. Within this general hypothetico-deductive 'feel', however, there is little indication that she considers there is any fixed method for this exploratory process. There appears to be an ambiguity in her understanding about the way in which scientists work, their motivations and the role of tests within their inquiry. Response 5, for example, could suggest that tests might be used to confirm ideas, whilst response 10 appears to be falsificationist in tone, with the aim of the process being to challenge ideas rather than seeking to support them. Her comments on the role of observation in this response suggest that her thinking has an inductivist element as well.

Her responses indicate that she believes scientific understanding to be provisional.

Science is an aspect of a general human drive to explore (7, supported by 1 and 9). This idea is encapsulated in her characterisation of science as a process of 'finding out' (1,4,5), but she is sceptical of the validity of any knowledge produced. Response 6 seems to raise an interesting reflection on the aims and beliefs of scientists themselves, suggesting that she considers
practising scientists hold a much stronger attitude of certainty towards knowledge than she does herself. There is an implication that she knows better. The general tone of nearly all the responses, in particular 1, 2, 4, 5, 6, 9 and 10, seems to indicate that she considers knowledge formation to be personal and constructed. This could indicate a relativist position.

She therefore holds a rather 'eclectic' (Koulaidis and Ogborn, 1989) understanding of science, with contradictory ideas relating to science and science teaching. It is almost as though she has two halves, battling it out within her practice. On the one side, there is her own personal philosophy that education should reflect what she sees as the inevitability of a child's 'holistic' experience, containing within it a consequent tension with the presentation of discrete 'subject' areas in the curriculum. She wants to see science as open and investigative, driven by the children's own interests. Yet on the other side, formative influences have given her a tacit understanding that learning science is about knowing right answers. She is strongly aware of these influences in her background and feels their effect keenly. The net effect is that there is a tension within her science sessions, in which she gives conflicting messages about the scope the children have to generate knowledge. This is exacerbated by a lack of conviction about the real purpose of science work with children of Reception age. When this insecurity is placed alongside a self-confessed inadequacy in the understanding of scientific knowledge, it is no wonder that her confidence is low.

**Autumn Term 1995**

During the period to 8.12.95, Carol begins to engage with her own action research. This seems to have two overall effects. From an initial confidence, the examination of her practice leads to deep insecurity about what she is doing. For example, the researcher's notes for 8.11.95 read:

I must tread carefully. She says that she is very anxious about the sessions as they make her focus on something she is unsure of. Not so much to do with me (she says) but to do with her complete insecurity about science.

(analytic memo entry 8.11.95)
As she begins to grapple with the tensions in her practice, she becomes increasingly despondent about her science teaching. She slowly begins to engage in a search for purpose and meaning in her teaching, precipitating an examination of the two conflicting elements of her practice - doing what she believes in and doing what she feels she ought. The sense of despondency can be seen to fill the greater part of the autumn term, but the result of the conflict is that by the end of that term she appears to be generating change in both her approach and her ideas about the nature and purpose of science. There is some evidence that she is beginning to emerge from the worst part by December:

...I really questioned what I was doing - really questioned - to the point where I decided that I really wasn't very good at this and felt really hopeless at it and I'm just about working my way to thinking after our last two really focused sessions that I'm actually getting the hang of it again.... (interview 8.12.95)

Progress over the term

At the beginning of the term she finds the identification of a focus for her own inquiry difficult. In July 1995, the evidence had suggested that her epistemological understanding was predominantly hypothetico-deductive, with (children's) ideas as the primary starting point for inquiry. She appears to confirm this at the beginning of September, choosing as her initial focus to try to identify and respond to what she perceives as the great number of ideas the children have during 'exploratory' work. To this end, she begins by focusing on what happens in her afternoon Plan, Do, Review sessions, thinking that these could become the main stimulus for science work in her classroom. Her aim is to collect children's ideas for future 'follow up' work - a hypothetico-deductive way of working:

The science area:

She will:
- Place 'interesting' things collection within it
- Encourage the children to go and 'discover' about these things
- Try to record/collate each group's ideas/discoveries in Review time.

(She hopes) this will develop children's understanding of the purpose of science, but in a holistic way, not told, but experienced. It will hopefully produce a series of ideas that (she) could...profitably follow up later.

(post-lesson reflective discussion 13.9.95)
The structure of the Plan, Do, Review sessions themselves can be seen to be a reflection of her general philosophy of encouraging children to take control of their own learning. Placing the major part of her science work there has implications in that it takes the onus of responsibility for the planning of sessions away from her, at least for a time. Although consistent with her pedagogical approach, it is also a convenient way to proceed for someone who has admitted she is insecure about science. It is non-threatening, with the focus being placed on the children.

The attempt to cover science work within these sessions lasts for over a month, but she then begins to display an increasing wish to focus the work more strongly. The researcher's notes for 27.9.95 refer to a discussion which 'centred around the possibility of focusing the science area and identifying its purpose' (post-lesson reflective discussion 27.9.95). By 4.10.95, her comments are reflecting what appears to be a growing disquiet with the way things are working:

She has this amount of time (PDR) everyday:
- she wants to use it effectively;
- she feels there is science activity everywhere;
- she 'knows' there is in English and maths; hopes there is in science;
- she wants to know how to identify and follow up ideas.

Unsure what to do with children's ideas - how much to follow up/ how to record?' (post-lesson reflective discussion 4.10.95)

Although at this point Carol still appears to be clinging to the position that ideas should be the stimulus for the scientific process, by 8.11.95 her understanding can be seen to be changing. By this time, her insecurity has affected her confidence severely and she is now reluctant to plan firmly for any science sessions, writing up her plans retrospectively. Accompanying this is also a shift in her approach. There is a move away from a reliance on children raising their own ideas through free exploration to a decision that she must structure their experience more. This structuring seems to take the form of a switch of focus, from encouraging ideas to promoting observation. Epistemologically, this could indicate an emergence of a more inductivist understanding of science, although it has to be recognised that
she has continually identified that observation plays a major part within the overall scientific process. This extract from the researcher's notes after a structured session shows how she is battling with the conflicting elements of her practice and is beginning to focus her action in response:

Seemed to be unsure of her own focus. Considered that there may be too much demand in an explanatory way in what she is doing. Wants to encourage observation....Agrees that she has a problem with developing her own focus and 'going with the children's ideas'. Could this be a focus for her reflection? She wants to start some recording - re. weather - to focus children's attention on what is happening (observation) - will introduce this soon.

(analytic memo, 8.11.95)

She agrees to plan something for the next week.

On November 15th there is suddenly a mass of planning. This consists both of detailed intentions for her planned activity that day and a retrospective look at the work covered so far during the term. Of particular interest is that there appears to be no mention whatsoever of the previous conception that she was expecting children to initiate inquiry with their own ideas. All suddenly appears to be focused on the development of observation:

Work this term so far:

*Observation of the seasons
*Sorting Autumn windfalls
*Unstructured sorting of objects of interest
*Focus on 'the Senses' - through games
*Using the senses during a walk in the school grounds
*Sorting fabrics and identifying different types of materials and their uses (clothing related)
*Observing the changes in the weather and its effect on the trees and plants in the school grounds
*Observing and monitoring the weather through keeping a daily weather chart.

Overall aims

*Use focused observation to acquire scientific knowledge understanding and skills: i.e.) through developing observation skills and giving opportunities for sensory exploration
*Relate to everyday and environmental contexts: i.e.) seasons-weather changes/fabrics-clothing/senses-everyday use

(teacher's planning notes 15.11.95)
Her plans for the session itself are likewise suddenly full of focused intentions, with an anticipation that the children will be able to cope with an exploration, some sorting, discussion and question raising, testing of materials, making predictions, making observations and measurements, and considering evidence (lesson plan, 15.11.95). From a reliance on very free, open-ended exploration, there is now an abundance of intended structure. Evidence from the session itself supports the idea that she is now much more focused on the generation of observation, with many attempts to focus the children and get them to communicate what they see or feel. She keeps fairly closely to her anticipated structure, but the result of this is that the session appears to be rather rushed. Here, however, an interesting irony emerges, for although she is trying to promote observation, there is a strong tacit message within the session that she wants the children to arrive at predetermined understanding. This seems to make her largely ignore the children's own ideas. They are encouraged to observe, but at times she is almost directing the sense they are to make of their observations. There is still a strong sense in this session that science is about learning some predetermined knowledge. This extract shows her trying to control the understanding the children develop during the session, regardless of their observations. They are examining materials, prior to making a postman's bag:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>It's very heavy when it's full - it takes two people to carry it. I'm going to ask you to think about something else. (Gets example bag) What's it made of?</td>
<td>Ch. 5 - paper&lt;br&gt;Ch. 4 - paper&lt;br&gt;Ch. 3 - it's hard&lt;br&gt;Ch. 2 - it smells in there&lt;br&gt;Ch.1 - plastic</td>
<td>Why not? Explore the nature of the feel?</td>
</tr>
<tr>
<td>Feel it. Is it paper, you have to look. Feel in there, does it feel like plastic?</td>
<td>Ch. 1 - No&lt;br&gt;Ch. 1 - plastic&lt;br&gt;Ch.2 - plastic</td>
<td></td>
</tr>
<tr>
<td>(Brings out plastic bag)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 3 - plastic</td>
<td>Compare with similar materials?</td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------------------</td>
<td></td>
</tr>
<tr>
<td>Ch. 4 - We all agree plastic sticks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 4 - sticks /straw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 2 - No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. feel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 3 - Sponge (the straps)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 1 - no, these are really hard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 2 - it's a bit big</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 1 - that's plastic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 1 - No</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ch. 3 - (feels it over the outside)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you had to put it in a group? The same as these?

No....

(Ch. explore)

Ch. 5 - it feels like (rucksack) inside

More focus needed?

I don't think it's the same material.
They have the same texture. They look similar

(Ch. sort into groups)

What about the potato bag?
Where does it belong?
What's it made of?

Ch. 3 - paper
Ch. 2 - paper

Very difficult?!

Is it the same as this? (other paper bag)

I think they probably would look...We'll put them together.

(lesson observation 15.11.95)

By the following week (22.11.95), she appears to have reflected on these points. There is less planning and the session is less crowded with objectives. There is more attempt to value the children's ideas, but the same tensions are still apparent in the finish of the session and the way she handles some of the children's suggestions for sorting.

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By the end of term interview on 8.12.95 there have been many changes. In the first place, her experience with science seems to be promoting a reappraisal of aspects of her general approach to the teaching of Reception children. There is a much stronger need for a sense of progression in the children's development, with an implicit move away from the more 'open-ended' approach which she initially wanted. She relates this change to a developing understanding of the 'differences' between Reception and playgroup (where she worked before entering teaching):

...it's probably me having misinterpreted 'child led' actually, cos a lot of the active things we, I, do, you know, that I like the children to be involved with are so called self-initiated tasks, but they can't self initiate things if they haven't got any idea about where they're going with it, so it's really helped me, actually on a broader scale it's helped me with other aspects of my teaching as well.

I'm still sort of learning. A lot of it, I mean- the differences between what I was doing in playgroup - there it was purely exploratory for their own sake and we just need to channel it a bit more...

(interview 8.12.95)

In her conception of science the primacy of knowledge appears to have given way to a much greater focus on the place of procedural skills, especially observation, in the generation of scientific activity. The general tone of her reflections seems to indicate that she is developing a much stronger inductivist model of understanding. On more than one occasion she links observational ability to the construction of knowledge in science. For example, during the December interview she talks about priorities for her science work and how her research has helped her become analytical about her practice:

SWA: So what do you think you should be doing?
Carol: I really need to know how much and what I need to be teaching and that's not just got to come from me, its got to come from the whole skills map of the school.
SWA: And is that in terms of conceptual areas or is that in terms of...?
Carol: Just skills, yeah.
SWA: Observation, communication?"
Carol: All those sorts of things, yeah. But in terms of understanding, which is a different ball game, isn't it? No, it isn't really because observation, that's your major one...

and again:

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"...It's (the inquiry) really broken down my thought processes so I am thinking more clearly that it's okay not to try to teach everything - I mean observation skills are, you know, are your starting point; you have to start by looking and by looking you can find out."

(both interview 8.12.95)

This second extract is strongly inductivist in tone. Science is starting to become knowledge through exploration.

Reflecting on the way she used to plan her science work, she recognises how much she has changed, explicitly acknowledging the conflict that her previous conception of scientific knowledge had been creating in her practice. Her new perspective is helping her to see a way of coping with her own lack of understanding. She is still sceptical about the value and status of scientific knowledge and she makes a statement that reveals the same strongly provisional standpoint as regards its validity that she held initially:

...(children) needing to know that there are reasons and sometimes to need to know that there aren't,...that maybe the grown ups haven't got it all sewn up either, that they're still finding out too - I think that's an important part of it, I mean that's a deeper concept, isn't it?

(interview 8.12.95)

She ends the interview with a statement that reaffirms her understanding of the place of scientific enquiry within the natural motivation of the 'whole' person and supports the new sense of purpose she is generating about science. She again relates science to a fundamental need to develop order and meaning. Talking about how children 'love the sense of order and pattern', she says:

It's making sense of the world, ordering it into groups and types and just so that you can find your own place in it, but maybe that's what science is anyway!

(interview 8.12.95)

Spring Term 1996

By the end of this term, Carol claims that she has made considerable movement in her understanding of science and her way of teaching. She describes a feeling of 'coming full circle' in her approach, indicating that she can herself sense a development in her understanding which is beginning to let her accommodate science within her earlier 'holistic' philosophy:
I would say that I've come full circle, I mean really I started off looking at science as something that I really wasn't that fussed about, I wasn't particularly threatened about doing. I knew I wasn't particularly focused, but I think what's happened is that now I have focused myself ....I feel more comfortable in going back to how I was in the first place, which is approaching science in a very sort of holistic sense...

(interview 26.3.96)

She attributes this change in understanding to the issues she has confronted during the term within her own research. In this extract from her written reflections a month earlier, she brings all three elements of the conflict in her practice - how to respond to children's ideas, the place of observation and experience, and the need to 'pass on' knowledge - together in a passage that shows just how much her thinking has been in flux:

I am finding it difficult to actually describe what I think Science teaching in the Early Years should be - apart from to say that it should involve First Hand Experiences and that as a teacher I need to have a clear focus as to what I want the children to 'know' and 'understand' at the end of the topic....It has taken me a while to get to this point. Personally, I guess that one of the main difficulties within Reception class teaching is that the children throw out so many ideas that one becomes intent on answering their questions rather than providing opportunities for them to keep their ideas flowing...

(reflective commentary, 23.2.96)

Not only has her approach to the teaching of science changed, but her understanding of effective pedagogy for Reception children appears to have been affected. Her reflection on her tendency to answer children's questions rather than 'keep their ideas flowing' is general, not specific to her science teaching. Two possibilities suggest themselves: that she treats the teaching of science no differently from any other subject, or that her attitude to knowledge in science affects her approach to any knowledge in her teaching. From whichever perspective, change in one aspect will mean change in both. A month later, she appears to have moved further with her thinking, reaching a point where she has clearly decided that the need to transmit knowledge as such has become less important. Even how she should respond to the children's ideas has become of secondary importance; she implies that the prime concern now in her science teaching is to offer the children experiences:

I think I've confronted it and I've actually really looked at what I have been doing and I've looked at what the children are understanding and really I've gone from the idea, using the expression - you know, taking children's ideas and working with them - and just having an expression that I'd heard and perhaps really hadn't thought a lot about, to really looking at what that meant for them and what it meant for my teaching, and then
really just refocusing. I mean the main thing that's happened is that I'm going back down to the first broad experiences of, you know, offering them observation, yeah, just experiences, you know...

(interview 26.3.96)

Progress over the term

The evidence from Carol's practice itself does not reflect the same amount of movement that she claims, but confirms the general trends. The change evident in the last weeks before December 1995 appears to have continued, with an increasing focus on observation as the central element of her planning. A suggestion of the tension between tacit knowledge expectations and the open teaching she is espousing can immediately be seen in the new term, although she is now becoming much more aware of this and it forms a focus in her own reflections. Her comments after a session on 17.1.96, in which her aims were 'generating talk, observation skills, communicating ideas', show an awareness that she had in fact closed down the children's thinking. She wrote:

'The session lost direction and pace for various reasons.....I am aware that I tried to maintain the pace (and interest) of the session and in so doing defeated most of my own objectives, i.e. the children were not given enough time to explore for themselves'.

(Reflective commentary, 17.1.96)

Carol gives an indication that the link between her science practice and the rest of her teaching will occupy her during this term. She raises the possibility that change in one will affect the other, recognising a general weaknesses in her teaching repertoire:

I do think that this is a weak area in my teaching in general...I need to develop the confidence to allow the children time to develop their own ideas, and to have the time to share these. I can see that by not doing this, the children look for 'right answers' and are generally less confident in asserting their own ideas (surprise!).

(Reflective commentary, 17.1.96)

This tension is apparent in the session on 8.2.96, but there is a definite change to a more open structure, with many more questions designed to encourage the children to observe and explore for themselves. The result, however, appears to be an increased uncertainty about the precise objectives of the session. Compare this extract with that of 15.11.95 (above). She is clearly trying to encourage observation and the elicitation of ideas, but there is very little sense
that she has any fixed idea of where she wants the lesson to go and whether she wants the children to develop any conceptual understanding at all:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>We’re going to make a book of things that move in the classroom to share with the rest. (Refers to a previous list of suggestions). We’re going to look through some magazines in a moment. First, let’s have a few different ideas...</td>
<td>Flap books...</td>
<td></td>
</tr>
<tr>
<td>How can we make them move? Ch. 1 had said toy cars move with your hand.</td>
<td>Ch. 2 - the clock moves</td>
<td></td>
</tr>
<tr>
<td>How does the clock move? What makes it move?</td>
<td>Ch. 2 - the hands move</td>
<td></td>
</tr>
<tr>
<td>(Shows with a teaching clock) How?</td>
<td>Ch. 2 - with a finger</td>
<td></td>
</tr>
<tr>
<td>(Draws HAND set) Does the clock move in the same way as cars?</td>
<td>No.</td>
<td></td>
</tr>
<tr>
<td>How? That clock? (on the wall) Ah - that’s what makes it move</td>
<td>Finger makes it move</td>
<td></td>
</tr>
<tr>
<td>To wind it up with</td>
<td>Ch. 3 - I said batteries</td>
<td></td>
</tr>
<tr>
<td>I’ve got a clock at home to wind up - that’s different.</td>
<td>Ch. 3 - I guessed - I’ve never looked inside a clock</td>
<td></td>
</tr>
<tr>
<td>Anything else with batteries?</td>
<td>Ch. 4 - My clock has something on the back</td>
<td></td>
</tr>
<tr>
<td>How else can we make things move?</td>
<td>Ch. 4 - Yeah</td>
<td></td>
</tr>
<tr>
<td>We’ve only got a few things How?</td>
<td>Ch. 4 - Mine is a blue clock</td>
<td></td>
</tr>
<tr>
<td>What are you going to use to make them move?</td>
<td>Ch. 5 - Louise’s cat. It makes it sound.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ch. 6 - cats...</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ch. 7 - those puppets up there</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ch. 7 Cos they’ve got split pins in and they can move their arms and legs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ch. 7 - Your hands (Ideas about puppets)</td>
<td></td>
</tr>
</tbody>
</table>
There is one, go and find it

Do you need to put your hand on?

We've got lots we can move with our hand. Not many battery things.

Let's get the magazines - we might find lots of different things that move in different ways.

We're going to make a collection of things we know we can move. Maybe they all don't move in the same way.

The other day we found that different things move in different ways...

Sometimes by hand

Sometimes pull them...

Ch. 4 - I know battery cars (Returns with train) It's got batteries in and it works like this... (shows)

No - it goes on its own.

Reluctance to say 'push'/'pull'? Teacher/Child expectations?

(Lesson observation 8.2.96)

This uncertainty is also present in the session on 14.3.96. During this session, in which she is intending to encourage the children to explore the properties of dough, she still frequently imposes her own ideas and directions for exploration onto the procedure. However, she indicates in the interview on 26.3.96 how much she considers her approach to her practice is changing. She suggests that her engagement in the action research is continually forcing her to challenge the previously tacit assumptions within her practice (and the difficulty that such realisations can cause):

I've actually come round again to feeling very comfortable with using material just to offer them experiences, because having tried to offer them a so called deeper experience, I realise there were some things they're just not ready for. But having said that... the thing that came up last week very much was that, you know, in making the dough it was valuable for them to feel the flour as the whole thing about the change in substance, the playing with material, the naming of the textures or whatever; actually touching it, seeing, talking about it in its common use, context, you know, the fact that they don't always see people making cakes and it sort of breaking away from my own expectations and assumptions..... And that I think you need to be permanently reminded of, when you're teaching about not just where children come from, but it's like your expectations and challenging your own assumptions all the time and in that way you can teach effectively.

(interview, 26.3.96)
There is a strong link with her 'holistic' viewpoint towards education. The focus on observation appears to enable her to feel comfortable with an image of science that does not contradict her central idea that children's experiences cannot be compartmentalised. She gives a long example which indicates just how this kind of perception has become established, pulling together the idea of the primacy of observation, the search for patterns and the sense of 'wholeness', in which her approach to science and her educational philosophy seem to be mutually justified:

A few weeks ago I was walking round the grounds and I was doing the colours of the garden in February, and we looked around and I was asking them to notice what they saw and we were collecting, you know, just the colours, and we had the pastels and we were trying to match the colours that were outside to the pastels that we had in the box and that was quite difficult but it was really good looking and talking. And I said to the children, I asked if they knew what was going to happen, what next? Well, some of them knew that they would have leaves, that they would change.....Today, because it's got a little bit warmer, S looked out of the window at the blossom tree and she said look, there's a flower tree out there and someone sort of looked at her and said oh yes - and she'd remembered! She said we looked at that, it wasn't like that before, was it Mrs. G? Because, okay, it would have happened and she would have noticed it was a flower tree, but to know that it was going to happen, well that makes me feel that I'm teaching science, because I'm teaching that there are patterns and things to understand - that you don't have to be a top scientist, but that there are patterns of things...And within all that there is that very strong sense that it's our environment and we have to look after it, that we are all working as one within that environment because, you know, we need to get that sorted now, at four and five. And it's just that they're matching at this age, they know that this bit is the same as that out there...It's interesting as well because, also, whilst you're looking at the blossom out there, are you really looking at it or do you just see this mass of pink? We've looked at it here with magnifying glasses, we've drawn it - I mean we're not going into higher order stuff, but they know now when they look at it that it isn't just sort of like lots of pink all over it, it's like what's inside there and when you look at their drawings there are drawings of blossom which are very detailed. That to me is science and it's not art, cos if you're drawing in art you're getting more impressions, but what they are doing is that they really look and they know something about that and that's a real sort of starting block.

(interview 26.3.96)

The following extract from the same interview illustrates how strongly her epistemological understanding appears to be linked to the particular perspective she generates as a Reception teacher. In discussing how 'looking and experiencing' is 'appropriate for the age group for a start and developmentally it's not appropriate to go on much beyond...you're just doing what is right for them and just opening their eyes...as it unfurls', she sees a wider relevance of this approach to the nature of science itself:
SWA: So what’s that got to do with science?
Carol: Right...you’re right, it has changed...my attitude has changed, although it’s been so subtle I hadn't really noticed. Because without looking, I suppose... you can't teach understanding without looking at things, you can't teach knowledge without looking at things, it's the basis for all the other things and I don't think that ever stops. I think I see scientists now as people who are always looking at things, so perhaps you have to look at things in order to be able to do the rest and it's a foundation stone, isn't it?

(interview 26.3.96)

The extent of her development over the term is captured by a normal beginning of day 'carpet session' on 7.3.96. The children have brought toys to 'show and tell'. She spontaneously engages them in a 'one word' game in which they have to say something descriptive about the toys, then involves them in an activity which involves even greater focusing and comparison. The researcher’s notes from the post-lesson reflective discussion read:

When is discrimination/similarities and differences not science? She did not plan it as science, but she recognises it as such. (Back to her holistic view?)
(post-lesson reflective discussion 7.3.96)

Summer Term 1996

Carol’s research has taken her into the depths of despondency about her teaching of science and she has been forced to challenge her approach and her attitudes in order to find some equanimity. She now feels much more confident. Indeed, shortly after half term, she extends the image of a circle in her development, saying that she feels as though she has ‘gone a full round circle and back out again now’ (post-lesson reflective discussion, 13.6.96). The summer term sees her trying to consolidate her sense of confidence, though not without raising new conflicts.

Pedagogically, she continues to explore the potential of observation in the development of ideas. This can be seen in sessions observed on 10.5.96 and 13.6.96 (appendix 12). The purpose of science as ‘investigation’ is communicated in the preamble to the session on 13.6.96, in which she tells the children to ‘put on their scientist’s hats and become really good
investigators' and then to 'put in their scientist's eyes'. Her organisation of the session and her questioning within it encourages close observation and comparison as a way of carrying out this investigation. The session on 10.5.96 is a very focused observation session in which, through the medium of observational drawing of flowers, she both encourages focus and comparison as a way of 'finding out' and encourages the children's understanding of the process itself. The aim of the session is to provide an experience that will promote the children's appreciation of the fragility of the environment. These intentions, together with her comments on the relationship between science and aesthetics which the session raised, in which she is critical of the way in which they are conventionally placed in opposition (post-lesson reflective discussion, 10.5.96), suggest again that her new confidence in science is linked to the way she can now draw together the various elements of her personal conflicts.

Once again, her pedagogical comments can be seen to convey her changing perspectives on the nature of science. Following the session on 13.6.96, she comments:

SWA: Why was it science?
Carol: Because we had our scientists' hats on and we had our scientists' brains on.... And sometimes they'll say we're being scientists... we do get to the point when they start saying we're investigating, so we're scientists.... That's probably the bit that really, the underlying message, the main aim of all what I'm doing in science, that there are these people who are interested, who find out and who keep on finding out all sorts of things - and that actually is relevant to our lives in an everyday context. (post-lesson reflective discussion, 13.6.96)

This is very positive and confident. Her views of science have lost the somewhat mysterious, esoteric and slightly frightening nature of her original perception. One senses that this might be a victory in her personal battle, as well as a statement of educational intention. She goes on to say:

It takes away a lot of the myths about what being a scientist is. We're scientists, cos we're finding out.

This is not to say, however, that she has no more concerns about the place of scientific knowledge within her teaching. Indeed, even as she is enjoying her new confidence, the challenge of her own inquiry is raising significant doubts again. She is still very aware of her

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own limitations in knowledge and begins to ask how far she should let children merely follow their own ideas during this process of finding out. She is worried that she does not have structure in her planning and teaching, in both curriculum terms and in her own knowledge of scientific concepts. An adequate knowledge of these, she claims, would enable her to understand what constitutes meaningful progression for the children. She is sensing that her reliance on observation is not enough. Talking about the approach she brings to children's (and adults') learning, she discusses this need for structure using a powerful analogy:

Carol: ....both yourself and the children have a very organic way of learning which I do really believe in, but even with an organic situation, there are certain things which require certain environments to grow and so it's the same thing and one of the things I've written...is about having a 'trellis for the vine'; which is exactly how it is. I think it's a sort of Zen thing, but you need to have those sort of foundations, those rods, those....

SWA: Structures?
Carol: Structures, that's the word! It's like a trellis, in fact, because without it things become rampant and wild and not particularly helpful...

SWA: Otherwise vines don't grow upwards, do they?
Carol: Indeed, they grow all over the place, yeah....That's very much how I feel.

SWA: How's your trellis in science?
Carol: Well, I've taken away from myself some of the myths that I need to know everything, but I find it limiting - they're relatively short poles!...Something I found when I was thinking about all this was that I do need to know more than I know or at least I need to know where it's going within this school, because without that I'm not sure exactly what I'm building, or I don't know where to plant my trellis! So I need to know exactly where what's going to lead on to next....

(post-lesson reflective discussion, 13.6.96)

Her reflective commentary for 17.5.96 raises the idea that 'surely in order to offer purposeful and valid experiences one needs to have an understanding of the bigger picture?' and she later articulates the way her practice is once again being challenged:

What I'm thinking is that, going from being very focused and saying this is fine, this is science because we're looking at this, because we're doing that and I justified my science - yeah? - now what I'm doing is saying that it's just not enough to be really focused, I really need to know where I need to take it, because in just offering them the experiences and saying right, we're looking at, say, feathers......I don't know enough about all the other things about flight and feathers and birds and the mechanics to ask the right questions...

(post-lesson reflective discussion, 13.6.96)

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The session on 18th June can be seen as a critical experience for her, for its aftermath shows her struggling again with the amount of knowledge she should be transmitting to the children. The children are preparing to visit a local forest:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw a picture of the things we might see in the forest</td>
<td>Children draw: Horse, Bird</td>
<td></td>
</tr>
<tr>
<td>How many birds do you think you will see?</td>
<td>Loads of them. Butterfly (2) Tree (3) Spider Ladybird (2) Caterpillar Rabbit Giraffes Fox Bee</td>
<td></td>
</tr>
<tr>
<td>(Labels children's drawings)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I wonder how many different types of things we'll see... When we were looking at trees the other day, what did they look like? Were they all the same? Were they all the same type of tree?</td>
<td>They had different leaves</td>
<td></td>
</tr>
<tr>
<td>When you go to the woods, I wonder if all the trees will look the same or if they'll be different?</td>
<td>When I went with my friend James we saw a railway line</td>
<td></td>
</tr>
<tr>
<td>Last year when we went the ranger told us to look very closely at the trees - there were lots of different kinds.</td>
<td>Berries, turning colour Rabbits (Children get book with pictures of trees, animals and birds - storks.) The book (Aesop's fables) has a lion on the front)</td>
<td></td>
</tr>
<tr>
<td>(Asks D what kind of birds) Do you think we'll see seagulls in the forest? What sort of birds live in the forest</td>
<td>Seagulls</td>
<td></td>
</tr>
</tbody>
</table>

What idea might this be giving? Tone implying the answer 'No'? (Why not?)
Listen carefully and think very carefully about what you might see in the forest. Make a list, cos when you come back I'm going to ask you if you have seen what you thought.

Do you think we'll see some water?

Ch. draws a sunflower.
We'll see a bird in the water
A bear
A peach tree
The sun

Why water?
If water, why not a giraffe?
Wrong?
Historically true!

Natural world?

(lesson observation 18.6.96)

The session causes her a great deal of anguish. Her recent approach has been to accept children's ideas, so she does not contradict them, but she is very uncertain about how she should respond to their more bizarre suggestions. Old tensions about the place of knowledge and the extent to which she should be involved in ensuring that some of it is transmitted, are awoken:

I genuinely don't know whether or not it's okay to say - it doesn't feel okay to say - yeah that's fine, we're going to see giraffes and it's sort of by not saying look, you're not going to see giraffes......but if I'm asking her to think for herself about what she knows about forests, actually at that level I clearly doesn't know that she's not going to see giraffes in the forest.....So perhaps it isn't my place to say to her that's not what you're going to see, but I do feel uncomfortable about her saying that's something she expects to see, without turning round and saying well, actually, you're not.

(post-lesson reflective discussion, 18.6.96)

The solution she generates is interesting. It does not involve her in negating the child's ideas, but she involves the child herself in a form of scientific comparison of evidence. This appears to revalidate a hypothetico-deductive (and here falsificationist) approach of working from children's own ideas. She will not contradict the child, but will encourage her (and others) to consult reference books about forests in the hope that she will notice there are not giraffes in our forests. She links this process back to the fundamental purposes for science that she has always suggested - the recognition of patterns and the making of meaning. However, there seems to be a wry acceptance that structures will not always achieve what you want:
...what I will do is that I will start, between now and Friday, to be looking at information books, getting a few posters and really drawing their awareness to the things that we can see and that there will be patterns in that, there will be, oh look, this book has got lots of trees in, this one's got squirrels in it, you know, so that's what other people seem to think lives in the forest, and if she still comes out with we're going to see giraffes, well I mean....
(post-lesson reflective discussion, 17.6.96)

End of project interview 16.7.96

This looks back over the year, catching the main points of Carol’s development. It finds her leaving the project year a much more confident teacher of science than when she started.

The interview opens with a discussion of the semantic differential results (appendix 7). Comparison of her two responses shows a surprising degree of similarity, but suggests change in a few areas. Perhaps the most significant of these is the movement along the objective-subjective continuum and discussion of this indicates that the experience of the inquiry has consolidated an understanding that scientific knowledge is constructed and context dependent.

The discussion also shows how much her ideas are not static, but in a continual state of flux:

Carol: I suppose the most astounding leap is from being something that is objective or subjective and I realise that a lot of what the children are learning is in part...well, you can't be objective about science because your own experiences inform your ideas so that anything you're teaching the children or that they're learning has come from somewhere, so it's got a bias...

SWA: So this is about science as something? Do you see it more as subjective now?

Carol: No, because I think that's something which undoubtedly colours I suppose where you live, your own culture, context within that, within your own framework of your experiences, within even a degree of what you're studying and why, is going to be formed by your own opinions, so I think it's very hard to totally remove yourself from that.

SWA: So the ideas that scientists follow up, the questions they ask, might be actually, might derive from subjective...

Carol: It's like the world being round, or not, because you can only see so far. I think that probably still colours very much...yes...I'm sure it does. That's really interesting, actually, isn't it? Gosh! I'm in the middle of a state about this.

She goes on to emphasise her understanding of the provisionality of scientific knowledge. Her response demonstrates again the interlinked nature of her thoughts about teaching and science
and the applicability of one to the other. Here we have a sense of a general epistemological realisation which has pedagogical implications:

SWA: What about the certain-provisional one?
Carol: Well, because science as such is only certain until...It's certain for that moment, but it's only provisional because of the nature of it being exploratory, and everything else. I mean the fact that it is an on-going ever-evolving thing and that undoubtedly teachers are - scientists, it doesn't matter whether you're a teacher or not - scientists are only sure of what they've got in front of them at the moment.

It is significant that her tacit perspective on science knowledge is not now generating the strength of feeling it once did. This is confirmed within a long response in which she discusses her answers to the scale and conveys how her participation in her own research has helped her come to terms with science and her science teaching. She communicates the systematic path that her inquiry took:

It's like you start with the housework, you know, you start in one corner, you have to start in one corner and work your way through and I feel that in many respects this has given me the opportunity to do that, start in one corner with my teaching, as it were, and tackle things and to really look at what I'm teaching.... I've been thinking about coming to talk to you today, I realise that it doesn't frighten me so much... I think it would be true to say that if I were teaching further up the school as well that I don't actually feel there are answers, that I should be providing the instant knowledge about things that I really felt the weight of when I first started the project.... There are some things that I realise that you need to be quite systematic about what you're teaching, and yet you have to... it has to be quite exploratory and yet within that you have to accept that it is subjective, so this was quite useful to do...

The researcher tries for a greater part of the interview to encourage her to articulate thoughts about the nature of science as a discipline. This proves extremely difficult, with very few unambiguous responses forthcoming. She shows yet again that she would prefer to convey philosophical perspectives through anecdotes from, or descriptions of, her teaching and that she quite easily confuse science as a discipline with science as a subject in the curriculum. This makes analysis complex, but there is continually the sense that she is talking about what she passionately believes in. The interview continues with the researcher asking whether her comment about questions is to do with her teaching or with science as such. Her response is firmly located in her teaching, yet she is clearly talking about something beyond - science itself:

I'd like to think it was science, actually, cos I think there are... no, no it is science, because undoubtedly there are areas of the curriculum which... which don't have the
same values as well. I’ve actually come to really, really enjoy it, actually, because of those questions and not having to come up with the answers and also teaching things like study skills, you know, how do you find out about things, which is, I think, an equally useful skill to develop with children. I mean that’s the systematic inquiry, it’s all part of teaching children generally, giving them a good start to being interested, to finding out, and I can’t see that that would actually come up through any other curriculum area. If we didn’t offer it through science, then where would it come up?

...I mean that with science, because it’s changing, cos ideas are changing, you’ve only got to look at the way, if you’re doing planets or something, that’s even changed in the last five years. It’s ever evolving and I think that’s a really good thing to teach children, that while some things, for example seven sevens will always be forty nine, there are other things that we know as truths that we’re also questioning. It goes back to my deep philosophical part of teaching anyway!

The inquiry has left Carol with the central idea that science is an enterprise of understanding, with her job being to promote children’s ability to participate within that enterprise. She discusses the extent to which her approach has changed over the course of the year, showing how she can now identify formative influences on her original ideas and be critical of them. This extract shows her identifying teaching potential within the way she herself was taught science in primary school. Responding to the question of whether her understanding of science (which she again interprets as the teaching of science) has changed, she says:

Oh, very definitely, yes. I think so. Because I think, perhaps, because I was taught by people who thought you had to know certain things and it is rooted in that, you know, em...and we got very bogged down...We were taught, you know, we had the nature table and general knowledge...way of working, but it was a bit undirected and I think perhaps there were a lot of opportunities which were missed which I would, you know, given that I’d had a nature table and that children had been part of it...We had a wonderful thing happen the other day - I must tell you this....

She then launches into a long description of a child’s discovery learning in her classroom. This encapsulates how much she has changed during the project. On 18.6.96, the question of whether she should be transmitting any knowledge in her teaching was once again troubling her. At that point, she decided to trust to the instrumental nature of scientific processes - in that instance, comparison and discussion - to do the job for her. Now the approach has been consolidated and she is increasingly confident. She can delight in the child’s discovery without worrying whether she should interfere, allowing her to go full circle and return to her position of 10.7.95. However, now the position is rather different. Whereas at the beginning of the inquiry the reality of her practice was that it was uncertain and plagued by contradictions, her
own inquiry has developed an understanding of science and science teaching which finally accords with her educational philosophy. She has identified for herself a usefulness within the scientific processes of observation and considered their relevance to children of Reception age. Apart from what she sees as their appropriateness for this age, it is their usefulness that is the key. They are not ends in themselves. Science is still an enterprise of understanding, just as she described a year before. The answers are still what is important, it is just that now they do not have to come from her. Now, providing she is promoting children’s ability to use scientific skills and processes, she can sit back and let them explore and discover. Her role is to control the children’s knowledge formation at a distance through planning experiences for them which fit into general science knowledge areas. She is very confident with this understanding:

| SWA: | When it comes to external factors, what would make you change your practice there. What about if somebody came in and said: “No, Carol, you’re doing it all wrong, you should be doing it this way.” How would you feel? |
| Carol: | I don’t know....I think I’d take on board if someone actually had something else to offer, I’d listen to what they had to say and I’d try to assimilate what they said.... I think it would be a mistake to think there weren’t lots of ways to explore the same ideas, I mean there’s more than one way to skin a cat, so I think I’d take those things on board. I’m not sure about...if somebody came and asked me to, yes, if the Ofsted had actually...I think I would fundamentally disagree with what they need. I think that what I’m saying is that I am beginning to evolve a picture of what I feel Reception children can take on board and whilst I would probably try other people’s ideas, I would still have this at the core of my teaching that I actually think the children would need. |

Overall, it is the sense of legitimation of practice and philosophy which comes through most clearly within the interview. The year has often been a struggle for Carol and she feels keenly the sense of empowerment that the inquiry has given her. The strength of this feeling is probably indicative of the importance she places on science itself. There is a strong degree of resolution of her initial conflicts: science fits in with her educational philosophy, knowledge still lies at the heart of science (but it is now its purpose, rather than its nature) and she doesn’t have to know it all. There is a profound sense that she now values what she does so much more:

| Carol: | So, if it sounds similar to what I said in the first place, you know, from ages ago; if it sounds similar, it’s probably because maybe I had the ideas then, but I didn’t really know where they were coming from. But I now know; I feel more comfortable in that. |
SWA: Is that maybe because your image of what science is and your ideas have actually come together now?
Carol: Oh yes, yes...They're heading in the same direction!
Chapter 5 – Case Studies

STUDY 3 - Heather

1) Initial period - to July 1995

At the beginning of the inquiry, Heather is perhaps the least confident teacher of the four in her teaching of science. Her written planning is minimal and she freely admits that she does not really know what she ought to be doing in her science work. Most of the evidence regarding her understanding of science and science teaching at this point comes from the interview in July 1995 and from preliminary lesson observations, but there is not the range of comment that was produced by Elizabeth and Carol. This first section does not therefore include the same analysis of a list of comments as seen in the first two studies.

Heather shows the common tendency of all the teachers to respond to questions about the nature of science by referring to her teaching, or to science in the curriculum. Her general understanding has to be gleaned from these references. At the end of the preliminary period, it appears that she considers science to be a way of understanding explanations for phenomena. It is strongly characterised by certain procedures or methods. There is a strongly realist emphasis within her comments, partly tacit, but also in her reflections, as she conveys an impression that she believes the explanations of science relate strongly to the world as it is. The methods of science are to help you achieve the right answer:

SWA: What would make something somebody was doing science, rather than something else?
Heather: An exploration or testing of an idea. Hopefully coming out at the end of it with an answer or knowing whether your idea was correct or not... You may have to go on then to test another idea I suppose. Trying to get an explanation or pick up ideas about why things happened.

(interview 7.95)

This understanding sounds strongly hypothetico-deductive in character, but certainly not falsificationist. It is more like trial and error, hopefully working towards a correct understanding. The characterisation of method appears to be the most important aspect of her understanding of science. Science is about exploring; it is what she looks for in her teaching of it. But for it to be called science, it is about exploring in a certain way. It has to be what she describes as 'methodical' and she seems to consider that there is a fixed
procedure to scientific inquiry. This creates the first of two tensions within her teaching. There is a conflict with her general pedagogical understanding when she is conducting science sessions, for she also considers that children should sometimes be allowed as much free rein as possible for their exploration to be effective:

SWA: So the exploration is what characterises an activity as science? so it’s something to do with the way in which one explores...?
Heather: Mmm...Sort of going through a ...I still find it...I’m saying it’s a methodical approach, because that is the way I did it, but with the children really, you don’t need that structure all the time, sometimes it’s better to just go in there and explore willy nilly in a way.
(interview 7.95)

But the notion of allowing free exploration in science creates another tension in her practice. She sees science as consisting of an integrated body of knowledge and that her teaching should help children develop and appreciate this. Wholly free exploration might hold dangers:

SWA: But would that be something you would be aiming for with the children?
Heather: I would like to think I would be aiming for that, letting them just have a complete free go at trying to find things out, but at the end of it I would like it to be sorted in a way, you know...
SWA: Methodical, as you said before...
Heather: Yes, a structure to the way they are exploring. So they’ve got an idea they’re testing and then they go ahead and have a go at doing it and then at the end of it they’re able, I suppose, to review it, go through what they have done, but without any structure they’re not actually going to get an awful lot out of it, it’s still going to be lots of ideas and there will be no formulation at the end of it. The aim is to build up into some kind of system that they work with.

SWA: So the system would become almost the sort of evidence that they’re being scientific?
Heather: Mmm, yes.
(interview, 7.95)

Heather is aware of these tensions. She identifies their origins as a mix of her own experiences in science at school and the messages from her teacher education course (a P.G.C.E.). Her ideas illustrate the problematic nature of any attempt to isolate the sources of teachers’ ideas about science (see Chapter 2). The two sets of experiences appear to have influenced different aspects of her understanding. The culture and approach that she acquired during her school science, where the aim was to learn facts or explanations assumed to be right, have affected her epistemological and ontological understanding. The
result is her focus on getting the right answer over to children. On the other hand, she attributes her pedagogical philosophy of more exploratory teaching to the messages given to her whilst on her P.G.C.E. It is unclear whether this is the result of a more mature rational consideration, or whether she has, again, merely taken on the prevailing culture and approach portrayed within the institution. She describes these conflicts early in the interview:

Heather: That’s always been my problem. I suppose because I mean you always go from your own experiences, don’t you, and my science background at grammar school was the learn it off the board kind of thing. So I suppose I’m up against that in a way, you know, having to give them the understanding, without actually giving them the facts all the time, rather than letting them explore.

SWA: Is that the way you actually feel about teaching it then?
Heather: No, no... I mean going to teaching college told me the way they actually pick things up is by exploring, by having a go, but I’m still up against this having to dish out the facts sort of thing, rather than letting them explore and then forming their own understanding afterwards.

(interview 7,96)

She is very realistic about the effect that her limited knowledge and understanding has on her practice. She thinks of scientific concepts in the terms she has been taught and recognises the inapplicability of this to children. The interview continues:

SWA: And is that because you don’t have the confidence to...the confidence to let them go, or the ideas...?
Heather: Probably a bit of both. It’s confidence to let them have a go and not letting them run riot while they’re doing it and also it’s just my ideas; I just can’t formulate them into a simple way...

SWA: Is that to do with breaking down your understanding of the concepts?
Heather: I think so, I think so...I think I’ve got a real hurdle with it because I’m so stuck in the ways I’m used to. It didn’t work for me. I mean I didn’t get any science O levels, which proves it didn’t work for me at all...

The net effect of these tensions appears to be that she withdraws from her teaching, not giving it the attention it needs. This probably exacerbates the problem, but the conflicts are so strong that she finds it hard to proceed with her science, something which emerges after a particularly leading question from the researcher:

Heather: I mean that children who actually do well in science are the children who have a lot of free play at home and, you know, have learnt through finding out themselves, so that’s the proof that that’s the way to do it. But just doing it in the classroom...! A lot of it is that I don't prepare myself enough and I don’t actually take the time to sit through and think things through before I do it, you know, I say right, I’ve got to do this so let’s get on and do it...
SWA: Is that because that's... I mean, is that unique to science?
Heather: It is because I'm not particularly into science
SWA: Is it because you've got a block about science?
Heather: Yes, and so it's something I can quickly get over and done with... I regret spending time on something that I'm not particularly comfortable or happy to get involved with myself.
(interview 7.95)

She describes herself as being 'frightened' about her teaching:

Heather: Sometimes I can do science and at the end of it think that was okay. I can see that they've worked their way through it and are okay, but a lot of the time I think I'm missing it completely. I know a lot of it's to do with my input at the beginning. What I actually do at the beginning I'm not very good at. I tend to give out a lot, but not in a particularly sensible way, you know I want them to sort things out in a system in a way, but I've got to give them something to go on and I know I'm very frightened of giving them too much. So I end up actually not giving them enough to start on, so I give them lots of gabbled ideas and they give me lots of gabbled ideas and none of us really know where we are going! I think that's a confidence sort of thing, though. I'm so frightened of, you know, giving them too much that I almost hold back.
(interview 7.95)

Heather latches on to the idea of method. She wants her teaching to be investigational, but she retains strong control over the questions children ask and the procedures they use. For example, during the session on 22.6.95, she gives her children a set sequence of questions to work through during their own investigation:

What are we trying to find out?
What will we look at?
How will we do the test?
What will we keep the same?
What happened?
What we found out?
What would happen if....?
(from lesson observation, 22.6.95)

This kind of sequence becomes almost formulaic, and is typical of her science lessons. There is a also strong sense that she wants the children to reach certain conclusions, with little interest in whether they have been challenged to look at the consequences of various actions or their meanings. There is little sense of procedure for epistemological ends, as observations are used to demonstrate pre-determined ideas rather than as an aid to the constructive cognitive processes of induction or hypothetico-deduction.

Given this evidence, it is possible to speculate that Heather's reliance on specific elements of method within her teaching is a way of trying to reconcile her tensions. She
truly has little idea of what she should be doing in her science, but her understanding that there may be certain procedures that scientists use gives her a way of bridging the gap between her tacit understanding that science is about pre-existing facts or correct answers and her idea that children learn through exploration.

2) Autumn Term 1995

During this period there is the beginning of action to counter her lack of confidence and interest in science. On 4.10.95, she makes a verbal respondent validation of the researcher's portrait, in which she is portrayed as having a 'block' towards science, accompanied by a lack of interest, purpose or application in her teaching. She does not wish to change anything and states: 'it's a bit frightening when you see it written down. It needs somebody to say it for you.' As the term progresses, however, she begins to allow children more space to follow their own ideas and she starts to address the issue of how much content she should cover within sessions or the longer term. There is little more clarity in her expressed understanding of the nature of science or its pedagogy, but there is a sense that she is now actively questioning that understanding. Owing to developing personal circumstances, there is no interview in December, but a taped, extended post-lesson reflective discussion on 15.11.95 provides useful data as to her perception of change over the term.

Heather decides initially to focus her own inquiry on her questioning style, trying to see the effects of the various kinds of questions she asks. This focus reveals a major facet of her overall practice. Regardless of her lack of confidence in the science itself, she demonstrates an ease and naturalness in the handling of children's inquiries, showing an impressive ability to respond to the immediate demands of a session and ask focused and pertinent questions.

The session on 4.10.95 (appendix 4) demonstrates this very clearly. It shows how well she can respond to children's questions and experiences. The incident where she allows a boy to explore the consequences of his ideas about holes and their relation to floating, not only shows that she has an ability to recognise opportunities for inquiry work.
and structure her interactions positively, it also supports her espoused leaning towards the importance of some kind of inquiry ‘method’ to science.

What is most distinctive about the sessions which follow through October and November, is the very rapid drop in the amount she tries to get through in a session, coupled with an opening up of her teaching style. She appears to be moving towards the production of a more genuine space for children to develop their ideas. The result of this is that she seems to be getting much closer to her espoused constructivist position that it is important to take account of children’s ideas in their learning. For example, the session on 22.11.95 has the following sequence, containing space for elicitation of ideas leading to application and new experience. The children are investigating shadows:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Points out shadow on the carpet) Find a really strong shadow and one not so good. What happened with the spider moving?</td>
<td>The shadow moved Yes. Ch.1 -Yes Ch.2 - Light will get through the holes</td>
<td>Very motivated</td>
</tr>
<tr>
<td>The bottle? (Ball) Will this be good?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Plastic brick) I think it will depend on which way you hold it.</td>
<td>(J wants to discuss every object)</td>
<td></td>
</tr>
<tr>
<td>(Variety of objects) Brick with holes?</td>
<td>J - it will show the holes up</td>
<td></td>
</tr>
<tr>
<td>Will the holes have a shadow?</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Will we have a shadow with the plastic sheet?</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Why? D?</td>
<td>J - that’s lighter plastic D - because you can see through it. Light can get through it.</td>
<td></td>
</tr>
<tr>
<td>(Holds up different colours of sheet) What do you think?</td>
<td>M - if you cut a hole in them</td>
<td></td>
</tr>
<tr>
<td>What about the magnifying glass?</td>
<td>J - No, you can see through it</td>
<td></td>
</tr>
<tr>
<td>Clearly? (Two sorts of bottle)</td>
<td>J - No, it's upside down. J - Not that one D - Only some of it you'll see</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Which bit will have a shadow?</td>
<td>J - only this bit (paper label) (A/C/Ca/J - all unsure)</td>
<td></td>
</tr>
<tr>
<td>What about the perspex sheet? Make piles of good and poor shadows (Interacts and focuses)</td>
<td>(Find out shadows around the edge of the perspex)</td>
<td></td>
</tr>
<tr>
<td>Why?</td>
<td>(J - finds out that the bottle makes one upside down) (M - finds two horse shadows.)</td>
<td></td>
</tr>
<tr>
<td>Tell me one thing you've found that's interesting. D - Your paintbrush</td>
<td>J - 'cos there's two lights</td>
<td></td>
</tr>
<tr>
<td>J - The driftwood</td>
<td>D - 'cos close to the light you couldn't see a lot of the light J - 'cos of the hole - it showed through. It's all wobbly</td>
<td></td>
</tr>
<tr>
<td>Which part let the light through?</td>
<td>The hole</td>
<td></td>
</tr>
<tr>
<td>.....cont.</td>
<td>Taking cues from the teacher?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Light sources are a problem - torches give poor beam.</th>
</tr>
</thead>
<tbody>
<tr>
<td>What implicit understanding here?</td>
</tr>
</tbody>
</table>

(lesson observation, 15.11.95)

By 15.11.95 she shows a much greater application to the planning of science work.

She states that she is 'getting better at allowing time to think about it' and that she is 'prepared to do it now whereas before I would have just thought ergh - another science lesson' (both 15.11.95). There is a consequent change in her understanding of the level of content and demand required.

...before I just didn't bother to go and collect properly so you end up doing a botch job, not really having what would be the best things to have, so at least now I'm planning - I get in earlier when I know I've got to collect things, so that's another thing. The other thing I suppose is that my expectations are being more realistic, both in the amount of work and the level of the work. (post lesson reflective discussion, 15.11.95)

The stronger focus on allowing the development of the children's own ideas suggests that she is developing the hypothetico-deductive understanding implicit within her initial conviction that science has a set method. She is more prepared to acknowledge that...
the children's ideas in her sessions might be important and is making more sense of the
content and purpose of her sessions. For example, having commented that the children have
'such wonderful ideas for going on with things that it's a shame not to let them experiment
with them a bit', she says:

I felt I was better at allowing the lesson to go as it seems to go itself, from what the
children are saying, - rather than me saying I was going to do this, so tough luck
what they've just said, never mind that comment, you're going to do what I've
planned. I'm better at sort of feeling more relaxed and saying okay, forget what I've
got planned, let's go with what your ideas are. I'm getting better at that; I'm still not
all the way there...

(post lesson reflective discussion, 15.11.95)

She is aware how the idea that science was predominantly about learning facts was affecting
her teaching and she wants to focus on the balance between exploration and recording in her
teaching:

Heather The only other thing I picked up on was that I still think I have this
need to get something down on paper with them, which is another
old thing I've always had. You know, gosh, what have we done
today, we've got nothing written down, you know. So I've said
perhaps I need to be more creative with how they record what
they've done, perhaps using a tape recorder or more pictures, I mean
I suppose I've always got to get some writing down, perhaps I need
to talk to Elizabeth about that, she's got some lovely ideas, hasn't
she?

SWA: Does that relate to you recognising and being confident that they are
actually working in a scientific way or what you think is a scientific
way?

Heather: Yes. I suppose I forget the thinking side of science and I want to get
the fact side of science down, so yes, allowing more time for them
just to be talking and that's equally important...

(post lesson reflective discussion 15.11.95)

She can now question what she saw as a pressure imposed by the National
Curriculum content. Her move to Year 1 from Year 2 is helping this and children's
exploration of their own ideas is becoming crucial to the science experience. She says a little
earlier in the discussion:

I suppose I'm so National Curriculum centred in a way, perhaps that's having done
SATs and things, that I almost sort of forgot about what the children were doing and
what they need and what they were getting out of it. So I'm getting better at going
back towards the child, rather than I've got to cover all this. I think it's letting them
lead a bit more. I mean obviously you have got things you have got to cover, but it's
letting them...I mean, I'm almost cutting off their thought processes by saying,
tough luck, I've got to do this, aren't I?

(post lesson reflective discussion, 15.11.95)
However, there is still a sense that the exploration she is encouraging is not as free as it might appear, for she implies that she knows what the outcome of the children’s deliberations should be. She suggests that ‘allowing them to follow their thoughts’ will take longer to get where we’re heading for’. However, this highlights a major contradiction between the application of constructivist thinking to the teaching of science within a prescribed curriculum and the basing of pedagogical strategies on epistemological understanding. Whilst there are prescribed goals of understanding within education, all action is circumscribed.

A picture of Heather’s development is therefore emerging. Her own research on questioning is making her focus on the nature of her interactions with children, challenging her conception of science as a fixed body of knowledge and her tacit approach to science teaching as transmission. The initial espousal of a method, hypothetico-deductive in character, but understood much as a formula rather than in terms of purpose or epistemological procedure, is becoming strengthened and more articulated. There is the appearance in her practice of a confidence in the promotion of children’s investigation, tacitly confirming her general pedagogical approach. The overall sense is that her understanding of what science is (or what should be taught about science) has become more provisional.

3) Spring term 1996

Heather’s engagement in this period was much reduced, owing to difficult personal circumstances which focused her elsewhere. However, the evidence from the sessions observed (17.1.96 & 22.2.96) show that, although she considered that the science topic for the term (the body and nutrition) did not lend itself to much that she would have termed scientific inquiry work, the style she employed in handling the informational and conceptual aspects involved maintained her change. Both sessions show that she tried to promote the application of children’s existing ideas in her attempt to build conceptual understanding, rather than relying solely on transmission. She confirms in her interview on 26.3.96 that she is hoping to ‘get stuck in again after Easter’. In focusing herself for the coming term,
4) Summer term 1996

The first part of the summer term shows a strong re-engagement with the project. Heather’s confidence in her science teaching increases markedly and she finds articulating her ideas about science and teaching easier. She is taking a much greater interest in science and appreciates the relationship between her own understanding and her teaching. An extended, taped, post lesson reflective discussion after the session on 12.6.96 allows her to explore her thinking at this time. She now appears much more confident about science itself, as well as the teaching of it:

SWA: Do you think about science at all apart from your teaching?
Heather: I do. I’ve got a much more positive feeling about science than I used to have. I think it’s more to do with...it’s not a separate thing, it’s part of everyday life and it’s something that you can do quite easily and I feel more like that. Whereas before, it was science is a sort of thing that is all on its own that you have to somehow get over to children...

SWA: So do you not see it so much as a distinct thing anymore?
Heather: No, I see it fitting in...you know, what is science? Well, science is all around us now; it’s easier to see that whereas before it was science is a subject I hate and I don’t want and I don’t want to teach it - I don’t know what to do with it. So it’s becoming easier to me in that sense to, er, see the reality, why it’s so important...

(post lesson reflective discussion 12.6.96)

She talks more easily about the purpose and nature of her practice. In the following extract from the discussion, she can be seen to be talking confidently about the way she structured the preceding session. There is more purpose to her practice and a suggestion that she might be developing a structure that is helping her resolve the tension between knowledge transmission and children’s exploration. The elicitation of children’s ideas forms the basis of the session. It is interesting to relate this structure to her initial idea of method in science. She has certainly not given up the understanding that science is methodical, but rather than trying to impose her formulaic methodological structure on the children, she now seems to be allowing for more open inquiry, related to the building up or testing of experiences. Although she, as the teacher, retains overall control about the direction she wants the children’s understanding to go in, the image she is presenting to them is more
provisional and tentative. It is more one of science as an adventure in observation and ideas.

The children's own ideas are important and there is more focus on inductive processes:

SWA: That structure you had - I mean you had the collection and they talked about it and you had three different kinds of sorting, you got them to... That presumably was a deliberate idea?

Heather: Yeah, I didn't want to dive into the houses bit, because I thought that was a bit, perhaps a bit abstract for them; I thought that the hard and the soft were perhaps words they were going to use.

SWA: Heavy and light, then clothes and not clothes...

Heather: Yes... Something that cropped up earlier was the word materials and somebody had said it's clothes, so that was something else I was trying to clarify as well - the term - you know, materials... I hadn't written labels beforehand, I'd thought I'll leave it, I'll see what things they come up with when they're going round on their own and that's why I sort of scribbled down the sets; they were theirs really.

SWA: Were you happy with it as a session?

Heather: Yes. I think I got things from them today. I know where they are today...

(post lesson reflective discussion, 12.6.96)

Heather talks about the way she has been wrestling with her previous ideas about science and their legacy in her teaching. In planning for the session her old lack of confidence had come to the fore, with insecurities about the scientific nature of what she was going to do. The battle between the deeply influential conception of science as a fixed method with firmly determined goals of conceptual learning and her newly developing sense that it could be a much more open procedure is clearly evident as she reflects on her feelings before the session:

Heather: Last night when I decided what I was going to do I felt mmmm, it's a bit wishy washy, it's a bit vague and not particularly scientific and then when I came in today I said don't be so stupid, it's going to be perfectly alright and of course it has been...

SWA: Why did you not think it was scientific?

Heather: I was panicking, I suppose! I don't know, I just get like that. Everything has to be so structured for me. It's just the way I've always been, but I'm beginning to lose that; I can feel it going slowly. It's just an attitude bred into me I think. It comes from your own experiences, I suppose; it's the way I did it. You wrote down, you know, method, results, conclusions all the time and of course I don't remember science from when I was at primary school, I don't think we did an awful lot then and if we did I wasn't conscious of it. You know, I'm getting better, I feel I'm getting there...

(post lesson reflective discussion, 12.6.96)

'Getting there' appears to mean much more emphasis on induction. She talks further about the way the children learn in the subject, describing a process of knowledge formation based on the building of ideas from observation:
SWA: How do children learn science?
Heather: It's experiences. It's things that they experience around them and I think it's our job as a teacher to try and somehow point those experiences in a purposeful direction. I mean, a typical example: D has had so many wonderful experiences in his home life, I think he's allowed to run riot at home, but that's how he learns so much, because he's explored and tested things out himself and in doing that a lot of times he sort of formulates his ideas.
(post lesson reflective discussion, 12.6.96)

The change in her own conception is evident as she continues:

And I think there's a lot of children that perhaps don't get the experiences and you have to try and do that a bit more in school with them, giving them hands on with the materials. They've all touched something today, whereas perhaps two years ago I would have sat there and said this is yours, don't touch it, put it in front of you....! And not really had the experience with it.
(post lesson reflective discussion 12.6.96)

The conviction in these responses is evident. Her science teaching is becoming a place where she can experience what she sees as the rewards of teaching. A few weeks earlier, she had responded to the questionnaire in the following way:

Q.2: We all have an idea of what characterises our best teaching. What do you see as the main characteristics of your best teaching? (Please, your own thoughts, not necessarily what OFSTED etc. might want!)
Response: Holding the children's interests - being able to keep the majority focussed and interested, using questions to keep children's thoughts moving without demanding 'set' answers.
Q.3: What does it feel like when it's happening?
Response: Easy when it's actually happening - sometimes hard getting there. Things flow naturally when the children show genuine interest and keeping this 'moving' becomes easier the more it happens. Fascinating when you hear what ideas they have - it's like unlocking a secret door! Listening to their thoughts out loud.
(questionnaire response, 5.96)

Through her new focus on induction and elicitation, Heather is now considering it possible to unlock their 'secret doors' within an area of her teaching hitherto closed to such action. Science is still structured and systematic, but it has become a way of thinking that is linked meaningfully with the rest of experience:

SWA: You talk about science being all around us. Do you think there is something still distinct as science?
Heather: Yes. It's not something that is dissolved into everything else in that sense. I think it is definitely, what is the word, a discipline, I suppose - a certain way of thinking. But it's not an abstract way of thinking, it builds out with everything.
(post lesson reflective discussion, 12.6.96)

There is, however, some conflict between her espoused position in this discussion and the tacit messages still evident in the sessions observed during the first half of the
summer term. Although there is not a return to the large amount of conceptual expectation evident in her initial sessions, there is a certain amount of strong teacher direction in the sessions on 25.4.96 and 10.5.96. There is still a sense in these sessions that she is trying to push through a procedure in order to reach an already formulated result, for example where she ignores the evidence of a ‘test’ by the children during 25.4.96 or the following sequence from 10.5.96, in which the children are trying to find out which material will make a good window:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>(White paper) Now, G. can you see?</td>
<td>Yes</td>
<td>(l) Whose ideas? Implication of a right answer?</td>
</tr>
<tr>
<td>Are you sure? I can’t, you must have a good imagination. I think you saw a shadow (Brown paper) E. Do you think it will be any good? I don’t. (Tissue paper) N. (Draws attention to overlap effects). Can you see inside?</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Yes, but you can’t see the real colours and shapes</td>
<td>I can see a shadow</td>
<td></td>
</tr>
<tr>
<td>Which is the best so far? I’ll tell you what, none of them were very good</td>
<td>I can (Children think)</td>
<td></td>
</tr>
</tbody>
</table>

(lesson observation, 10.5.96)

The session on 12.6.96, to which the above discussion specifically relates, and that on 18.6.96 seem to represent some kind of watershed. Heather handles the children’s observations in a more exploratory way. Although her questioning is often closed, thereby encouraging knowledge recall, the course of the two sessions shows her moving steadily towards a position where she is trying to promote children’s thinking from their observation. Tacit messages about right answers, evident particularly in the first part of 12.6.96, are fading, and she is apparently content to leave the focus of the session on 18.6.96 as the children’s observations and ideas. Her planning for the session (appendix 13) can be seen to reflect this and it becomes apparent that her objectives for the children to understand properties of materials could mean that she wanted them to have experience of
the fact that materials differed (or were similar), not that they should learn predetermined qualities:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Child</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>(after initial exploration of items in 'feely box'.) In here, we've got lots of other things. This box has different things. E. choose something out of the box (leaves to see other children in the class) E. tell me something about yours Anything else? Is it bendy? What's it made of? J? (dish) What's it made of? E? I thought it was metal. Look at the top - it's got metal. It may have some plastic on it N?(wood) What's it made of? What else is made of wood? Anything else? Do you think it's metal? S? (worn brick) Heavy? I would have said it feels smooth. Why smooth Do you remember the pebble? I wonder if it's the same thing? T - yours is similar (brick) What is it used for? What's it made of? N? Right, clay brick G? (tile)</td>
<td>Children pick something out of the box. You can see yourself in it. It might break if you bend it too much. Plastic Hard White inside Clay I know - plastic It's off a table Wood Wall? Cupboard Floors And the wall is made of metal Wood Hard Soft (Ideas) Many ideas It won't bend If you throw it, it will hurt Metal Clay</td>
<td></td>
</tr>
</tbody>
</table>
What's it madeof?
I, m wondering if anyonecan
find a way to sort these.
C,- put all the hard things in
one set

The mirror's not hard - it's a
bit
Well done G.
Anothcr way of sorting?
Whataboutdiffercnt t).pcs?

Tcll thcm about your scts
Is it making a houseor
an)-thing?
N- anything you would
ehange?
Whv?
Whýt for?
I'm going to stop you.
Wc'%-cdonc lots of sorting. I
thought that was a rcally
goodway.

Roof
It's like wavcs
Wood?
Clay, like that one (brick)
From the ground

- tile
bricks
wood
metal dish
glass
mirror
Bendy
(Discussion about the
amount the dish bent)
(Children think of different
placingsof hard/soft)

Valid - previous
cxperience

E- things you can make
things of9
brick
glass
tile
worn brick
mirror
metal dish
wood panel
For the roof/ house/
windows
House

Wood
Cos inside it's madeof wood
Windows - aroundthe edge

of

essonobservation -I
Taken in conjunction with her statementsin the discussionon 12.6.96,this change
0
but may also representa
may not solely indicate a revision of her pedagogical
approach,
00
developmentin her understandingof the natureof science.There is an overt movement
towardsan inductive conceptionof method.The approachis definitely in conflict with the
hypothetico-deductivestancewithin her statedproceduralaims for the summerterm:

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ATI:
Children need to have experience of testing their ideas:
- How could we try your ideas out.
- Predicting what might happen
- Testing
- Discussing results - why did this happen?
  what else could you try?
- Did we do everything in a fair way?
  (planning notes April 96)

Within the end of year interview on 16.7.96, she confirms the increase in confidence that has developed through the year and reflects on the same major elements she has noted before: a greater application to science, the fact that it now feels easier to teach and that she is developing a bank of ideas for teaching. She also considers the way she now understands science, reiterating many of the ideas seen in the discussion on 12.6.96. She compares her new understanding to that which came from her background, in which she says the attitude was that ‘you didn’t have to explore it, you wrote it down, you made notes and that was it, you know’. In an interesting sequence she overtly acknowledges the influence that these early experiences had on her conception of science and her subsequent confidence in the teaching of it. Describing how her engagement with her action research has forced her to come to terms with conflicting elements of her understanding, she seems to recognise the once tacit conflict between her ideas about science and her pedagogical philosophy. This realisation has taken a huge effort. Her fear of science made her reluctant to explore the subject in sufficient depth for an accommodation to take place. She would rather have ignored it, putting the tensions to the back of her mind. The effect of the effort she has made has been liberating:

SWA: Do you feel that your understanding of science has changed over the last year? What it’s about...? Heather: I think I’ve always known what it’s about, it’s that I haven’t really wanted to know it, if you see what I mean. It’s been easier for me to pretend not to know about it. I think deep down I’ve always known what it’s about.....My background in science was horrendous, really, but at the same time I was aware that it was a bad background. I never really got to do science properly, I didn’t enjoy it at all.

SWA: And do you feel more confident now, about...? Heather: Yeah. It’s really weird. It’s not happened overnight, it’s a gradual thing that I feel I don’t have to worry about it any more. You can do it. There are always going to be days when you don’t do so well and there will be days when you stand and spout, but there are times
when that’s appropriate. I said before I did it all the time and I knew it was not right, so you just lose your confidence...
(interview, 16.7.96)

Her discussion of the two bi-polar scales, indicates how although the responses are very similar, the level of her engagement with science has increased markedly. However, she discusses the ideas almost exclusively through exploration of her teaching:

SWA: I think the only places that you’ve changed are on the subjective/objective one - there may be very little significance at all, you moved it a notch towards objective - can you think of any reason why you did that or do you think that just is....?

Heather: (Long pause) I think it is to do with them being wrong more of the time, you know, and giving them a bit of leeway for there to be not necessarily right or wrong answers, but for the children their thinking might be different to mine. I think it’s more to do with really, rather than there’s always a right answer...It’s somewhere in the middle, playing safe!

SWA: And the discovered/constructed, you’ve moved into the middle from being over on the discovered side. Is that anything, do you think?

Heather: I think that was to do with them formulatnin their ideas and building on them a bit more.

SWA: So the way in which the ideas build up - is that what you’re saying?

Heather: Yes, more of a discovery thing over a series of things, rather than something that’s built up.

(interview 16.7.96)

Her use of the term ‘discovery’ is interesting here, especially given her movement away from it on the scale. It is probable that she is referring to a pedagogical understanding of the way children acquire knowledge slowly. If it were taken to mean ‘inquiry’ or ‘exploration’, there would be more consistency with the preceding comments. Her reflections on the other responses on the scale indicate an understanding of tentativeness and provisionality in science which would be consistent with this interpretation:

SWA: The changing one you’ve moved from number one to number two
Heather: Again, that’s probably me relaxing a bit and saying that things are changing all the time, ideas are changing.

SWA: .......Those threes down the middle. Are they ‘don’t knows’ or are they genuinely part of each, or...?

Heather: Em...That personal and public one I thought should be in the middle; sometimes it’s things which are very personal to you and other times it’s things that you’ve talked about, so I actually chose that one.....That one was more an opt for the middle -

SWA: The verified/unconfirmed?
Heather: Yeah...And again I sat and thought about this one, the rigorous/laissez faire one as well and changed it and put it in the middle. They’re probably a reflection of things I really need to go and give more thought to before I could actually commit myself one way or the other.

SWA: Why did you put that rigorous/laissez faire one in the middle?

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Heather: Because half of me is still hung up on this rigorous bit and half of me is still thinking nah...!!! Chill out about it a bit! I just didn’t have a feeling about it one way or the other and I probably just thought, go for the middle.

SWA: And this one, the sure and the tentative?
Heather: That one I think it is in the middle for me. There are things that are set and sure in science and there are things that there’s a lot of leeway in.

(interview 16.7.96)

Towards the end of the interview, Heather confirms how much her confidence has increased when she talks about her planning for the next year and her interactions with other members of staff. They also suggest that she will take her changing perceptions to a new (older) class. She realises there are still strong tensions inside her, but there is the impression that she now feels she has a conception of science that fits with her overall pedagogical philosophy:

‘Heather: I just want to really keep working at opening it up for the children, especially with older children, because I think I might just revert back to my old ways of stand and spout, because talking to the teacher that’s had them - it’s year three I’m going to have - she’s just class taught them all the time. I’m not going to do that, I don’t think I could take it all in. I can’t listen to the children if it’s the whole class, not really........There was a big debate in the staffroom about planning, about whether to do a topic web before the term starts or really whether you should do it after you have the children; you’ve got their ideas and you know where they are and then do it, because then you know what you are planning for.....So I was saying I would be much happier if we started off the first couple of weeks; I would like to see how they get on, how they’ve done that really and, then spread it out once you’ve seen the children. That’s where the change is...

SWA: So you think that a year ago you would have been on the other side in the staffroom debate?
Heather: Yeah, yeah. But I was really strong, I was saying that’s not right, we don’t know how the children are going to cope, we don’t know how they’ve been used to doing science before, whether this is going to be a completely different way to them...I think that’s been my focus, you know, relaxing a bit about this tight knit planning, yeah, have some aims that you want them to do, but see how it goes really, see what comes from the children. A is going to trial out this planning scheme where you have children’s ideas and then they have to say how they’re going to answer them, whether they’re going to go and find out, or whether they can test out this idea and you have to put up a display with these ideas on...and some people were reluctant to have a go, but I was saying I’ll do it, I’ll go for it, that sounds good!

(interview 16.7.96)
Chapter 5 – Case Studies

STUDY 4 - Andrea

1) Spring term 1996

Andrea joined the inquiry six months later than the other three teachers, with immediate pressures upon her to take control of her new role as science co-ordinator, especially as an Ofsted inspection was approaching. In addition, her Year Six children were approaching SATs in the following May and she was concerned to take them through a programme of revision. As a consequence, the more leisurely introductory and focusing period afforded to Elizabeth, Carol and Heather was significantly curtailed. It is interesting to consider the importance of such a period in the promotion of individual action research, for although Andrea wished to engage immediately with her own inquiry, it still took perhaps six to eight weeks of the spring term before she began to feel at home with its purpose, focus and method.

Andrea participated in an interview at the end of the spring term. Her thoughts about science at this point are complex, suggesting a view which is characterised at its heart by the generation of knowledge and the development of certain attitudes and approaches. Her analysis of what she wants her teaching to involve suggests that she considers the nature of science itself to be a process of inquiry, driven by the idea of knowledge rather than led by it:

Andrea: I'm not sure if I really want the children to understand - not understand, to learn scientific facts; I'm not sure that's what it's about. I would want to make them curious about what goes on. I'm not sure that knowing exactly what goes on is necessarily what to do. I want them to do something which is based on some kind of knowledge, not just an impossible investigation, and actually want to do it, be curious about it and use skills that they will need for other things...

SWA: So you see it as a vehicle for developing this curiosity and inquiry?
Andrea: Yes, because of the nature of science - children are involved in finding out how things work, what goes on....

(interview, 26.3.96)

It is unclear whether she considers the knowledge itself to be discovered or constructed. She seems to allude to both possibilities as she goes on to relate the process of science to a basic human drive to find 'answers':

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SWA: So what do you see as the nature of science?
Andrea: Trying to find answers, I think. Looking at particular things, but still trying to find answers.
SWA: That's interesting the way you put that - it's about trying to find answers. Is the nature of it primarily the trying to find, or primarily the answers?
Andrea: I suppose the trying to find and where that leads you. It might lead you to the answer.

(interview 16.3.96)

It seems probable that her use of the word answer relates to the idea that science is a search for explanation, rather than the discovery of truth. When questioned further, she conveys an understanding that scientific knowledge is provisional and she implies that this provisionality has inherent meaning for the scientist, spurring on the quest for understanding:

SWA: Do you think science finds answers?
Andrea: It finds answers that are not necessarily set in stone, but they're answers for that moment, though they may be changed.
SWA: So why do they change?
Andrea: Because there's always another question later; you may have found the answer to that one, but there's always something else. Now I know this, I want to know that.

(interview 26.3.96)

There is evidence that she holds a hypothetico-deductive position. She frequently refers to her need to help children develop the ability to explore their ideas or base their investigations on prior understanding. The application of knowledge to a situation and the investigation of its validity is characteristic of her approach. Investigation features strongly in her descriptions of the process of science and her aims for the classroom. She sees it as pedagogically crucial, essential to promoting the children's learning. Her analysis of its nature confirms a view of knowledge formation which derives from previously held ideas and that is tested by application to a new situation:

I don't think all of science has to be investigative, some of it. They incorporate so many aspects of that activity. Not only do they have to apply what they think they know, they're investigating that; they're using their previous scientific knowledge, whatever it is, to discover something new and change that knowledge maybe, and actually be able to develop questions about it, to teach it to somebody else. So there's lots in there they wouldn't get out of me saying what we'd done...

(interview 26.3.96)

She is strongly committed to developing the children's understanding that this hypothetico-deductive approach is the right way to go about their science work. A sequence a little later in the interview illustrates this. She sees the approach as essential in the
promotion of the children's learning, clearly taking the position that they need active experience in order to learn scientific concepts. Although there are tensions with curriculum demands, children need to be confident with uncertainty if they are to learn:

**Andrea:** It's much, much more valid to have thought of a question which they have gone through some process to investigate and arrived at some conclusion even if that’s not the answer we thought we were going to get or... but they don’t seem to want that, that’s too...

**SWA:** Is that too insecure?

**Andrea:** Mmm.

(Thoughts about the children’s history in the school and what she thinks they should have learnt by now).

They have to know all these things and you can’t guarantee if they’re going to know it if you give them something that’s too much open-ended work...

**SWA:** So that’s a problem?

**Andrea:** And I don't think they will know it, I don’t think they will know it unless they actually get to grips with it in their own way.

**SWA:** So do you think that all the knowledge that they’re meant to be dealing with in SATs can only be learnt in one way?

**Andrea:** Within science specifically...

**SWA:** Within science?

**Andrea:** ...I'm trying to think of something that they wouldn’t learn. Well, for example, you can’t investigate exactly how your ear works, you need a diagram, but I still think you need to do something which is going to show ... something to vibrate and so some of it's got to be some kind of practical application of what you’re telling them...I thought that perhaps we should ask them to prove some statement, maybe. That might be quite an interesting thing to try, saying this is a scientific statement, can you actually...

**SWA:** ...find any evidence that might....?

**Andrea:** Yes, can you prove it practically.

(interview, 26.3.96)

From the perspective of her own inquiry, Andrea is initially concerned with investigating whether she is allowing for enough differentiation within the tasks she is setting. With the pressures of revision work, she considers that her approach to teaching is constrained and she comments after the session on 17.1.96 that its structure is not as she would want. The session itself (appendix 14) is largely directed towards helping the children demonstrate phenomena of light they have observed in a video. She does encourage the children to speculate about explanations, but largely so that they have the knowledge she wants. Much of the children's actions, however, reveals a focus on *effects* rather than explanation and there are some confused descriptions of what is happening. In the post-lesson reflective discussion she suggests that she would like to analyse the kinds of thinking implied by the tasks. By the session on 7.3.96, she has changed her revision approach
considerably and has produced a plan which is much more investigative in content. Her planning indicates a definite procedure for the children’s investigation, with a strong hypothetico-deductive feel. There is a strong assumption that the children will be testing:

Aims:
- Suggest things to test connected with previous work in science.
- Raise questions from suggestions.
- Decide whether the question can be practically investigated and adjust accordingly.
- Make a plan of an investigation before starting.

Objectives/content
1. Look through work on sound, light, electricity, magnetism and identify something of particular interest which you would like to investigate further.
2. Raise a question about this area of interest.
3. Share areas of interest as a class. Help each other to raise appropriate questions. Team up common questions/areas of interest.
4. Decide whether question can be practically investigated.
5. Discuss planning of an investigation - Question, materials needed, what you are going to do, how are you going to record results.
6. Identify reference material available.

Notes on board during lesson:

Idea/Question
Materials - List
How are you going to do it?
How are you going to make it fair?
How are you going to record your results?

The focus on what she characterises as an investigative procedure continues in the next session, in which she encourages the children to consider the structure of each other’s investigations from the previous week. Subsequent to the lesson, she communicates what could be seen as a tacit understanding of a public element to valid scientific knowledge when she decides to engage the children in a process of trying to replicate the results of another group. (analytic memo, 14.3.96).

2) Summer Term 1996

Andrea begins the term preoccupied with the administration of SATs and it is not really until after half term that she can immerse herself in her own inquiry again. When she does so, her sessions show a strong focus on the development of the children’s
understanding of scientific process. It is evident that she holds the fostering of children’s
ability to engage in this process as an important pedagogical aim. An analytic memo entry
after the session on 11.6.96 shows her struggling with the issues she was raising before
Easter, especially the conflict between curriculum pressure and her wish to promote
meaningful learning. Her engagement with these conflicts in her practice is raising
dissatisfaction with the general level of educational debate within the school:

Describing feelings about children being able to make links, emphasising the tension
created between the pressure of coverage demands and the feeling that the children
are not really coping with what they’re asked to do. About them making meaning
and it being purposeful. Talked about the way in which she feels that she is always
questioning, leading to a sense that she is not (yet at least) achieving what she wants
(tension between aims/values and what goes on). Dissatisfaction with planning and
curriculum demands. Wants to discuss educational issues with someone, but feels
there is no real forum to do so. Disappointed that there is no real sense of
educational debate in the staffroom - almost disencouraged to talk about ideas?
(Refers to Elizabeth, whom she says does discuss ideas, but she does not get any
encouragement.) Could do it at college. Is very thoughtful, wants children to
develop their ability to think, justifies this as an important part of injecting purpose
into curriculum and school experience.
(analytic memo entry, 11.6.96)

Within the end of term interview, she again emphasises the centrality of inquiry
within her conceptualisation of science, suggesting that her understanding of science is
founded on a sense of the provisional character of knowledge:

I think it’s answering questions...not necessarily proving anything, perhaps in some
cases, not necessarily...it’s not discrete, it’s not finding out something and then it
stops, to me it’s being able to...I’m trying to think of a way of explaining what it is
to me...maybe it’s like being on a surfboard and going up and down in lots of
waves - you’ve got to one and you’re exploring it and you find out something but
that’s not the end of it, so you can keep on going, keep on going, keep on going...
(interview 16.7.96)

It is unclear whether this represents a realist or relative conception; it has room for
both. There is much, however, in the interview that provides an indication of her
understanding of the link between scientific procedure and knowledge generation. For
example, she talks about her conviction that what is important in school science is success.
This is understandably connected with ensuring that children are not disenchanted with
science:

I’m not going to worry about them not knowing things; I want to give them some
measure of success in some way, to get positive feelings in science....
(interview 16.7.96)
but, in addition, it seems to have a deeper relevance to the scientific enterprise itself. She describes one girl’s approach to her work and the way in which she has developed a systematic approach which is transferable to new situations. This approach appears to be based on an understanding of what methods or results are going to be useful to investigators in their search for an answer:

SWA: Do you think that’s being scientific?
Andrea: It must be scientific to somehow.....discover they’re not giving you accurate results or results which are going to be any use to you...I just think that that’s important in science. If you can do it there, then you should be able to somehow teach them to do it all the time, I think.

(interview, 16.7.96)

Provisionality, in this interpretation, lies within a realist conception, with the view from the ‘wavetops’ (see above, 16.7.96) leading the eye eventually to a fixed point, rather than to one that does not as yet exist. Science may not reach that point - ‘keep on going, keep on going, keep on going...’ - but the point would exist and sometimes science does reach its destination. She refers to science as ‘not necessarily proving anything, perhaps in some cases, not necessarily’. There is an obvious possibility that this conception, and the ambiguity in her articulation of it, might generate tensions within her practice. There is a dialectical contradiction within the messages she is giving. If she is espousing the promotion of uncertainty as a way of achieving understanding of given knowledge, there is an obvious potential for a clash of interest.

Within Andrea’s understanding, therefore, science may be a way of accomplishing what you set out to do and less of an open investigation into the nature of things. Although this is not clear cut, for she also hints at relativism in places, the majority of her interview supports this realist conception of knowledge. For example, when talking about the identification of patterns through the adoption of a systematic method of working in science, she implies that she may consider the patterns to be already existing. They may be there to be discovered, rather than generated a posteriori. This, in turn, suggests the possibility that she considers science to be slowly building up true understanding in an incremental way.

The interview continues:
SWA: You say they're (the methods and results) important in science. Does that mean that being scientific is doing certain things?

Andrea: Yes, because they have to be methodical to a certain degree. You can't be random, if they do things randomly, then they will not be able to do an interpretation about what they are supposed to have found out.

SWA: Why not?

Andrea: Because there will be no patterns to discover, because patterns tell you, seem to tell you something. To me that means things that you can then ask another question about what that seems to be telling you, but if you've got random things, they're not going to tell you anything; you're not going to come to any conclusion...

(interview 16.7.96)

The evidence from her practice this half term offers support to the analysis emerging from this interview. It can be seen that the hypothetico-deductive way of working with the children is promoted strongly within her sessions and the tacit message that science consists of certain knowledge to be confirmed is often not far from the surface. She is, however, keen to develop the children's ability to work systematically and the observation notes from the session on 4.6.96 show her trying to promote a procedure for the children's investigation, based firmly on the exploration of their ideas. She suggests eight steps, reminiscent of Heather's formulaic approach:

1) What is your question?
2) What do you know already?
3) What do you predict?
4) What information do you need to collect to answer your question?
5) How will you collect it?
6) How will you make sure it's a fair test?
7) What resources do you need?
8) How will you record your results?

(from lesson observation, 4.6.96)

The way she handles the session sees her encouraging the children to use their own ideas as starting points for inquiry, promoting recall of previous experience and the formation of exploratory questions for investigation. With SATs out of the way, she no longer feels the pressure of reaching knowledge targets and she decides to focus on developing the children's understanding of a procedure in science and their ability to use it. The learning of specific knowledge becomes secondary and she removes the need for formal recording of the task. She begins by asking the children to think of some possible investigations about dissolving, noting their questions as they come up:
<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember our discussion (from the last week): I want the salt back. We had an example left upon the shelf for a while. We said we wanted it back quickly, it took a week. You asked how we could make it quicker. What questions did you ask?</td>
<td>- What will dissolve/not dissolve. - How much salt will dissolve in cold/hot water. - Time sugar in cold/hot water, see which dissolves first. - How many spoonsful of sugar dissolve in cold/hot water.</td>
<td></td>
</tr>
<tr>
<td>What would happen if you froze a salt solution?</td>
<td>- Can you speed up the evaporation?</td>
<td></td>
</tr>
<tr>
<td>Was the salt left behind the same as you put in?</td>
<td>- Instead of the sun’s rays, just put it in a microwave. - Freeze it and then bash it up and get it back. - Freeze it, then warm it up, the water will be water, the salt stays salt, then sieve it and get the salt out.</td>
<td></td>
</tr>
<tr>
<td>Anything about soap?</td>
<td>It was harder.</td>
<td></td>
</tr>
<tr>
<td>Does bubble bath dissolve?</td>
<td>- Does soap have anything to do with dissolving? - It changes the colour of the water. - If it did evaporate, why don’t we get the soap back? - Bubble bath’s liquid and soap isn’t.</td>
<td></td>
</tr>
<tr>
<td>Does it make a difference if it’s liquid?</td>
<td>Yes.</td>
<td></td>
</tr>
<tr>
<td>What do we want to know?</td>
<td>- Yes, it mixes more easily and liquid will not come back because they’re the same kind of material. Soap might, but it might not. - When we looked at the salt it was different, like crystals.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- I think it was the same, but in a different form.</td>
<td></td>
</tr>
</tbody>
</table>
Will sugar return to its original state after evaporation?

Choose one of the six questions.  
Plan an investigation to try to answer it.  
Concentrate on good planning.  
As much information as possible.  
You won't have to write it up.

Do the questions promote the intended thinking?

(lesson observation, 4.6.96)

Her reflective commentary from 11.6.96 sees her exploring her reasons for developing this way of working, confirming how important the hypothetico-deductive conception is in her understanding and how she sees it as a key thinking strategy for children to acquire. She is particularly enthusiastic about the importance of science as a location for the promotion of children’s cognitive ability, commenting within the post-lesson reflective discussion of the same day that science is to be viewed as a perfect vehicle for teaching ways of thinking. She considers that science and mathematics are ‘more creative’ than English or art, emphasising how she wants children to develop the ability to draw conclusions. However, her discussion of this aspect in her reflective commentary again raises the idea that science proceeds in a linear progression to understanding:

I felt that the recapping part and the questions which the children came up with was ‘real’ science because they were trying to establish what they knew from previous investigations and then trying to see what the next unknown step was which it was possible to find out.  
I want to build on the ‘what they know’ or think they know and therefore make it easier to identify what they don’t know or challenge the conclusions which they draw.  
Very few of them make links between things in any subject - it seems a hard skill to acquire - and science seems the ideal vehicle to make this process part of ‘normal’ thinking. I’m not convinced I can teach this particular class to get into the habit of making links but at the very least it is a start.  
(reflective commentary, 11.6.96)

Her reflections then proceed to raise questions about her practice which show that reliance on this procedure for the generation of knowledge is creating tensions. Furthermore, she is also becoming critical of the pressures coming from the curriculum, raising questions which cast doubt on her acceptance of the amount or complexity of
knowledge she is supposed to be teaching. This is creating a situation fraught with difficulties:

The investigations were relatively simple to plan, not many variables to control, but I feel it gave those who find this difficult a measure of success. This leads me on to wonder whether I (we) make things too complicated and therefore the focus is not on making links or drawing conclusions or asking questions but just on understanding and coping with the task in hand. It makes me feel that I should be much clearer about my objectives and what I actually want them to learn.

It also seems that when they are trying to answer their own questions they are motivated to learn more but I feel a little insecure about this as I am conscious of 'content' to cover.

(Reflective commentary, 11.6.96)

Tensions are clearly evident in her practice during the session on 18.6.96, in which the wish to promote understanding of a methodological procedure is mixed with a strong tacit message to the children that science knowledge is ultimately a question of recourse to a greater authority. The knowledge children have to learn is given; the children have to use the procedures of science to check whether they are right. The possible falsificationist understanding in the reflective commentary - 'challenge the conclusions which they draw' - is not present; in this session, testing is a means to demonstrate hypotheses, not refute them. Epistemologically, what she is giving with one hand - exploration, tentativeness, provisionality - she is taking away with the other. She begins by asking the children how she as a teacher knows what to teach them in science. The children's responses hardly suggest that they consider science to be an open process of inquiry and the rest of the introduction confirms their passive role in the generation of knowledge:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
</table>
|         | - From our reports.  
|         | - You look through science books. 
|         | - The government tells you what to do. You will have a meeting with the other teachers. 
|         | - You've got books you buy and look at them to see what to do. 
|         | - We've all got Records of Achievement - you look at them. | We have science tests |

If they are thought of as individuals, there are 27 different things. Do we do this?
I'm going to give you a list of statements (not a question). Can you recognise any? Is there one particular one that interests you?

No!

Yes!

How do I know which one to do?

- You are told by the government.
- You pick one at random.
- You look through science books. If we've done one on magnets, you're not going to pick that one.
- The government say what they think children our age should learn. They tell you what to do, say for example through the year magnets, light, electricity and it's up to you to fit them in.
- Going back to '27 times'. You teach it to us at the beginning. Then who doesn't catch on as quickly you give them a bit more.

I have the National Curriculum Key Stages 1 and 2. In here it tells me what I have to cover in every subject at Key Stage 2 and I have to decide what each one of you should be doing with that. When we do science, how do you know what you're supposed to be doing as an activity?

- You have a discussion with us.
- You have a piece of paper that tells us what to do.
- The title.
- The groups.
- We choose a question.
- You give us a piece of paper that tells us what to do.
- You give us a list of statements (not a question).
- The title.
- The groups.
- We choose a question.
- You give us a piece of paper that tells us what to do.

What's at the top?

- The title.
- The groups.
- We choose a question.

When you get told what to do, don't you get told specific things?

Yes....

What else? (about them knowing what to do)

- You put it on the board.
- There are questions.
- We choose a question.
- You give us a piece of paper that tells us what to do.
- You give us a piece of paper that tells us what to do.

I'm going to give you a list of statements (not a question). Can you recognise any? Is there one particular one that interests you?
Any you are interested in?  
Now, here's my problem.  
Can you solve it for us?  
Potentially, there are twelve groups. How will we decide them?

Have you got a question?
Give me an example
Somebody - A? D?
If I write A - K on the board (the questions), can you write your name next to the letter?

(Refers to instructions on the board: Plan investigation: What materials? What will you do? How record results? What will you need?)

There is one thing left out, near the beginning

No, it begins with a P
Then what? Listen carefully. Write down what you already know. (Emphasized)

<table>
<thead>
<tr>
<th>(Children read)</th>
<th>Who's got the same question? You've got a statement, you can turn it into a question. The one about forces and balance - you can add 'can'. (Children try)</th>
<th>(The children get into groups)</th>
</tr>
</thead>
</table>

(lesson observation, 18.6.96)

Andrea recognises some of this tension. She knows that the imposed conceptual demand of the National Curriculum is producing a conflict with her pedagogical aim of promoting children's ability as scientists. She conveys this understanding powerfully during the end of term interview, in which she indicates that her ideas are themselves in a state of flux. In the following extract, another tension appears: realistically, she is not free to pursue a line of teaching based on the promotion of children's procedural understanding. She is accountable to others about the amount of knowledge they have covered and she realises that if other teachers do not approach things in the same way as her it could be difficult for the children:

Andrea: So there's a sort of clash there between what I'm asked to teach, or the way I'm asked to teach it and what I personally think that it is or how to be approaching it. I'm not saying I'm right about that either; that's a dilemma for me. I'm thinking about it all the time because I
know I’m supposed to be doing things, but I’m not sure the children as scientists are getting out of it what they should be. It is a problem.

So where does the problem lie?

Andrea: It lies with having to follow particular routes, so there is an amount of content to get through, but that doesn’t necessarily follow the same path as the children’s development in any of the areas. So they may not be ready to learn about forces and then they have to - they have to - and that makes it a bit difficult, cos some children cope very well and some children don’t and just need more exploration, which I don’t think they get...It might be alright to do that, but I haven’t worked out that yet, I haven’t decided whether it’s alright just to allow some children to be explorers.

SWA: You obviously feel that it might be alright. Why?

Andrea: Well, I think it might be alright in the long run. I think in the long term it will be better for them, but it might not be better for me. I have to justify what I’ve done in my year, I have to think about when they inherit this child who maybe hasn’t done much on the content they should have done and they’re not doing the same thing and following my way of thinking, then it all goes wrong...

(interview 16.7.96)

Autumn term 1996

This term shows perhaps the most significant change in her understanding and practice. It is a very important phase for her. Andrea has changed to a new, slightly younger, class (Year five), and thus does not have the stress of preparation for SATs in the following summer. However, her focus for the term takes a few weeks to crystallise, for the Ofsted inspection tends to deflect her from her own inquiry. In addition, she is feeling keenly the pressures of her role as science co-ordinator, as she tries to raise the profile of science teaching within the school and introduce a new set of published resources to act as the backbone of the teachers’ approach and planning. This latter action is meeting some resistance, with some teachers objecting to the element of direction involved. Eventually, Andrea returns to her interest in the development of children’s procedural understanding, deciding to concentrate with her new class on the development of their ability to plan a science investigation. She wants it to include an element of exploration and testing of ideas. She articulates her main aims in her planning notes for the session on 12.11.96:

Aims for the term:
To make a simple plan independently
To recognise what is fair/unfair
To carry out a practical task sensibly and independently
To talk about what they have done and found out confidently

(planning notes, 12.11.96)
Within the sessions themselves, she can be seen to be wrestling with the question of what the children’s plans should consist of, showing, again, the wish to develop the children’s ability to apply their understanding from one situation to another. Increasingly, however, she closes down the children’s opportunities for independent action as it becomes clear that they are unable to cope with the level of her demand. The early sessions in the term confirm her espoused hypothetico-deductive approach, with those on 24.9.96 and 1.10.96 including the elicitation of children’s understanding in order to derive ideas or questions for them to explore. Observations of these sessions, however, show the children floundering and Andrea increasingly reverting to demonstration rather than investigation.

Her reflections on the sessions on 1.10.96 and 2.10.96 show her profoundly unhappy with the situation. She begins to focus on what she can do to change things:

A pretty disastrous session in my opinion. I forgot that I would probably need to revise the previous two weeks’ work and assumed a great deal of understanding about switches. I also didn’t give enough guidelines to the group making signs, which meant they didn’t work independently which is what I wanted. I also didn’t give enough thought to the use of the resources which caused delay in getting started and frustration for me and the children. I think I realised pretty early on that things were not going as I had hoped but felt almost powerless to stop anything.

(reflective commentary, 8.10.96)

The sessions from 8.10.96 through to 12.11.96 show her limiting the demands on the children as she imposes a tighter control over her planning. It is the beginning of a period of intense reflection on her practice and, over the next few weeks, her approach begins to change. From a situation in which nearly all her science work was focused on developing the children’s understanding of a fixed sequential procedure to science work, the sessions start to show a wider variety of possible approaches. The session on 5.11.96 is almost pure elicitation, with little further purpose conveyed to the children (or the researcher). Most interesting, however, is what she encourages the children to do with the result of the elicitation. She asks them to sort their elicited ideas about light into groups. This is the first time in the year that such a strategy has appeared in her teaching. It has clear inductive implications. By 11.11.96 her focus is becoming clearer and her reflections on the next five sessions - 11,12,18,19 & 25.11.96 - show her developing an increasing sense of success as she tightens down the amount that she wants the children to include in their planned investigation. The drive to produce tests that will demonstrate specific knowledge is
beginning to fade and there is an undoubted move towards induction within the sessions, as exemplified by this extract from 12.11.96. The children are finding out which materials will let through light:

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the torch for? (Reminder about the use of equipment) If you think you’ve finished investigating, write down what you think you’ve found out. (Break) Who thinks they’ve found out something they’d like to share?</td>
<td>(Children test materials) It’s for investigating</td>
<td>- It only goes through see through things and thin stuff. - It goes through glass ‘cos it’s see through. - (re. concave/convex mirror) One side it’s the right way up, the other upside down - I think thickness has something to do with it, ‘cos thin stuff it will go straight through. - The thinner it is the more you can see through. - No...some thin stuff it won’t go through. - Like wood. - I had wood this thin and put the torch on it and you could see it.</td>
</tr>
<tr>
<td>Who thinks that thickness has something to do with it?</td>
<td></td>
<td>(extension activity)</td>
</tr>
<tr>
<td>I’d like to see that. Why didn’t it go through the blutack? If you’ve not managed to write it down, write it down at another time.</td>
<td></td>
<td>‘Cos it’s sticky</td>
</tr>
</tbody>
</table>

(lesson observation, 12.11.96)
Her account of the work on 18 & 19.11.96 suggests that she is pleased with the results that the inclusion of a more inductive approach for the children is giving her:

I decided that for this first lesson I would concentrate on just exploring with a structure. I talked to the children about shadows and asked for their ideas. We then talked through some questions I wanted them to try and answer which I had written on sugar paper. We then went outside, taped the sugar paper to the fence and then in pairs they set out to explore their shadows. It was brilliant! They enjoyed themselves, they behaved themselves and I felt that they found out a lot on their own.

(Reflective commentary for 18.11.96 and 19.11.96)

Her final interview on 17.12.96 helps to clarify understanding of her position at the end of her involvement in the inquiry. Looking back over the year, the picture emerges of someone whose engagement with science has been a struggle. Tensions in her practice have created strong uncertainties about what she should be doing in her teaching and challenged her understanding of the nature of science as a subject. This situation has been complicated further by general educational aims which have had a considerable influence on what she has done in the classroom, for example, the wish to promote generic strategies for enhancing children's cognitive ability. She has struggled to reach some kind of resolution of these conflicts and her espoused ideas have changed. The growing disquiet that she has been developing over the year about the amount of demand being placed upon the curriculum and children is crystallising into a more clearly articulated philosophy about what she does not want, namely the kind of prescriptive demand in terms of conceptual understanding that the National Curriculum seems to be placing on her. She is still unclear as to exactly what she would like to see, but she is developing more confidence and acceptance of this position.

She appears herself to trace at least some of the origins of her tensions to change in her understanding of the nature of science. Whilst her articulation of this understanding might not appear to have changed much over the year (see responses to the bi-polar scale, below and appendix 7), either the depth of her engagement with her ideas has developed or the mere fact of prolonged and constant focusing on the same questions has promoted a deeper understanding. She now overtly recognises a link between her thinking and her action:
SWA: You were saying how things are changing. Do you feel that your ideas about this kind of thing (understanding of the nature of science) are changing at the same time as you're realising things about the ways of handling the children? Do you think there's been a relationship between the two?

Andrea: Yes, because that's my way into thinking about these things (nature of science issues), isn't it? Because what they (the children) do makes me think about areas like these and the less sure I get, the less sure I am that the National Curriculum is what science should be about at all. I'm almost convinced it isn't.

(interview 17.12.96)

She seems to have reached a point where she can feel confident in her own criticism of the curriculum. The above passage continues with a strong criticism of the current structure of science education in primary schools, interestingly making a damning reference to the promotion of prediction, which she had focused on herself when trying to teach the hypothetico-deductive method earlier in the year. She is now very uncertain as to the purpose of primary science teaching. The above sequence from the interview continues:

Andrea: For children of this age, I think they've got it wrong. I really don't think it's going to help them at all when they get to High School, the fact that we've had to do all these things. I don't think it will help them at all and looking at my own children going through High School and the sort of things they do in science, I'm not sure they've got it right there either, but I don't think that what we do necessarily help. I think they've had overkill on recording and predicting.

SWA: So would you say that it should be less process based, or do you think that there is generally too much demand within it?

Andrea: I'm not sure what the aims are. I'm not sure why we should do this. What is the aim of it for the children? I don't understand it really, because I don't think they're getting there, so what have we really achieved? And my feeling is that there has been some kind of panic that children don't know anything about science....I'm not saying that we shouldn't do science, I think we should. I mean I didn't do science when I was at primary school and it didn't help me at secondary school at all, I didn't have a clue. I'm just not sure what the aims are. What do they want out of it?

(interview 17.12.96)

Her uncertainty as to the appropriateness of the conceptual demand in the early stages of the National Curriculum is clear in her following comments. From a developmental perspective, she sees the teaching of large amounts of knowledge to primary children as irrelevant and possibly counter-productive:

My own daughter, who is fairly bright - not brilliant - is repeating what she's already done, but not really. I say to her didn't you do this in year seven and she says I vaguely remember something about gravity, but not really. She wasn't relating what she'd done then to what they were asking her to do and it was really quite worrying really...
From a position earlier in the year in which she had a clear understanding of a set procedure for scientific inquiry and a confidence that such an approach would promote conceptual understanding, she is now uncertain about both. Re-establishing a position that science is about rightness, she continues by criticising the expectation that children will develop a coherent conceptual framework through the application of a particular methodology. She suggests that promoting work in that way can create vague and confused understandings in children which are hard to challenge:

Andrea: And you leave children with really things that are wrong, but you have to leave it there and that is the bit they’re going to remember. They take away the bit that they’ve found out, but actually what they found out wasn’t right, scientifically, but you can bet that’s what they’ll remember. I’m not sure how you change that; I’m not sure their ideas are evolving at all, cos you can’t say what you’ve found out is actually wrong.

SWA: And you feel you’re almost not allowed to say that?
Andrea: No, I don’t think you are. It would be too negative. But if you did say that, a lot of children would want to know what was right then and they may not be at a level to understand...That’s how it feels to me; I’m not sure we’re doing the right things at all.

(interview 17.12.96)

She has generated a clear dilemma regarding the inclusion of procedural elements in her teaching: on the one hand they can promote meaningful understanding, on the other, they can lead to erroneous and unchallenged ideas.

When discussing her responses to the bi-polar scale, she emphasises the importance of inquiry in the overall enterprise of science itself, but the responses themselves also demonstrate the extent to which her understanding of science is in flux. In the first scale, she put five responses in the central position; now eight out of the fourteen categories are left blank. Her reason for this is illuminating:

SWA: So what are all the blanks about?
Andrea: Because I felt it could be both of those things at each end of the scale, sometimes, so I couldn’t put down science is certain, sometimes it can be, sometimes it’s the other. So, I think I could have done that with all of them, in some ways.......It’s quite difficult really. It was easy to put change in, cos it changes, and questioning. But subjective and objective - it can be subjective, but it could be objective as well.

SWA: What do you think it is more often then not?
Andrea: For them, probably subjective.
SWA: For you, how you view it.
Andrea: For me it could be either, depending on what I’m doing. How much I know about it...I found it quite difficult to fill in at all.

(interview 17.12.96)
Her further discussion gives more evidence of the depth of her dilemma and the origins of the tensions in her teaching. She suggests that there might be two kinds of science. There is a kind of 'ordinary' science, quite possibly including the knowledge-based 'right' science that children need to learn, and there is another, more exploratory process, in which science is about research for its own sake. She seems to draw a distinct line between the two:

\[\text{SWA: As a discipline, do you think it's a public thing or a personal thing?} \\
\text{Andrea: I think it's generally a public thing. I don't think you actually think about personal ideas in science. You don't think about it being personal. If you were doing it, then I think you would; I think there are a lot of people pursuing personal things in science which they'll never reach the answer.} \]

\[\text{SWA: Why don't they get there?} \\
\text{Andrea: Because they don't want to. I can see that doing research for its own sake, not for everybody but for some people...I don't think research has to always have some sort of goal; maybe it depends what you find out and where it takes you...} \]

(interview 17.12.96)

This suggestion of 'goal-less' research also has a strong sense of induction about it and her next statement shows that she is quite clear that the processes which support the derivation of inductive inferences (exploration, systematic and logical action) should be present in her teaching. The relationship between her wider educational aims and the place of procedural action in science is again hinted at, with a suggestion that she can identify specific processes as 'scientific', finding them in activities that are not necessarily 'science', but justifying the activities because those processes are there:

\[\text{SWA: So do you think that your understanding of science is changing or consolidating?} \\
\text{Andrea: I think it's changing, though I'm not sure it's getting any clearer.... I think it's getting a broader idea of what it might or should be....I'm not sure how a scientist, looking at those children this morning would think they were doing science, but to me they were, they were still exploring, they were still trying out....they were being quite logical about what they were doing... they were doing things they should be doing in science, even though it wasn't necessarily what the scientist would call it.} \]

(interview 17.12.96)

At the end of the year, therefore, there is a clear image of someone whose understanding of the nature of science is strong but confused; it is also in a dynamic and possibly ambiguous relationship with her general educational aims and procedures. There is little sense of resolution for Andrea. The autumn term has seen the rate of change within her
practice increasing, rather than stabilising, as she developed an awareness of contradictions within it. Her involvement with the issues raised by her action research is probably greater now than at any other time. The collaborative stimulus of the formal inquiry is about to end and the pressures of her role as science co-ordinator are strong, but she gives the impression that she will keep looking at her practice. The changes that have occurred will not allow her to revert to her original position.
Chapter 6

ANALYSIS

Introduction

The methodology of this inquiry was founded on premises which suggested that teachers' understanding of the nature of science can only properly be accessed by including a consideration of their practice. This argument implicitly presupposes that a link between understanding and practice exists. This presupposition differentiates the study from those reviewed in Chapter 2. Even those authors who argue strongly for a link, for example Lantz and Kass (1987), Brickhouse (1989, 1990) or Aguirre et al. (1990), do so from a supposed methodological perspective of neutrality. The justification for the position adopted by this study has been laid out in Chapter 3, but it is important to reiterate that the presupposition exists and that it must constitute a potential bias within analysis. This study aims to shed light on the nature of the link between teachers' understanding of the nature of science and their practice and the degree to which that understanding has significance in teachers' actions. The present chapter will explore the data presented in the four Case Studies, attempting to analyse key themes.

As discussed in Chapters 3 and 4, the process of accessing teachers' espoused ideas is not straightforward. Two factors complicate the issue. Firstly, the teachers' responses to questions relating directly to philosophical aspects of science reveal an insecurity with vocabulary and an unfamiliarity with the expression of syntactical understanding. This insecurity, reflecting Lakin and Wellington's (1994) suggestion that teachers are generally unused to reflecting on the philosophy of science, can be seen in Elizabeth's interview on 16.7.96 and is a common feature. The second factor compounds the difficulties in access raised by the first. When questioned directly about their understanding of science, the teachers tend to equate a discussion of the nature of science with a discussion of the nature of their science teaching. This tendency is either manifested in description of their approach to teaching, in which the teachers clarify their intentions about what the children are to do (see Heather's interview, 16.7.96, Carol's 16.7.96 response, or Andrea, 26.3.96), or it can be seen as a propensity to slip into anecdotal reference to their own practice. This latter
feature frequently takes the form of a recounting of stories from their own teaching (see for example, Carol, interview 26.3.96). The effect of this indirect evidence is to make a clear identification of the teachers' espoused understanding of science problematic, as their responses are inherently difficult to categorise. This makes a degree of speculation inevitable.

As a result, similar kinds of evidence are often being used to determine both espoused and tacit understanding, suggesting that separate analysis may be difficult. This is, however, a strength of the methodology, not a weakness. The nature of tacit understanding itself is problematic, for the teachers often seemed aware of aspects of their personality or background that were influencing their 'theories in use', although they did not espouse the understanding these aspects were producing. Thus Carol was aware of the impact of her family background (respondent validation comments, 7.95) and Elizabeth was conscious of the tensions within her approach to the transmission of knowledge in her early sessions (interview, 7.95). Heather (interview, 7.95) was also strongly aware that influences from her schooling and higher education were affecting the messages she was giving in her teaching. Such features disturb the simple distinction between espoused and tacit knowledge discussed by Altricher et al. (1993) or Torff (1999), suggesting a more complex picture working at varying depths of conscious awareness. The fact that the methodology in this inquiry allows for that clear distinction to be blurred, paradoxically confers clarity on an inherently complex situation. To align tacit understanding purely with intuitive knowledge is too stark.

It further becomes clear when considering the evidence of the studies that the espoused positions the teachers articulate are not simply the result of consideration of the nature of science per se. Just as they tend to articulate their understanding of science through examples of science teaching, so their thoughts about science teaching are influential in their understanding of what science is about. The significance of this feature will be discussed at length; it is necessary here to point out that vocabulary may be used in one context in a way that does not necessarily imply the conventional interpretation it may carry in another. Thus, when Heather uses the term 'discovery' (interview 16.7.96) when responding to questions
about her bi-polar scale scores, the fact that her reply is located in an example of children's action suggests that the normal epistemological interpretation of the word may need to be reviewed. Within the classroom, she uses the word in a more exploratory way.

1) The factors at work in the teachers' practice

Within the context and structure of this inquiry, it is simplistic to attempt a straightforward juxtaposition of the teachers' espoused positions and their practice. The inquiry's strength derives from its ability to examine the complex interplay that occurred over time as the teachers engaged in their action research. The idea of such a juxtaposition also creates a considerable problem for analysis, as there is no fixed point upon which to base any judgement. The studies indicate a fluidity which needs to be considered in total, rather than in discrete elements. However, if the initial elicitation of the teachers' understanding of science is compared to the nature of their practice at the beginning of the inquiry, there is little direct link between the two. The table below summarises these initial positions and, as Koulaidis and Ogborn would predict (Koulaidis and Ogborn 1989, 1995), the teachers appear to hold a range of views of science which are not always consistent. In particular, Elizabeth and Carol are verging, at this stage of the inquiry, on the 'eclectic' category (Koulaidis and Ogborn, 1989), holding sufficiently varied ideas to prevent categorisation.
Table 2. Teachers’ apparent initial espoused positions regarding the nature of science

<table>
<thead>
<tr>
<th>Elements of science</th>
<th>Elizabeth</th>
<th>Carol</th>
<th>Heather</th>
<th>Andrea</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) a process</td>
<td>a) a process</td>
<td>a) a set method</td>
<td>a) a process</td>
<td>a) a process</td>
</tr>
<tr>
<td>b) a set method</td>
<td>b) a human</td>
<td>b) a human</td>
<td>b) a body of knowledge</td>
<td>b) a body of knowledge</td>
</tr>
<tr>
<td>c) a body of knowledge</td>
<td>c) a body of knowledge</td>
<td>c) a body of knowledge</td>
<td>c) a body of knowledge</td>
<td>c) a body of knowledge</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aims/purposes of science</th>
<th>Elizabeth</th>
<th>Carol</th>
<th>Heather</th>
<th>Andrea</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) finding out</td>
<td>a) exploration</td>
<td>a) exploration</td>
<td>a) trying to find answers</td>
<td></td>
</tr>
<tr>
<td>b) discovery</td>
<td>b) finding out</td>
<td>b) a search for answers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) seeking order and meaning</td>
<td>c) seeking order and meaning</td>
<td>b) the generation of knowledge</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Epistemology</th>
<th>Elizabeth</th>
<th>Carol</th>
<th>Heather</th>
<th>Andrea</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) hypothetico-deductive</td>
<td>a) hypothetico-deductive</td>
<td>a) hypothetico-deductive</td>
<td>a) hypothetico-deductive</td>
<td></td>
</tr>
<tr>
<td>b) falsificationist</td>
<td>b) falsificationist</td>
<td>b) falsificationist</td>
<td>b) falsificationist</td>
<td></td>
</tr>
<tr>
<td>c) public knowledge</td>
<td>c) empirical</td>
<td>c) empirical</td>
<td>c) empirical</td>
<td></td>
</tr>
<tr>
<td>d) provisional</td>
<td>d) provisional</td>
<td>d) provisional</td>
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<td>e) empirical</td>
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<td>f) inductivist</td>
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<table>
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<tr>
<th>Ontology</th>
<th>Elizabeth</th>
<th>Carol</th>
<th>Heather</th>
<th>Andrea</th>
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<td>a) realist (?)</td>
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Elizabeth’s clear espousal of a hypothetico-deductive epistemology and her emphasis on empirical procedures, are not borne out in her practice. Analysis of her science teaching at the beginning of the inquiry reveals a preoccupation with ensuring the children learn specific pre-determined facts. In like manner, Carol’s strongly held ideas about the limitations of scientific knowledge and the centrality of the processes of exploration and inquiry (interview 7.95) do not find a place in a practice which is, at this point, highly tentative, poorly focused and promoting factual learning. Heather begins the inquiry with an insecure but restricted understanding that science is characterized by specific procedures aimed at achieving explanations for phenomena, but her teaching indicates that although she
tries to incorporate such exploratory procedures into her planning, she is more concerned, like Elizabeth and Carol, that the children learn specific items of knowledge. It is perhaps only in Andrea's work that any agreement between espoused position and practice is evident, as she consistently tries to encourage the children to follow a set hypothetico-deductive procedure which seems to relate strongly to her understanding of the place of the process in scientific activity.

The obvious question that arises from such findings is why there is little linkage, particularly when, as in the case of Carol, she holds some of her espoused thoughts so strongly. It is possible that the varied and uncertain nature of Elizabeth's and Carol's ideas mitigate against their translation into coherent practice, but that does not explain why Heather's more straightforward and consistent understanding is not in easy accord with the tenor of her classroom performance. Duschl and Wright (1989) and Lederman (1992) suggest that the phenomenon may be the result of a range of situational factors that are mediating the translation of espoused ideas into practice and, with this in mind, it is instructive to explore more fully the basis upon which the teachers' practice appears to be founded.

Lederman's idea of mediation by situational factors is powerful. It raises suggestions as to where understanding of teachers' practice may be found, but its apparent categorization of those situational factors as external to the teacher does not allow for the influence of the teachers' own tacit understanding in the overall picture. A central contention of this thesis is that when it comes to the understanding of practice, the identification of teachers' views about the nature of science must include both espoused and tacit elements. Thus, whereas Heather's initial practice seems to contradict her wish to promote investigation, the need to 'dish out facts' (interview 7.95), of which she is aware, provides a strong tacit impetus to her teaching, directing her sessions in a way her espoused ideas would not wish. In the same way, Carol finds it extremely difficult to break away from the strong tacit understanding she has of science as a body of knowledge, even though she can intellectualise against it and is struggling to incorporate more open investigational work in her teaching, at no insignificant cost to herself. Andrea's understanding of the nature of
science clearly includes the naive realist (Abell and Smith 1994) idea that science is a body of true knowledge and that learning in science is ultimately a question of recourse to greater authority. This is not to say that she consciously articulates such understanding, but it is present tacitly in her statements at the beginning of the inquiry and remains a strong influence in her practice even as she is wishing to encourage the children to become tentative and speculative (lesson observation 19.6.96).

Taking this perspective on the teachers' views, it could be said that, in fact, there were clear elements of correspondence between them and the teachers' practice at the beginning of the inquiry, but that the correspondence relates mostly to tacit understanding. This analysis will proceed later to determine whether a resolution of the differences between espoused and tacit positions was possible and whether this meant the achievement by the teachers of a strong espoused philosophical base to inform their pedagogy. In order to proceed to this discussion, the origins of these tacit positions and any other influences there appeared to be on the teachers' practice will be explored.

A range of factors influencing the derivation of tacit positions can be identified. Heather, strongly aware of tensions in her practice, recognises that the culture of her secondary schooling which was 'the learn it off the board kind of thing' (interview, 7.96), had exerted a profound effect on her own understanding and approach to teaching. In articulating this link, she adds support to the claims of Abell and Smith (1994), Aguirre et al. (1990) and Gustafson and Rowell (1995), all of whom considered the teacher's schooling to be the most crucial factor in the generation of their understanding of science. In Heather's case this understanding has lodged at the tacit level in her practice, but the extent of her awareness of this position is remarkable, for it emphasises how deeply influential such ideas can be. Some fifteen years after her experience at school and espousing a very different understanding of science, she did not want her science practice to be characterised by a transmission approach; it was as though she could not help what she was doing. Carol also indicates the existence of strong determinants of her teaching approach, indicating two that are closely linked. Like Heather, there is the influence from school, this time giving her little confidence in scientific knowledge. This insecurity is further compounded by
experiences in her own family. With three of her four brothers graduates in science subjects and her father a practising scientist, it is easy to imagine how Carol’s sense of inadequacy has transferred into a deep seated sense that someone had all the answers and that science was about knowing things. It is interesting to consider that the strength of her statements about the provisionality of science and its limitations (interview, 7.95) may represent a backlash to this experience. At the outset of the inquiry, however, it is the legacy of this family experience that lies tacit within her practice as its driving message. Elizabeth shows a similar insecurity about her science teaching that is founded primarily on her perceived lack of subject knowledge. It is feasible that this insecurity is the cause of her similar tendency to structure her teaching towards the children learning specific knowledge, a closed approach very much out of sympathy with her normal promotion of inquiry within the classroom (see Portrait, appendix 9).

The situational factors which Lederman claims mediate espoused understanding may also have played a part in the determination of tacit positions. All four teachers had a tendency to transmit the same idea of knowledge to their children, even though their espoused positions varied considerably. Cross argues that this is a result of the closed circle created in all schooling by the effect of the ‘ideological hegemony’ at work through science teaching (Cross, 1997). It is pertinent to look for a single causal factor which may be part of the explanation for such uniformity. In this case, there is evidence to suggest that the Science National Curriculum (DES/WO, 1989, 1991, DfE/WO, 1995) may be a powerful situational influence, governing the overall content of the teachers’ practice. All four teachers refer frequently to its influence.

Elizabeth’s planning for the half term reconnaissance phase at the beginning of the inquiry is a good example of the potential influence on the teachers’ approach of perceived National Curriculum expectations. The proposed aims for the half term (12.5.95, appendix 10) read largely as a list of statements taken directly from the Curriculum attainment targets. There is little sense there that she is interpreting their relevance to Reception children. Within her preliminary interview she can be seen to be struggling with the Curriculum’s relevance to her teaching and the strength of its influence can be clearly felt. Six months later she is
becoming much more selective, making choices from Curriculum areas which reflect considerably greater understanding of their content and indicate an increased control of her practice. Similarly, Heather, moving from Year Two to Year One in the autumn term and also beginning to engage with the tensions within her practice, sheds light on the extent to which she realises that the Curriculum expectations must have been directing her teaching (post lesson reflective discussion 15.11.95). Andrea suggests that the hypothetico-deductive procedure she was promoting in her classroom may have been derived in part from her understanding of how she could achieve National Curriculum ends, thus strengthening the tacit realist ontology that she was tending to transmit to the children. By the end of the inquiry she is seriously questioning this understanding and the relationship of the Curriculum to her developing appreciation of the nature and purpose of science teaching.

The National Curriculum can therefore be seen as a powerful factor affecting the teachers’ approach to their science teaching. The supposition that it is linked with their tacit understanding of science itself is more problematic and it raises a further complexity for the methodology and a problem for analysis. It could be argued that teachers are inevitably going to align their practice to the Curriculum. As knowledge targets are a central feature, a feature reinforced by the expectations of compulsory SATs tests at Year Six, optional ones at Year Four and focused Teacher Assessment at Year Two, then of course the teachers would be bound to promote the learning of given knowledge within their sessions, regardless of their personal understanding of the nature of science. In a situation so closely controlled by external demands, it is inevitable that this control will be manifest within teachers’ practice. Analytically, therefore, it becomes questionable whether their references to knowledge are there merely because they have to ensure knowledge is present in their planning - indeed, they are assessed themselves against the progress their children make towards gaining it - or whether it represents a true tacit understanding. There is a danger of reading too much into the evidence. Whilst accepting this reservation, however, this merely adds complication to analysis, not frustration. If it were simply a situation of curriculum inevitability, then it could be expected that all teachers would demonstrate the same attitude to knowledge within their teaching. The fact that the four teachers in this inquiry proceed to
question, review and in some cases change their own attitudes, demonstrates that this is not inevitable. The National Curriculum expectations exist as potentially powerful determinants of teachers' thinking which can affect either espoused or tacit ideas about science. Their impact, however, will be determined by other factors within the teachers' lives. The teachers in this inquiry seem to show that these other factors meant that they had an initial predisposition to interpret the demands in ways that reinforced or developed their tacit ideas; it is interesting to speculate whether this is true of the teaching population as a whole.

The teachers frequently communicated their espoused understanding of science through examples from their practice or description of their pedagogical approach to science teaching. This pedagogical understanding will have been influenced by external factors. Teaching science in primary schools at the end of the twentieth century, it is likely that the teachers will have been affected by prevailing pedagogical theories, of which by far the most prominent concerns the application of a constructivist understanding of children's learning to science teaching. It is beyond the scope of this discussion to enter into a detailed description of this application (see, for example, Driver and Oldham (1989) or von Glasersfeld (1989) for general principles), but it is important to appreciate that most texts concerning primary science education published in the last decade have taken the relationship as a matter of course (for example, Harlen (1993, 1996) or Ollerenshaw and Ritchie (1993)). In addition, some very influential resource materials published for schools (for example, Bath Science 5-16 (1993) or Nuffield Primary Science (1995)) have quite deliberately been based firmly on the development of a 'constructivist approach'. Such an approach, founded generally on the elicitation, exploration, development or challenge of children’s ideas, can be seen to promote a strongly hypothetico-deductive way of working. The frequent exhortation to start with the children’s ideas leaves little alternative. Although the application of constructivism to science teaching has been criticised, notably by Matthews (1993), Millar (1991) and Suchting (1992), with a recent debate occupying the letters pages of Science Teacher Education for over a year (Keogh and Naylor 1997, 1998; Jenkins, 1997, 1998), little sense of this critique filters down to schools.
In this atmosphere, it is no wonder that teachers frequently espouse epistemological positions in science which are hypothetico-deductive in character. Indeed, in this inquiry it is very possible that Andrea and Heather, both of whom focus strongly on the development of fixed procedural elements within their teaching, have been strongly influenced by the approach. Their espoused positions appear to reflect this. Elizabeth's developing practice shows her adopting something similar, quite possibly as a result of her then current reading of Harlen and Jelly (1989). The point is made within the case study that the pedagogical strategy suggested within the book of challenging the children to 'find out if their ideas are right', promotes a realist epistemology, paradoxically contradictory to the spirit of constructivist psychology.

Heather confirms the supposition that she has been influenced by constructivist messages and indicates that she recognises this influence by tracing its origin to the pedagogical messages of her P.G.C.E. programme (interview 7.95). In a revealing passage, she lays bare the basic tension in her teaching, giving a strong sense that she espouses exploratory approaches now because she accepted the prevailing culture within the H.E. institution she attended ('I mean going to college told me the way they actually pick things up is by exploring, by having a go...'), rather than as the result of any reworking of ideas by herself. In so saying, however, she hints at another highly significant area in the derivation of the teachers' practice: the existence of their personal beliefs about the aims of their teaching and what constitute appropriate pedagogical strategies and approaches for their children, together with the values which derive from these beliefs.

**Indications of teachers' beliefs about teaching**

It would be impossible to generate a satisfactory understanding of the dynamics of change in the teachers' practice, or of the relationship between that practice and their views of the nature of science, if consideration were not given to factors potentially as influential as the teachers' general beliefs about education and pedagogy. Their beliefs about the aims of education, together with those about how children learn and how curriculum should be structured, have a powerful determining effect on their understanding of what constitutes
appropriate pedagogical strategies for their children. Although not situational in Lederman’s terms, the very nature of these beliefs suggests a prima facie reason why they should be included in the factors which might affect teachers’ ideas or mediate their translation into practice. For example, within Carol’s study it is possible to see immediately how her commitment to the promotion of children’s independence affected her initial organisation of science sessions. Her wish not to ‘interfere’ with the children’s activity was strong and there was a significant tension produced by the fact that her teaching cut across such exploration, generating a profound contradiction as she eventually tried to make the children all learn the same answer. In the same way, Andrea’s commitment to the promotion of children’s ‘life skills’ springs into sharp focus when considered against her struggle to determine the best way to help develop her children’s thinking in science and their understanding of the epistemological value of systematic activity. The teachers’ beliefs were not an initial focus of the research. However, as can be seen from the Portraits (appendix 9), it is possible to identify key aspects of the beliefs the teachers conveyed through their action, their responses to the questionnaire or during discussion. These are summarised below to aid discussion:

Table 3: Summary of the teacher’s main beliefs about teaching

<table>
<thead>
<tr>
<th>Elizabeth</th>
<th>Carol</th>
<th>Heather</th>
<th>Andrea</th>
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<tbody>
<tr>
<td><strong>Beliefs about the aims of teaching:</strong></td>
<td><strong>Beliefs about the aims of teaching:</strong></td>
<td><strong>Beliefs about the aims of teaching:</strong></td>
<td><strong>Beliefs about the aims of teaching:</strong></td>
</tr>
<tr>
<td><em>The development of children’s self esteem;</em></td>
<td><em>The development of children’s ability to work independently;</em></td>
<td><em>The development of children’s self-reliance;</em></td>
<td><em>The promotion of the children’s ‘life skills’;</em></td>
</tr>
<tr>
<td><em>The development of children’s respect for others;</em></td>
<td><em>The development of children’s thinking skills;</em></td>
<td><em>The development of children’s ability to think and inquire</em></td>
<td><em>The development of children’s ‘life skills’.</em></td>
</tr>
<tr>
<td><em>The development of children’s ‘life skills’.</em></td>
<td><em>The development of children’s understanding and respect for the environment.</em></td>
<td><em>The promotion of children’s independence</em></td>
<td></td>
</tr>
<tr>
<td><strong>Beliefs about the way children learn:</strong></td>
<td><strong>Beliefs about the way children learn:</strong></td>
<td><strong>Beliefs about the way children learn:</strong></td>
<td><strong>Beliefs about the way children learn:</strong></td>
</tr>
<tr>
<td><em>That children learn through activity and experience;</em></td>
<td><em>That young children are active learners, generating understanding through experience;</em></td>
<td><em>Through practical activity and investigation;</em></td>
<td><em>Through inquiry and challenge;</em></td>
</tr>
</tbody>
</table>
Beliefs about the way curriculum should be structured:
* That it should allow for the 'emergence' of children's understanding and capability;
* That it should be delivered through investigative activity;

Beliefs about the way curriculum should be structured:
* That it should be integrated;
* That it should reflect the holistic nature of children's experience;
* That it should be delivered through investigative activity;

Beliefs about the way curriculum should be structured:
* That it should be delivered through investigative activity;

Beliefs about the way curriculum should be structured:
* That its purpose lies in the promotion of transferable conceptual understanding and thinking skills;
* That it should be based on continuity of experience;

Beliefs about appropriate pedagogy:
* That the teacher should be a facilitator;
* That children should be involved in investigative work;

Beliefs about appropriate pedagogy:
* That children should be involved in investigative work;
* That teaching should encourage exploratory and 'discovery' learning;
* That the teacher's role is one of facilitator, not instructor.

Beliefs about appropriate pedagogy:
* That children should be involved in independent activity;
* That activities should include practical challenges;
* That activities should promote children's inquiry and thinking.

Beliefs about appropriate pedagogy:
* That children should be involved in activities which promote inquiry and challenge;
* That teaching approaches should ensure success for children;
* That teaching approaches should inject a sense of purpose into the curriculum.

A range of factors therefore influenced the teachers' practice. If these factors are taken together, it can be seen that they are replete with tensions, whose presence created a fertile dialectical situation for change. The following tensions could be identified in some or all of the teachers:

- between espoused and tacit understanding of the nature of science;
- between espoused understanding and external demands;
- between espoused or tacit understanding of the nature of science and beliefs about the aims of teaching;
- between the reality of the teachers' chosen pedagogical strategies in science and their understanding of appropriate teaching approaches for their children.

2) Development of teachers' practice

Action research is about change. The attempt to resolve perceived tensions within practice can produce change in both action and the understanding that informs that action.
Action research was included in the methodology for this inquiry in order to render the teachers' understanding of science and its relationship to practice more accessible to research (see Chapter 3), but, including it as a central feature also opened up the possibility that the teachers' practice might change over the period of the inquiry. As practice consists of both action and theory, change in action can be taken as a possible indicator of change in understanding. There is strong evidence within the studies that, as the teachers confronted the contradictions inherent within the tensions in their practice, they changed both their understanding of science and science teaching and their actions in the classroom.

The rate at which the teachers changed and the style of that change varied considerably. Thus, whilst Elizabeth seems to have engaged in a steady progression towards increased confidence, finding participation in her action research to be constructive and stimulating from the outset, Carol's experience is very different. As conflicts and tensions within her practice become ever more apparent to her, she descends into a marked despondency during the first term of her inquiry. It is her commitment that sees her through, for it is not until about six months later that she is displaying confidence in what she is doing (interview 26.3.96). Heather's change is more gentle and her involvement more patchy, but, when viewed over the inquiry year it is possible to see how far she has moved and the extent to which her confidence has increased (interview 16.7.96). As with Carol, her commitment is impressive, motivating her when she had initially a strong reluctance to address science at all. Because of her late entry to the inquiry, of pressures from SATs, her role as co-ordinator and an imminent Ofsted inspection, Andrea makes slow progress at first and it is not until her last term's engagement that there is a sense of real movement within her research. That autumn term, however, sees considerable change, as if she finally has space to explore the contradictions that are plaguing her. Her change here is reminiscent of Carol's in the autumn term 1995; both show an initial resistance followed by a rush of reflection and planning, as though floodgates had been opened.

In order to explore further what issues may have arisen from this change, the cases of Elizabeth, Carol and Heather will first be analysed separately from that of Andrea. There are two reasons for taking such an approach. These three teachers all entered the inquiry at
the same time, participating in the same kinds of introductory discussions and reconnaissance activities. It has already been pointed out that the lack of this more structured entry to the inquiry may have affected the intensity of Andrea’s initial involvement. Although the subsequent pattern of the three teachers’ experience differed (see particularly Heather, spring term 1996), it was likely that their common understanding of the purposes and procedures of the inquiry was closer than that of Andrea. Furthermore, Elizabeth, Carol and Heather were all teaching very young children during the time of the inquiry, Elizabeth and Carol in Reception (4-5 years) and Heather mostly in Year 1 (5-6 years). Andrea was teaching much older children, either Year 6 (10-11 years) or Year 5 (9-10 years). This difference may have conferred a significant similarity in context, attitude and intention between the three early years teachers. It could be argued that Elizabeth and Carol may form yet another subset of Reception teachers; this is acknowledged, but such further differentiation does not undermine the pertinence of the overall distinction. This is not to say that Andrea is to be thought of as a special case, nor that it is not possible for there to be patterns of understanding or change common to all four teachers. This analysis will proceed to apply any inductive generalisations derived from the consideration of the early years teachers to the case of Andrea, allowing for comparison of two potentially contrasted, yet also bounded, situations.

The early years teachers—Elizabeth, Carol and Heather:

Beginning, therefore, with Elizabeth, Carol and Heather, it has already been suggested that there is little correspondence between their espoused ideas about science and their practice at the start of the inquiry. The relationship is at the tacit level. By the end of the inquiry this situation has changed, with their espoused positions much more closely aligned with the nature of their teaching. This is at first sight something of a paradox, for there is also a high degree of similarity between both sets of espoused positions. At the same time, all the teachers became more confident in their science teaching. All three display an ease with the teaching of the subject at the end of the inquiry that was not there before. This is clearly evident in the sessions themselves, with their spoken comments further reinforcing
the general picture. From being three self-admittedly very insecure teachers of science, Carol feels she could argue with Ofsted if necessary (interview 16.7.96), Heather is amazed at how strongly she can enter into a staffroom debate (interview 16.7.96) and Elizabeth is positively bubbling as she describes the changes she feels in her approach and enjoyment of the subject (post lesson reflective discussion 6.6.96).

A further strength of the inclusion of action research within the methodology was that it created a situation in which the teachers were given the opportunity to identify their own criteria for improvement and change in practice. Such a feature was useful in the clarification of the relationship between espoused ideas and practice. By helping the teachers to focus on dialectical tensions, action research both raised information about possible links between ideas and practice, and promoted a situation in which the teachers themselves were stimulated to examine relationships within their practice. As they did so, it was more likely that aspects of the relationships which were significant in their decision making would become apparent.

On examination of the changes that occurred during the year, a distinct pattern emerges. By the end of the inquiry, the major elements of the teachers’ tacit understanding appear to be accommodated within their espoused positions. Thus it can be seen that Carol, who was originally driven by a tacit need to transmit right answers to her children, in contradiction to elements of her espoused ideas and her aims as a Reception teacher, is, by July 1996, much more secure about the place of knowledge in her teaching. In the same way, Elizabeth started with tacit messages about knowledge in contradiction to her aims, yet by the end of summer 1996 she can legitimate the position of knowledge within her teaching (interview 16.7.96).

Yet the change has not happened because a simple clarification of the teachers’ espoused ideas about science led to an understanding of how these should influence their practice. Carol, for example, has well articulated espoused views of science at the beginning of the inquiry, which are complex, encompassing a range of epistemological positions. Predominantly hypothetico-deductive in character, they acknowledge the place of inductivist methods and she shows thoughtful epistemological reflection. In addition, she has an almost
Scathing perspective on the importance of scientists and their utterances, reflecting a strong viewpoint on the provisional status of scientific ideas. However, few of these ideas seem to be reflected in her practice, which is profoundly influenced by her sense of personal inadequacy. It might be expected that she would be able to use the essence of her espoused ideas to generate criteria for judging improved practice in her science teaching. She tries, but these criteria form only a part of her overall understanding of success. The change of approach in her practice is also strongly justified by its relationship to more general pedagogical aims. Carol’s action at the beginning of her research is to place the science work within the child-led Plan, Do, Review session she runs each day. She places her science work here because of her hypothetico-deductive conviction that science is about the exploration of ideas, but it is also because, philosophically, she is strongly drawn to this session. She sees it as an extension of her ‘holistic’ approach to education, in which children should have the space to explore independently those ideas and experiences that are of interest to them and within contexts chosen by them, not the teacher. Her role as a teacher is to facilitate this exploration, but not to interfere (see Portrait, appendix 9). Elizabeth’s decision to incorporate more observational work in her sessions bears some relation to her espoused ideas, though it addresses her predominant hypothetico-deductivism only obliquely. Indeed, this way of working seems quickly to disappear from most of her science work. This change in practice is, however, strongly related to her thinking about ‘emergence’ as a characterisation of young children’s development and the importance of promoting their thinking skills (see Portrait, appendix 9). Extending a feature found particularly in her mathematics work, she includes an emphasis on observation in an attempt to make her science more procedural, encouraging the children to ‘behave like scientists’. In contrast to the tacit reality of her practice, she is clearly influenced in her initial criteria for change both by her thinking about science itself and her more general beliefs about appropriate pedagogy for young children (interview 7.95).

From this starting point, a complex relationship develops between three key elements: i) the teachers’ espoused ideas about the nature of science, ii) the approaches they adopt within their science teaching, iii) their beliefs about the kind of pedagogy which
supports their understanding of both how curriculum should be structured and what is appropriate for encouraging young children's learning. There is no doubt that the stimulus of the inquiry challenges the teachers to think about the nature of science (see for example interviews 26.3.96 Elizabeth and Carol, or comparison of bi-polar scales, interview 7.96 (Elizabeth, Carol and Heather)), but at no point does the understanding generated by this thinking become the sole or dominant factor in their teaching. More realistically, it seems to become part of a background of possibility against which their practice develops. The character of their teaching changes as a result of other influences as well. Frequently challenged to modify their teaching - an action which has the possibility of such disconcerting results (see, for example, Carol, autumn term 1995) - the teachers have confidence in their resulting practice only when it accords with elements of their deeply held beliefs about appropriate pedagogy. It is as if these beliefs become overriding concerns which filter any other criteria for the judging of practice, including those relating to an understanding of the nature of science.

Carol’s example is instructive. The year includes much anguish for her as she confronts her feelings of inadequacy and her avoidance of the teaching of science. Such action brings her eventually into direct conflict with her pedagogical beliefs, for she is eventually forced to abandon her commitment to science in the Plan, Do, Review sessions and impose a different structure on her teaching. The result is painful, with her practice becoming a battleground between her ideas about science, both tacit and espoused, and her overriding beliefs about how to teach Reception children. The challenge stimulates her to review the meaning of her spoken or written comments about science, overtly so similar between beginning and end of the inquiry. This process helps her to emerge out of the long period of despondency in the autumn term 1995. However, although this is a development of her understanding of science and science teaching, the driving force behind this review lies within a wider reappraisal in which she begins to challenge her understanding of how her beliefs about children’s learning and the way children should be taught should be realised. Starting this process at the end of the Christmas term (interview 8.12.95), she first questions her conception of ‘child-led’ activities for Reception children, and shows later
(interview 26.3.96) how this rethinking has had implications for her initial hypothetico-deductivist approach to teaching. Change in understanding of both science and the implementation of practice therefore proceed together, driven by a wish to arrive at practice that feels right and that she can implement with confidence.

However, although Carol's understanding of what her beliefs look like in action changes over the year, the beliefs themselves appear firm. At the end of the inquiry she has a new confidence in her science teaching and she can identify patterns of working in the subject that are consistent for her with the teaching of very young children. Overall, her understanding of the nature of the subject has not altered very much, but it now translates into her practice in a way she considers to be appropriate for her Reception class. Science is still fundamentally hypothetico-deductive, but her teaching is now primarily inductive. Her inquiry can be seen to have clarified her understanding of these two methodological aspects, both of which appeared in her initial espoused understanding. She justifies her new approach by claiming that children first need experiences in order to be able to generate ideas for exploration. Interestingly, her ideas about the provisionality of science knowledge are also now much more embedded in her rationale for teaching, at the same time as she is moving towards an understanding that such knowledge is also subjective and relative (interview 16.7.96). Most significantly, however, the ultimate justification for her new position is its relationship to her beliefs about the right way to teach. It makes sense for her. Her new conception of science teaching accords with her persistent belief that the education of young children must flow from their experiences. She is now confident that the children still ultimately have control. Once again, she can conceive of the teacher's role as one of facilitation rather than direction, confident that she is engaging the children in something that she can justify as science, with the instrumental nature of the scientific processes they are using ensuring that the children will generate their own ideas. The confidence that this realisation produces enables her to deal with the powerful conflicts that plagued her initially and to relax the tacit leaning towards knowledge transmission evident so strongly in the first few months of the inquiry.
This sense of a developing harmony between approach to science teaching and general beliefs about appropriate pedagogy can also be seen with Heather and to a greater degree with Elizabeth. Heather initially conceives of science as an almost formulaic hypothetico-deductivism, reflected in her attempt to impose a set method on the science work in her class. At the same time, however, she holds strong beliefs that children should be encouraged to develop their ability to inquire and to work independently (see Portrait, appendix 9). Her decision to focus on questioning can be seen to relate to these beliefs; in a science practice so lacking in focus and confidence, one of the few things she feels she ought to be doing is helping children raise and explore ideas through her own questioning. As the inquiry proceeds, she begins to derive for herself an understanding of science teaching that allows her to identify links between the nature of the subject and her more general aims of developing children’s inquiry. It is clear that when this starts to happen, she also starts to become more confident (post lesson reflective discussion 15.11.95). The initially unconnected and only partially conceptualised elements of hypothetico-deductive method, constructivist development of children’s ideas and the importance of her own questioning in the promotion of their learning, begin to link together, forming an approach to her science teaching that has clear potential in terms of encouraging children’s independent learning (post lesson reflective discussion 12.6.96). The strong tacit message within her teaching that science is primarily about learning facts has given way to much more exploration. She justifies this as science through a new understanding that such exploration is an integral feature of the hypothetico-deductive process she always wanted to impose in her classroom. Her tacit focus on the learning of knowledge has been changed into a legitimate focus for her teaching through the interplay of scientific process and her constructivist understanding. Her position is probably still realist, but her ideas about the tentative nature of knowledge that she indicated on her first bi-polar scale fit much more easily into the overall picture. She has found a way of teaching the subject that not only accords with her wish to incorporate pedagogical strategies which promote inquiry, but that also coincides with an aim that drove her as a teacher: the development of children’s
independence. She now has the chance to unlock the children's 'secret doors' (questionnaire response) in this element of her practice.

Elizabeth's progress towards this sense of agreement is perhaps the strongest of the three teachers, yet there is never the stark insecurity or denial that is found in Carol or Heather. Perhaps because of her maturity in the profession and most probably because of her intense commitment to teaching and children's education, she is never at a loss when it comes to what to teach and is strongly enthusiastic right from the beginning. Yet there is profound change in her thinking and practice over the course of the inquiry. She is insecure about her science teaching and, despite her strong espoused ideas about the subject, the tacit understanding evident in her practice that science is a body of knowledge to be learned generates considerable tensions with her beliefs about the way young children should be taught. She is passionately interested in the potential that education has to change lives, placing the development of children's thinking and the promotion of children's life skills as the central pillars of her educational aims (see Portrait, appendix 9, questionnaire responses, appendix 8). As with both Carol and Heather, it is not until she can see links with these aims that she starts to develop confidence in her science teaching. This confidence begins to develop quite early, as she quickly recognises the potential for the promotion of thinking within what the children are doing. Applying a strategy of observation and sorting that she is confident with in mathematics, she is able to explore how her initial hypothetico-deductive understanding has meaning within her practice and how the inductive processes she is using might link with it. As with Heather, she holds a constructivist perspective on children's learning and there is the suggestion that, as she develops an understanding of the relationship between constructivist approaches and elements of knowledge generation in science, her tacit understanding that science is a body of knowledge becomes legitimated (interview 16.7.96). At the same time, however, her understanding is changing. She still holds a realist conception of the status of scientific knowledge, but the drive for this knowledge to be transmitted is going (interview 26.3.96). Her understanding of the nature of knowledge in science is changing. She is seeing it as more provisional (interview 16.7.96, comparison of bi-polar scales, appendix 7) and this provisionality enables her to
recognise how she can legitimately encourage children to explore, think and change their understanding as they carry out their science work. Slowly, the tacit understanding fades, to a situation in which knowledge is still the focus in her practice, but it is generated knowledge rather than received. As this is occurring, the sense of reconciliation between her science practice and her central values is overwhelming. Her enthusiasm, always strong, is now bubbling over (post lesson reflective discussion 6.6.96). She can now locate what she is doing within her general aim of promoting life skills and her new teaching approach is enabling her to bring together the tacit and espoused elements of her initial understanding so that they both contribute to this aim. Resolution of many of her tensions is apparent; the strength of the resolution derives from the accommodation of her science work within her beliefs about appropriate pedagogy. There is a resonance between the two; the fact that her reflection and research has enabled her to generate a coherent understanding of science and science teaching that can be located within her general pedagogical approach, in turn legitimates this approach. This brings a further intellectual justification for the position she has adopted. It is important to recognise, however, that it is her science teaching and her understanding of the nature of science that has changed over the course of the inquiry, not her beliefs about the way children should be taught.

With regard, therefore, to the question of whether it was possible for these three early years’ teachers to hold a position in which their espoused understanding of science was congruent with the approach they generated in their teaching, it can be said that it was. However, this congruence was not a feature of the teachers’ normal practice before the inquiry took place; it needed the time and support of the inquiry. It is interesting to examine a little further the process through which this development took place.

To reiterate the main elements:

1. Initially, the teachers' tacit understanding had more effect on their practice than their espoused ideas.
2. The categories the teachers used to describe their espoused understanding of the nature of science changed little over the course of the inquiry, but their interpretation of those categories changed considerably.

3. The teachers were strongly influenced by the process of their action research to appraise their espoused understanding of science and to explore its implications.

4. The teachers' general beliefs underlying their understanding of the way their children should be taught, remained constant over the course of the inquiry. However, their understanding of how these beliefs might appear in practice was subject to change (see Carol in particular).

5. The teachers showed real confidence in their teaching of science when the approach they adopted accorded with the spirit of the beliefs which influenced their understanding of what constituted appropriate pedagogy for their children.

6. The fact that this approach to science teaching had been generated through rigorous inquiry and intellectual rationalisation, strengthened their confidence in both the approach itself and their beliefs about appropriate teaching, with which the approach now accorded.

7. The teachers' tacit understanding was no longer a strong influence on their practice by the end of the inquiry, but its essence could be recognised within their new approach.

The Key Stage 2 teacher - Andrea

Andrea certainly does not show the level of resolution at the end of her inquiry that is indicated by the three early years teachers. She begins with an apparently quite firm conception that science is characterised by curiosity and a hypothetico-deductive process of prediction and testing, the purpose of which is to provide knowledge in the form of explanation. Unlike the other three teachers, it can be seen that there are links between this espoused understanding and her practice; these ideas translate into teaching which emphasises the application and testing of the children's ideas. Her comments indicate a strongly realist epistemology and, although she wants children to be happy with uncertainty and provisionality in their science work, it appears that this is because she wants them to
learn the right answers and not hold on too firmly to alternative explanations. She is, however, a new appointee to the school, the science co-ordinator and in charge of a Year 6 class approaching SATs in the summer term. These facts must not be ignored, for it is quite possible that the pressures they produce could be linked to this initial preoccupation with knowledge. Indeed, soon after the children have taken their SATs, she begins to discuss her dissatisfaction with the curriculum pressures upon her and the difficulties she finds in the promotion of meaningful learning in the context they produce (analytic memo 11.6.96). It is only now that her beliefs about the aims of her teaching and how she should teach begin to become properly apparent, although she hinted at her overriding wish to promote children's generic thinking skills when talking about her practice just before Easter (interview 26.3.96).

It is not until after the SATs have finished, therefore, that Andrea’s action research truly starts. Once it does so, strong elements of change move her towards a situation where an important dilemma exists within her practice at the end of the inquiry. The change starts as wider concerns begin to become apparent in her justification for her science work. She begins to relate her science to her overall accountability to the children. This translates into a concern about what she can do to best help the children prepare for their next class, especially if their new teacher is going to have a different conception of science from her (interview 16.7.96). She wants the children to succeed. Initially, she interprets this as a need to ensure that the children reach the right answers through their practical work; this attitude possibly explains why her hypothetico-deductive methodology has up until now been handled as a means to a predetermined end.

By the autumn term, however, this conception has begun to change. In a different class, a year younger in age, she seems to find the space to explore her teaching more, despite the fact that she also has to help prepare the school in the approach to Ofsted inspection. She can be seen to be searching for meaning within her science teaching. It is clear that she judges whether it is present not only through her developing understanding of the subject but also by the same criterion of what will help the children later in their schooling (interview 17.12.96). This wider belief about the purpose of teaching is therefore
exerting a powerful influence on the way she looks at her science practice. This thinking
takes her to a position where she becomes convinced that the National Curriculum structure
as she interprets it is not helping children. It has too great a demand for knowledge and too
little space for the development of children’s transferable thinking skills (interview
17.12.96). She has always considered that science is the perfect place to encourage thinking
and, as she increasingly deconstructs her practice, it now becomes apparent that her
previous adherence to a formulaic hypothetico-deductive process might also have been
motivated by this aim. She may have assumed that the imposition of a rather rigid method
would guarantee thinking took place, even though the children were being encouraged to
move towards discovering the answers she wanted them to. Now, however, as she
develops more exploratory, inductive processes with the aim of letting the children generate
their own ideas, she begins to run into a powerful dilemma. At the same time as this core
belief that the promotion of inquiry and thinking should be central to her practice encourages
her to explore the potential of these inductive processes, her continuing attitude towards
correct scientific knowledge tells her that leaving knowledge generation to the children may
have dangerous consequences, if one is not allowed to tell them they are wrong (interview
17.12.96). The understanding of science she is developing is trapped in a dilemma
generated by two potentially incompatible elements of her beliefs about the aims of her
teaching: that children need to feel a sense of success and that teaching should also be
promoting their capability to question and think.

Andrea leaves the inquiry, therefore, in a state of flux. Her understanding of science
has become increasingly tentative, a position emphasised by the fact that she now places
eight out of the fourteen categories on the mid-point of the bi-polar scale. She has certainly
modified her practice in accordance with her beliefs, but her dilemma is too deep to assume
at this point that it will resolve itself into the confidence shown by the early years teachers.
She is beginning to conceptualise two kinds of science, one on each side of the dilemma:
public knowledge and personal inquiry. Personal inquiry can be provisional and tentative,
with no end point, but it is not for most people. Public knowledge is fixed and needs to be
learned.
Andrea feels a strong need to clarify her dilemma and identify purpose within her science teaching. It is conceivable that if she continues her reflection - and the strength of her involvement at the end of the inquiry gives every indication that she will - she may reach a resolution. It is likely that this may only occur if she reduces the tensions within her educational aims.

3) The significance of the teachers’ epistemological understanding

The discussion in appendix I highlights the range of possible philosophical positions within the subject of science. Methodologically and epistemologically it can be seen that its nature is complex and open to debate. The teachers had no direct access to these ideas through the inquiry, except through their own reading (see Elizabeth in particular) or possibly through casual discussion with the researcher. This was at a minimum level, but it is acknowledged that it took place. If the researcher is thought of simply as a resource, as is a book, then on one level it is illogical to suppose that discussion with him was any more significant than any other form of study the teachers may have undertaken. It must, however, be acknowledged that the researcher may have promoted a biased perspective on the nature of science. This could be significant, but it would appear that the teachers recognised the success of their science teaching through a range of criteria which were individual to each, and ultimately through whether they felt confident in it. The final arbiter of this feeling was not the understanding of science they held, but whether their actions accorded with their beliefs about appropriate pedagogy. There were commonalities in these beliefs between all three teachers (see table 4), but they were individual to each.

It is therefore most probable that the teachers were never likely to do more than choose an understanding of methodological or epistemological aspects of science that accorded with their existing beliefs about how they should teach children. It is difficult to think of any other explanation, for whilst their understanding of science and science teaching could be seen to evolve, their broader educational beliefs did not change. This implies that, during their action research, their reflection on the nature and purpose of their science teaching was affected continually by tacit criteria. This, however, is a perfectly
logical state of affairs. Science deals with knowledge and ways of making knowledge. To teach science entails the adoption of an epistemological position towards that knowledge, whether it is held tacitly or clearly espoused. The adoption of such a position is the stuff of teaching. A teacher's continual preoccupation is her children's position relative to the knowledge she has to teach, whether that knowledge is conceptual or procedural, creative or aesthetic, scientific, historical, musical or concerned with general life skills. As she adopts a position towards this knowledge, she applies, consolidates or generates central principles regarding its relevance to children and the way they should experience it. These processes give rise to a series of fundamental aims for her practice. Her science teaching, therefore, deals with the same issues that are central to all her pedagogy and the beliefs that underpin it; it is bound to be affected by them. It is logical to conclude that a teacher will feel confident in her science teaching when there is a resonance between the epistemology she adopts within it and that which is implicit within her beliefs about how children should be taught.

A further consequence of this close association is that change in one area may effect change in another. Elizabeth hints that her thinking regarding planning in science may be exerting an influence elsewhere and Carol begins to relate her epistemological understanding in science to her general perspective as a Reception teacher. Again, this is not surprising, for although all three teachers initially consider science to be something separate from the rest of their practice, epistemological issues are universal.

Andrea's dilemma at the end of her inquiry raises questions about the relationship between the teachers' epistemological positions and the nature and complexity of the tensions in their practice. In common with Elizabeth and Heather, she communicates a predominantly realist perspective on scientific knowledge, in which she appears to understand that the body of knowledge science has produced is, in some way, a direct though as yet imperfect representation of reality. On the other hand, Carol's position appears to be more relativist, with much greater emphasis put on personal construction, provisionality and the sense that reality is ultimately unknowable, although her tacit position that science is a body of knowledge to be learnt is in conflict with this. It is interesting to reflect, therefore, that Carol, Elizabeth and Heather all adopt a similar position towards
knowledge generation within science sessions; there is a potential tension between a realist position and the idea that children can be generating their own knowledge. This tension haunts Andrea towards the latter stages of her inquiry. Interestingly, however, what is strongly evident in the way Elizabeth and Heather resolve their teaching is their increasing ability to hold both perspectives at the same time, raising the suggestion that they might, quite consistently, be able to hold two differing epistemological positions simultaneously, depending on the context of their reflection. It is, however, perfectly consistent for a teacher to espouse a realist perspective on knowledge when asked to comment on the body of scientific understanding and yet proceed pedagogically to promote relativist strategies within the classroom. As the evidence of the studies shows overwhelmingly, the teachers' overriding focus is their practice, not philosophical reflection on the nature of science. Time after time they respond to direct questions about the latter with examples from their teaching, seemingly unaware that reflections on science education may be different from reflections on science. Yet this, and the possible contradiction it may suggest, is understandable; teaching is their main focus and, when considered from the perspective of children's development, relativist strategies may be eminently appropriate in giving children the wherewithal ultimately to understand the nature of that knowledge the teachers understand as real.

4) Summary

The main research question concerns the nature of the relationship between teachers' espoused understanding of the nature of science and their practice. The evidence of this inquiry indicates that a simple direct link does not exist. The appearance in teachers' practice of an apparent influence from their understanding of science cannot be understood without consideration of the teachers' beliefs about the aims of teaching, how children learn and how the curriculum should be structured, and what constitutes appropriate pedagogy. This finding endorses the claim by Lederman and Zeidler (1987) or Duschl and Wright (1989) that direct transmission from epistemological understanding about science to practice does not occur. However, rather than a mediation of epistemological understanding by
situational factors, it suggests that the determining influence is personal to the teacher. The following summary highlights the main findings of the study:

1. In the case of the three early years teachers, their espoused understanding of the nature of science did not at any time appear to exert a direct causal influence on their choice of strategies and approach for the teaching of science.

2. There was a minor degree of agreement between the Key Stage 2 teacher's espoused understanding and practice at the beginning of the inquiry.

3. There was some initial agreement between the teachers' tacit conceptions of science and their practice.

4. The process of the inquiry enabled the teachers to develop their understanding of how to teach science.

5. As they did so, the determining factors in their choice of teaching approach were the beliefs they held about children, curriculum and the nature of appropriate pedagogy, not their understanding of the nature of science.

6. This led to a situation where the teachers chose from their espoused ideas about the nature of science elements which would support the teaching approaches they had adopted. This frequently involved a reinterpretation of the meaning of those ideas about science.

7. The teachers acquired a confidence in their science practice only when there existed a resonance between their ideas about how to teach science, their understanding of the nature of science and their general beliefs about how they should be teaching children.
8. In other words, the direction of influence ran first from beliefs about children and curriculum to choice of teaching approach and then to the understanding of the nature of science. It follows that these beliefs, and teachers’ consequent understanding of what constitutes appropriate pedagogy, may have a controlling influence in the development of teachers’ understanding of epistemological issues in science.

9. It may be concluded that overtly similar ideas about the nature of science may link with different forms of practice, depending on the character of the teachers’ beliefs. It is not possible to form a generalisation which allows safe prediction of the character of a teacher’s approach to science from the evidence of her espoused understanding of the nature of the subject.

10. The teacher’s science practice can therefore be seen to be driven by educational, not subject specific, criteria.

These findings are tentative, but it is argued that they strongly grounded in the data. The following chapter will proceed to discuss their implications for science teaching and the development of teachers’ understanding and confidence with the subject.
Chapter 7

DISCUSSION

This inquiry has attempted to shed light on the nature of the relationship between teachers' understanding of the nature of science and their practice (action in the classroom and the thinking that informs it). It has explored the supposition that the former exerts a determining influence on the latter and it contributes to an understanding of the means by which teachers' espoused ideas about the nature of science appear in their teaching. It has taken place at a time when a model of the direct transmission of teacher knowledge into practice appears to be prominent within official and related literature (DfEE 1998), a model which generates a context relating to any discussion of the implications of the findings. This penultimate chapter aims to carry out such a discussion, beginning with a review of the suitability of the methodology and the possible limitations of the study, then considering the significance of the findings in connection with six further key areas:

- the direction of influence between understanding and practice;
- the significance of the age phase within which the teachers work;
- the nature of teacher knowledge;
- the affective nature of teachers' beliefs;
- change in teachers' beliefs;
- the structure, content and purpose of the science curriculum.

Following this discussion, the thesis will conclude with a brief chapter which highlights key recommendations for action.

1. Implications for methodology and some key limitations of the study

The identification of levels of complexity within the teachers' practice validates the methodological stance adopted within this study. Throughout the last decade there has been
a steady recognition that exploration of the relationship between teachers’ understanding of the nature of science and their teaching needs more than simple paper and pencil tests and quantitative measures (Lederman and O’Malley, 1990; Brickhouse, 1989, 1990; Gallagher, 1991; Nott and Wellington, 1996; Laplante, 1997). Nott and Wellington (1993) highlight how the results of a simple ‘snapshot’ of teachers’ ideas change on subsequent repetition of the test, indicating that teachers’ levels of understanding of their own ideas is insecure. This study supports this perspective, indicating that primary teachers’ science practice exists as the result of the interplay of a variety of factors, including their understanding of science, both tacit and espoused, their understanding of science pedagogy and their general beliefs about children, education and what constitute appropriate modes of teaching. Furthermore, it demonstrates that teachers feel confident in their science practice only when there is a harmony between all these factors.

The recognition of this complexity raises at the same time a strong implication for future research and a key limitation of the study. Whilst the methodology was designed i) to help teachers have the opportunity to reflect on science, ii) to enable identification of the teachers’ tacit knowledge in action and iii) to explore the dialectical relationship between their ideas and their action, it did not at the outset acknowledge the seemingly crucial importance of teachers’ beliefs in the identification and application of teaching strategies. A greater focus on the nature of the teachers’ beliefs about the aims of teaching, how children learn, how curriculum should be structured and the nature of appropriate pedagogical strategies and approaches would have yielded more detailed results for analysis. Interest in these beliefs developed as their potential significance emerged during the course of the inquiry. Only one instrument, the questionnaire, was designed specifically to access them; much more data could be collected if future research in the area began with a recognition of their importance and incorporated a more thorough and systematic approach to their identification. Indeed, it is logical to suggest that any future inquiry into the significance of teachers’ understanding of the nature of science must have cognisance of the effect of teachers’ beliefs in the above areas on their practice.
Three further implications for methodology are suggested by the current study. Firstly, in order to be able to identify teachers’ beliefs and to enable the dynamics within practice to become clear, it is important that research does not take the form of a snapshot. The experience of this study is that the underlying relationships between elements of the teachers’ practice only emerged after long involvement and detailed observation and discussion. Secondly, methodology must have regard to the fact that teachers’ espoused understanding of the nature of science is frequently not present in their usual practice. This practice may be replete with tacit messages about science which are very often different from espoused positions. A chosen methodology must allow for the identification of these tacit messages. Within this study, the promotion of action research by the teachers presented an opportunity for these tacit messages to be explored and provided a research timescale that allowed for change in the teachers’ practice to take place. This last feature is the third suggestion: a methodology which is exploring practice should allow for the possibility of change over time. Practice is dynamic; it therefore varies from day to day and hour to hour. This realisation must pervade any attempt to understand it, for it is paradoxically within the dynamics of the changes which inevitably occur in practice that insight into the factors which control those changes lies.

In addition, any analysis will be problematic. The study has endorsed Lakin and Wellington’s (1994) findings by showing that teachers do not readily discuss epistemological issues. When asked direct questions regarding the nature of science, teachers frequently respond by discussing examples of their teaching. Their use of vocabulary can therefore sometimes be confusing. A term such as ‘discovery’ has a specific epistemological significance, but when teachers use it to describe children’s actions in the classroom they frequently equate it with open exploration. This feature, that vocabulary can carry a different meaning depending on its context, presents an obvious potential for error in analysis.

This study is based on a sample of only four teachers. This is a small number from which to be attempting generalisation. Further research which attempts to repeat or extends this study is needed. However, following Hamilton (1981), generalisations are offered as
ideas to be explored, not as claims to truth. The propositions underpinning the following
discussion are therefore tentative; more exploration of teachers’ practice is required.

2. The direction of influence between understanding and practice

The research for this thesis offers little support to the contention that there is a direct
translation of teachers’ understanding of the nature of science into their practice. Indeed,
before the teachers were given the opportunity for prolonged and focused reflection on the
character of their science teaching, only Andrea’s practice seemed to demonstrate any
elements of general agreement between espoused ideas and the messages inherent within her
classroom action. The space afforded by the study seemed to allow an agreement to develop
subsequently in all four teachers, but the apparent lines of influence within that agreement
suggest that a reconceptualisation of the overall relationship between teachers’ espoused
ideas about science and their practice should be continued.

Lederman (1992) has faith that ‘each line of research (in this area) is but a piece of a
much larger puzzle’ (p.351). However, this puzzle appears to have no set picture on the
box. What picture there is seems to change with successive inquiries, especially over the last
decade. Writing in 1992, Lederman identified how his own and other research was showing
that the situation was one of increasing complexity. Despite this, he appeared to have a faith
that research would eventually reveal a unifying answer to the complexity. Subsequent
research however is beginning to identify many more potential factors at work, including the
significance of teachers’ individual lives. It is hinting that there might not be a single picture
on the box at all.

In the terms of Lederman’s metaphor, this study suggests that, at the very least,
research may have been looking at the picture the wrong way. It has been upside down. The
intuitive appeal of the proposal that ideas affect practice has dominated analysis of the
relationship between teachers’ understanding of the nature of science and their teaching. The
presupposition that the existence of a relationship must mean a causal influence running
from understanding to action has been strong. Although successive research studies have
shown that it is extremely difficult to identify such a direct influence, the assumed direction
of causality is still apparent in the interpretation that teachers' ideas are being 'mediated' by other factors (Lederman, 1992; Mellado 1998). This interpretation does not explain the results of this study. Its methodological emphasis on the observation and analysis of practice through the teachers' action research has given access to other chains of influence within the development of teachers' action. For the teachers in this study, thoughts about the nature of science and ways of teaching were initially largely separate elements; when linkages began to appear it was because the teachers had moulded (or at least selected from) their understanding of science to fit their practice and not the other way round. When their understanding of science appeared in their teaching, it was because they had recognised a potential within that understanding which supported their idea of the right way to teach science. It was not because the understanding itself exerted an influence which needed to be accommodated in what they did.

Crucially, this study suggests that the central influences on the teachers' practice were the beliefs they held about pedagogy in general. It was these that were the guiding criteria by which the teachers decided whether a session or a teaching approach was appropriate; it was these that provided the determining factor in the development of the teachers' understanding that an approach to teaching science was 'right'. Far from being a controlling factor in their action, this study suggests that teachers' espoused understanding of the nature of science may lie at the end of a chain of influence in which it is, surprisingly, the least important factor.

It is possible to find interpretations in other research which, although they do not go so far as to suggest the line of influence claimed here, lend support to the reasoning behind the supposition. There are, for example, tantalising references in both Abell and Smith (1994) and Gustafson and Rowell (1995). Abell and Smith state unequivocally that they believe their 'students' views about the nature of science are closely tied to their beliefs about teaching and learning' (p.484). However, they focus on beliefs about learning science, without probing to see whether there may be underlying beliefs about how children should be taught which may be determining these. Gustafson and Rowell go further, eliciting their students' understanding about the general question 'what it means to learn'.
and conclude that prior ideas about the way children learn can exert considerable influence on the levels of thinking and restructuring of concepts that students will experience on a teacher education programme. They found that for many students there was very little change in their ideas about teaching and learning over the course of their training. Students would choose those aspects of the ideas they were encountering that agreed with their prior alignment towards the purposes and nature of education. Gustafson and Rowell relate these findings to those of Hollingsworth (1989) and Calderhead (1989), both of whom proposed a similar position, with Calderhead suggesting that this alignment is ‘highly influential in shaping what student teachers extract from their preservice training, how they think about teaching, and the kind of teacher they become in the classroom’ (1989 p.47, in Gustafson and Rowell, p.599).

This study therefore adds to understanding of the complexity of the dynamics within a teacher’s science teaching. It suggests that analysis of teachers’ action in this area should in future look both ways; it must look towards the teachers’ espoused understanding of science, but also towards their beliefs about children’s development, curriculum and appropriate pedagogy. The latter perspective is implicit within a few studies, but is generally lacking. This is somewhat surprising, given the strength of the work carried out in the field of teachers’ beliefs over the last two decades (for example, Nias 1989, Woods 1995); it is as though science education has yet to recognise fully their significance. Even some recent work in the field (Meyer et al. 1999, Murcia and Schibeci 1999) virtually ignores the area, with the acknowledgement by Hogan (2000) of the potential importance of beliefs in the development of a person’s attitude towards science being still relatively unusual. This phenomenon may derive from the imponderable nature of beliefs and their potential immeasurability; the idea of determining factors lying within an unpredictable and non-reducible area of human experience sits uneasily with traditional interpretations of scientific method. Yet it must be clear that the pursuit of science education is not the same as the pursuit of science. Despite the acknowledgement that personal beliefs and prior orientations cannot be eradicated from scientific inquiry (see appendix 1), it is possible (and, indeed, a fact) for practising scientists to continue their work as if they did not exist. They rarely need
to enter the philosopher's world of uncertainty and argument. However, science education is different. It is not simply education in science, it is education about science. Study of education inevitably plunges the researcher into the complexities of human interactions and the thoughts, feelings and beliefs that surround those interactions and imbue them with meaning. It is important that the study of science education acknowledges this. Teachers' science practice will lie within this complexity. Practice itself consists of action and the understanding that informs it; this study suggests that beliefs play a significant part in that understanding. The danger inherent in many studies of teachers' science practice is that they underestimate the complexities of the situation by applying a hypothetical causality unproblematically.

3. The significance of the age phase within which the teachers work

In Chapter 2, it was suggested that comparison of the studies of teachers' understanding of the nature of science is difficult, given the wide range of their focus. Many concentrate on secondary teachers, some on primary and a significant number on students. Some merely state the nature of teachers' understanding; others consider possible relationships with practice. Despite its best intentions, this study became focused on a sample of teachers which was strongly biased towards the teaching of infant children.

Indeed, both Elizabeth and Carol taught Reception classes, containing children who were not yet involved directly with the National Curriculum. Heather was teaching either at Year Two or Year One. All three considered themselves to be 'early years teachers'. In these circumstances, it is worth considering the possibility that the age focus of the teachers might have constituted a factor affecting the strength of the influence between beliefs and ideas. It can certainly be seen that, although Andrea became locked into a dilemma which was a direct result of potential incompatibility in her beliefs about the aims of her teaching, her case also differs to an extent from the other three. She was a teacher at upper Key Stage Two. There was more congruence between her understanding of science and her practice at the outset and it is possible to interpret her initial situation as one in which lines of influence from knowledge to practice were evident.
If this variation constitutes a significant difference, the model being proposed by this thesis would imply that the early years teachers may have had beliefs which were more powerful determinants of action than Andrea's. This is not the same as saying that Andrea's beliefs did not affect her practice; they evidently did. What it does suggest is that the early years teachers may have had beliefs about children and their learning which formed a more coherent centre to their professional lives and which therefore enabled a clearer sense of progression to occur within their personal inquiries.

The ideology of early years teachers (Nursery, Reception and Key Stage 1) is historically very strong. It is founded on beliefs about children which have distinctive implications for the education of the very young and which have been increasingly under threat since the imposition of the 1988 Education Reform Act. These beliefs, centred around the notion of child-centred education, pervade Nurseries and the Key Stage 1 sections of primary schools. The idea of child-centred education itself, deriving from key ideas established and developed by Rousseau (1762), Pestalozzi (1802), Froebel (1826, 1840) and Dewey (1916) amongst others, slowly became influential in Britain during the first half of the twentieth century (Darling 1994, p.2). Rousseau rejected the contemporary view that children were to be treated as little adults, claiming that children passed through various stages of development. It was appropriate for the content of teaching to be determined by an understanding of the child's nature at each particular stage. These ideas were extended by Froebel's focus on the importance of play in the growth of a young child's knowledge of, and orientation in, the world and Dewey's emphasis that the child should be at the centre (Dewey, 1900, p.51) of an educational process which strove to promote the active engagement of the child in learning through shared activity. By the 1960s, the amalgam of these ideas had led to powerful conceptions of child development, pedagogical aims and curriculum for young children. These offered a focus for teachers dissatisfied with traditional approaches to primary education which were promoting knowledge transmission and a systematic progress from the 'basics' of literacy and numeracy to instruction in a narrow band of school subjects. Children were to be treated as individuals; through an awareness of child development, their growth was to be aided by a teacher as facilitator, not
governed by a teacher as instructor. Children were to be active within the classroom; their learning was to enable them to generate meaning and a link between the experience of school and the outside world. Project or topic work was common. These perspectives finally achieved public endorsement through the Plowden Report (CACE, 1967) for England and Wales and the Primary Memorandum (SED, 1965) for Scotland, but the strength of the growing educational philosophy within primary schools had also been noted within the Hadow Report (1931, Consultative Committee, Board of Education) some thirty five years earlier:

The primary school has its own canons of excellence and criteria of success; it must have the courage to stand by them.

(p. xxvi, cited in Darling, 1994, p.viii)

For Nursery teachers, the necessity for a distinctive early years curriculum and pedagogy was emphasised further by the work of Donaldson (Donaldson, 1975), who considered the 'embeddedness' of young children's thinking. Donaldson's major argument was that young children are capable of significant cognitive achievement when presented with problems or questions set within situations that are familiar to them. In the 'disembedded' situation of formal and abstract thinking, young children will fail. Dowling (1995) describes how Dowling and Dauncey (1984) showed that, given the embedding of a task within a familiar setting, even children as young as two could learn much that was thought beyond them (Dowling, 1995, p. 65). These findings supported the view that a special kind of curriculum is appropriate in the Nursery or infant class. Following Dewey, it should be integrated and pursue learning in a holistic way, because young children are 'continually making connections between the knowledge they have acquired in the different domains and do not need to distinguish learning by subject area' (Little, 1995 p.43). In the changing climate of the nineties, infant and Nursery teachers have been the last to abandon the much-derided sections of the Plowden report which tried to apply such integrated thinking to the whole of the primary school (see, for example, paras 535, 540, 542, 539). These beliefs in integrated learning have formed a central core of pedagogical thinking, establishing a distinctiveness between the approach in Nursery, Reception and early Key Stage One classes and the rest of the primary school (Edgington 1998, ch. 6). They have
given rise to the conceptual (if not substantive) difference between the National Curriculum and the Desirable Outcomes for Children's Learning on entering Compulsory Education (SCAA 1996) or the new Early Learning Goals (DfEE 2000); they have underpinned the continuing child-centredness of curriculum approaches for under-fives, even when they are dealing with identifiable 'subjects' in National Curriculum terms (Siraj-Blatchford and MacLeod-Brudenell, 1999, pp.54-56).

The effect has been to create a common set of beliefs amongst the teachers of young children that is coherent and resistant to change. This set of beliefs inevitably has the potential for affecting the teachers' attitudes to the imposition of new curriculum initiatives. The understanding that learning needs to be embedded in children's experience, the drive to establish in the classroom what Dowling describes as the 'human setting' for children's tasks, can affect early years teachers' responses to formal structures for the control of curriculum. The National Curriculum and even the character of the 'Desirable Outcomes' are frequently seen as removed from the reality of the children's life world. They are considered inappropriate, consisting of disembedded, abstracted goals divorced from an integrated, child-centred vision of children's needs. In this study, Carol's wish was for a holistic curriculum for her Reception class; Elizabeth wanted the focus of her teaching to be on facilitating the 'emergence' of children's understanding and the development of their self esteem and life skills. Both saw curriculum as developing from the children's experience and needs, not as an imposition from outside (Edgington, 1998 p. 98). In the eyes of these teachers, the reductionist structure of the National Curriculum lacked relevance for the children in their classes.

These kinds of attitudes amongst early years teachers can be seen frequently to transfer to the perception the teachers have of their place in a primary school. It is common for them to see themselves and their work as different from the rest of the school. What may work for older children will not work in their classrooms. Such a difference in perception was enshrined in the historical distinction between 'infant' and 'junior' elements of a primary school; it has been continued, albeit in a lesser form, in the present separation of Key Stage One and Key Stage Two. The identification of a separate 'Key Stage' of
education for children aged five to seven implicitly suggests that children and their learning are to be viewed differently within it. Teachers of the early years use this implicit suggestion to legitimate the application in their work of their beliefs about children and pedagogy.

Given the strength of this historical perspective within their work, it is perhaps unsurprising that the three early years teachers appeared to develop an accord between their beliefs and their science practice more readily than Andrea. Given the thesis that the teachers chose approaches in their science teaching which accorded with the underlying beliefs which determined what they considered to be appropriate pedagogy, then it is likely that those teachers with the most cohesive beliefs would show the most confident progression towards such teaching. Once the support of the inquiry had freed them from their insecurity about science, Elizabeth, Carol and Heather all show much steadier progression towards an accord between beliefs and teaching approach than Andrea. Moreover, the evidence that these beliefs were perhaps most strongly influential in the cases of Elizabeth and Carol is also predictable. Both were Reception teachers and each commented on the freedom they felt because they did not have to teach the National Curriculum. There was less for them to overcome in reaching harmony in their teaching than Heather, who had to follow the National Curriculum in her teaching of Year Two or Year One. In Andrea’s case, she does not make the same progress towards agreement as the infant teachers. Her development is more insecure. Once she has been freed from the restrictive influence of revision for Year Six SATs, she can be seen to be moving towards an accord with her underlying beliefs, but the beliefs themselves are not conveyed with the same assuredness as Elizabeth or Carol. There is less coherence and thus, presumably, less sense of a defining understanding of appropriate pedagogy.

It may therefore be possible that the strength and coherence of the belief system of early years teachers in terms of the way children learn and how best to teach them, renders their science practice and, ultimately, the epistemological understanding of science they recognise in their teaching, more susceptible to determination by these beliefs. As is demonstrated by the case of Andrea however, this does not imply that the same line of influence is not present in teachers of older children. It is, perhaps, a matter of degree and
much will depend on the strength of individual beliefs. Andrea had been teaching for little more than two years. Coming from a non-teaching background, it is not surprising that her beliefs may have been less strong or coherent. Although Carol was also only in her third year of teaching, her contact with the belief system of the early years was ensured not only through her experience during initial training, but also in her previous work as a playgroup leader. She, therefore, was steeped in the rationale for holistic education; Andrea was still developing her beliefs. It has been noted above that other studies of primary or elementary teachers have hinted at a similar interpretation of teachers’ action. There is, however, little support forthcoming from studies with a secondary focus. Yet if the thesis has validity, a similar influence must be present there. Guiding beliefs presumably do not switch off when teaching Year Seven or above.

The answer may well lie in the possibility that secondary teachers hold a less coherent set of beliefs than those at the upper end of primary schools. In a different phase of education, dominated by the epistemology of separate subject teaching, they have not been subject to the same normative implications of whole-phase recommendations, such as were included in the child-centredness of the Plowden report. Their understandings of pedagogy have been dominated by the mechanics of subject study, a factor which perhaps explains the orientation of research in science education already mentioned. The majority of studies have concerned secondary teachers and teaching. The result of these factors may be that secondary teachers of science hold weaker ideas about the nature of children’s learning than their primary colleagues. If this is the case, then it is quite likely that influences from other directions, including their understanding of the nature of science, will perhaps be more operational in their teaching. There may, however, be another important factor. It seems logical to assume that although there may not be the strength of beliefs about children’s development within the subject tradition of secondary teachers, their experience in the job will develop them. Individuals with ten years’ experience are more likely to hold strong beliefs about the way children learn and how they should be taught than those who are newly qualified. It is also likely that these beliefs will begin to carry normative assumptions about children per se, and not simply relate to children’s learning within the subject.
If this is so, then a reconceptualisation of secondary studies may be possible. This is largely beyond the scope of the current discussion, but a consideration of Brickhouse’s (1989, 1990) inquiry may serve as an example. Arguing strongly for a link between a teacher’s understanding of science and the character of her practice, she describes her two experienced teachers as operating:

from a consistent, self-reinforcing belief system. Their classroom instruction was remarkably consistent from one day to the next, and they expressed personal philosophies that were congruent with their actions in the classroom. The teachers’ understandings of what science is and how students learn science in schools formed a consistent system of beliefs for guiding classroom instruction. (p.60).

In contrast, her third teacher, newly qualified, was ‘unpredictable’, with classroom instruction which was ‘variable and could not be predicted from interview data’. Brickhouse considers that this teacher ‘had not reconciled his own conflicting beliefs or the impact of institutional constraints on his teaching’ (p.60). Although Brickhouse herself clearly thinks that influence will flow from syntactical ideas into practice through the development of pedagogical content knowledge, her evidence does not preclude an alternative, or at least additional, interpretation. It is possible that the consistency enjoyed by her experienced teachers has derived from the resonance they now feel between the core beliefs about children and teaching they have developed and their understanding of how to teach science. The newly qualified teacher is in a state of flux because nothing yet seems to fit at all.

4. The nature of teacher knowledge

There is much general discussion regarding the nature of the knowledge a teacher needs and brings to bear as she teaches. The findings of the study relate strongly to this area. Shulman (1986, 1987) developed an initial theoretical analysis of the knowledge required by teachers to do their job effectively (1986) into a list of seven kinds of knowledge base for successful teaching (1987). In his model, teachers’ espoused understandings of the nature of science fall within the syntactical element of ‘subject matter content knowledge’. According to Shulman, syntactical knowledge enables teachers to ‘not only understand that something is so, (but) further understand why it is so, on what grounds its warrant can be asserted, and under what circumstances our belief in its
justification can be weakened and even denied' (Shulman, 1986, p.9, original emphases). However, the milieu within which syntactical knowledge is supposed to operate is complex; Shulman’s categorisation of six further kinds of knowledge operational within practice (in addition to the substantive element of subject matter content knowledge) is an indication of the difficulty that research has encountered in this area. The clear identification of the relationships between elements of knowledge and their pedagogical relevance has proved elusive.

The nature of this complexity, especially the constitution of Shulman’s category of ‘pedagogical content knowledge’ has become the focus of extensive research. Shulman originally included three different elements within this single category: i) the understanding of the most powerful ways of representing the syntactical and substantive elements of ‘content’ knowledge, ii) the understanding of why certain topics were either easy or hard to learn, iii) the conceptions that children have of those topics and bring with them to lessons. Subsequent research has explored the accuracy of this representation, revising and modifying Shulman’s original categories where necessary (Grossman et al. 1989; Gess-Newsome and Lederman 1995). Turner-Bisset (1997, 1999) extends Shulman’s list of seven categories to eleven, all of which, she claims, may interact to produce the pedagogical content knowledge a teacher may present (Turner-Bisset, 1997, p.384). This multiplication of categories reflects the growing realisation that it is meaningless to view a single element of a teacher’s understanding in isolation. Bennett (1993, p.7) considers that Shulman’s categories ‘undeniably cloak complexities and...artificially split knowledge bases’ and Turner-Bisset (1997) describes the interplay of the various knowledge ‘bases’ as a ‘dialectic’ (p.384). Turner-Bisset (1999) emphasises how it is difficult to distinguish between content knowledge and pedagogical content knowledge within teaching, as all knowledge is presented pedagogically. She highlights both Marks’ (1990) and Stones’ (1992) criticism that if pedagogical content knowledge is derived from other forms of knowledge, it is likely to be ambiguous and become a ‘matter of focus’ (p.42).

These descriptions of the complexity within and between teachers’ knowledge bases only serve as models for understanding teacher behaviour if they also shed light on the
kinds of influence between the various aspects of knowledge. They need to predict whether any of the different kinds of knowledge may be more important than others in determining a teacher’s actions. Shulman (1987, p.15) relates his knowledge bases to a cyclical process of pedagogical reasoning and action not unlike conceptions of action research or reflective teaching (Pollard and Tann 1987). Turner-Bisset (1997), recognising the existence of important elements other than ‘subject matter knowledge’, describes teachers’ action as being the result of ‘a tension, a push and pull between the content (the knowledge bases which combine to produce pedagogical content knowledge) and the processes, skills and beliefs’ (p.384). Both these conceptualisations highlight the complexity of the teaching situation but neither of them go as far as to claim overriding importance for one particular element. Turner-Bisset describes how a single element may have a determining effect on a teacher’s action, but she considers it equally likely for this element to derive from any of the four major aspects of content, processes, skills and beliefs within a teacher’s practice.

Within science education specifically, Nott and Wellington (1996, p. 286), note Koulaidis and Ogborn’s (1989) contention that teachers’ understanding of the nature of science changes with time and context. They suggest that the teachers' developing pedagogical content knowledge would influence it. Mellado (1998) considers that science teachers’ pedagogical content knowledge derives from the interplay of a wide range of factors which include prior values and beliefs. He claims their pedagogical content knowledge has a personal ‘dynamic’ component as a controlling influence which allows teachers to ‘reconsider their static knowledge and conceptions, and to modify or reaffirm them’ (p. 209).

The findings of this study take these thoughts further. They point to the likelihood that the beliefs which underpin teachers’ understanding about the right way to teach children may be the major factors influencing their practice. They suggest that the links within a teacher’s practice can only be understood if these beliefs are taken into account. With this interpretation, the influence of teachers’ subject matter content knowledge on practice becomes significantly less, for the influence is working the other way. Not only were teachers’ beliefs in the study seen to have the determining influence on their choice of
teaching strategy and approach, but the teachers' espoused syntactical understanding itself was apparently shaped by these beliefs as well. Having gravitated towards approaches which reflected their general beliefs about how they should be teaching, the teachers' understanding of the nature of science seemed to consolidate around the essence of the approaches. The teachers' understanding became congruent with them. For example, as Carol emerged from the depths of despair that characterised her first term's involvement, she began to appreciate how she could teach science through the promotion of observation. By March 1996 there is a sense within her comments that she is finally able to sense a resonance between this new approach and her beliefs about the way Reception children learn:

looking and experiencing (is) appropriate for the age group...and developmentally it's not appropriate to go on much beyond...You're just doing what is right for them and just opening their eyes...  
(interview 26.3.96)

At the same time, she begins to indicate how her understanding of the procedures of science is forming around this idea. From a strong initial commitment to hypothetico-deductivism, she sees science as much more inductivist in character:

My attitude has changed, although it's been so subtle I hadn't really noticed. Because without looking, I suppose...you can't teach understanding without looking at things, you can't teach knowledge without looking at things, it's the basis for all the other things and I don't think that ever stops. I think I see scientists now as people who are always looking at things, so perhaps you have to look at things in order to be able to do the rest...  
(interview 26.3.96)

The teachers' approaches and beliefs can be seen to have become two sides of a process of mutual validation. Once they can link epistemological ideas with teaching approaches which feel 'right' because of their congruence with beliefs, both approaches and ideas are strengthened. These central beliefs therefore become of great significance. Shulman's categories do not encompass this area to any extent; there is a difference between his category of 'general pedagogical knowledge' and one that encompasses knowledge of personal pedagogical beliefs. Turner-Bisset goes further than Shulman, acknowledging the place of beliefs about teaching and learning as an important part of the 'amalgam' of a teacher's knowledge (1997, p.373). She describes (ibid. p.384) how beliefs can be essential to a teacher's functioning within a discipline, suggesting that pedagogy may
develop along the lines of beliefs about teaching and learning, a claim also made by McNamara (1994), in his exposition of the factors underlying the personal 'vernacular pedagogy' of individual teachers (pp.93-4). Turner-Bisset's suggestion is tantalising. Ultimately, however, she does not pursue it, leaving open the nature of the influence of teachers' beliefs within their overall pedagogy, grouping them as one element of the factors mediating subject matter knowledge. This study suggests that the relationship between beliefs and pedagogy could be explored further.

It follows, therefore, that no classification of knowledge bases for teaching, which also purports to offer an explanatory model of teachers' behaviour, is complete without an acknowledgement of the role played by teachers' beliefs about the aims of teaching, the way children learn and how curriculum should be structured in the derivation of their understanding of appropriate pedagogy. Shulman's categories rely too heavily on the intellect; they assume that decisions about teaching will flow from elements of rational understanding. Turner-Bisset acknowledges the simplistic nature of this idea and proposes a much wider conception of the reality of a teacher's practice. The findings of this study support her general position and extend it. Not only does Shulman's subject matter content knowledge appear to reside within a much more complex milieu in the reality of teachers' action, it can be seen that the syntactical element of the knowledge itself may be formed, at least in part, by beliefs. If this is so, then the nature of the knowledge itself becomes unpredictable and intensely personal. Although Shulman gives a general account of categories of knowledge, he also engages in an attempt to define what should be in them. With the model this thesis is presenting, such a definition is obviously problematic.

5. The affective nature of teachers' beliefs

Beliefs are part of the defining self of a teacher. Nias (1989) described how teachers develop a highly resistant 'substantial self' that is generated from a 'set of self-defining beliefs, values and attitudes' (p.203). The beliefs about the purpose of teaching and what good practice looks like that teachers bring to their science practice are an important element of that self. They are part of the way teachers see themselves within the classroom and their
profession, giving them rationale, purpose to their action, and helping them to establish professional identities. It is apparent, however, that not all of a teacher's knowledge or experience lies within this substantial self; examples of epistemological understanding that has no influence on practice, or teaching approaches that are followed mechanically are testament to this. Elements of knowledge may lie outside the self, including the teacher's espoused understanding of the nature of science or messages about practice she has encountered in literature, in-service courses or from other colleagues. These elements may be intellectually accommodated, allowing the teacher to draw on them in her teaching, but not yet assimilated into the defining core of the self. Such assimilation may occur, but the model of influence proposed by this thesis suggests that for meaning to be generated in the teaching situation from these ideas, there must be an active process by the inner self-as-teacher. The teacher must find something in the ideas that accords with her beliefs. This is not just an intellectual process; it is also an emotional one. Assimilation - and therefore a sense that the knowledge means something in her practice - will take place only when the teacher feels there is no conflict between the knowledge she is assimilating and the values that follow from her beliefs about appropriate pedagogy.

To use a metaphor from physics, the nature of the accord can be thought of as a kind of resonance, suggesting that there is a non-rational act of recognition which is operating at the level of feelings. In physics, the term is used to describe the phenomenon where a vibrating object produces a sympathetic vibration in another. When the idea is applied as a metaphor for the process of recognition that takes place when teachers accept teaching approaches as according with their beliefs, it suggests that the teacher's self may be operating perceptually in both rational and non-rational ways. Teachers may 'feel' something is right as much as rationalise that it is so.

If this is correct, it is to be expected that the teachers will use the language of feeling in their descriptions or evaluations of relevant sessions. A return to the case studies suggests that they do. For example, in a series of passages relating to the insecurity she felt had been caused by the adoption of teaching strategies for which she felt little real enthusiasm, Heather communicates a sense of despair in what she is doing. Her description of this state
and of the resolution that begins to emerge conveys a level of emotional involvement with the situation:

I know I'm very frightened of giving them too much. So I end up actually not giving them enough to start on, so I give them lots of gabbled ideas and they give me lots of gabbled ideas and none of us really know where we are going! I think that's a confidence sort of thing, though. I'm so frightened of, you know, giving them too much that I almost hold back.

(Case Study 3)

'I was panicking, I suppose! I don't know, I just get like that. Everything has to be so structured for me. It's just the way I've always been, but I'm beginning to lose that; I can feel it going slowly.'....You know, I'm getting better, I feel I'm getting there.'

(Case Study 3)

Elizabeth demonstrates the opposite end of the spectrum as she starts to 'feel' that her science work is complementing, rather than interfering with, her pedagogical aims:

I'm feeling really good about the project actually, because it seems all to have come to a good point over the work with materials. Suddenly, as I was preparing over the last few sessions, I didn't have this problem of not knowing what to do...I feel I do now, actually; I feel very positive about the science work that's going on - different things that were happening suddenly started to feed into my own development and I thought this is a real case of learning actually, this is what must happen to children...It's what happens to all of us, but somehow I could see it happening, I could feel it happening - I hope this doesn't sound too sloppy!

(Case Study 1)

Elizabeth is not being sloppy. She is communicating the extent to which her emotions are engaged in the validation of her understanding. She has been following a rational process of reflection and action, but her new practice is not accepted simply because of rational criteria; it is also deemed appropriate because it can produce a feeling of emotional excitement. Golby (1996) highlights how emotional states are not diffuse or general. They are focused, inherently connected with cognition. Emotions, he claims, 'take a predicate. Anger is always anger at something...fear is always fear of something' (p.425). Elizabeth is knowing affectively; her emotions are judging her action.

Elizabeth's emotions in this situation stem, at least in part, from her beliefs about teaching and the values which proceed from them. Her values are strong. She can articulate them clearly, far more so in fact than Heather (see Portraits), yet they are also implicit in her approach to teaching. New teaching strategies - and the epistemology which attends them - either fit with her values or work against them. There is either an accord or a tension between the strategies and those things which Elizabeth values in the teaching of young
children - the need for a child-centred curriculum and the fostering of emergent understanding. Although this accord or tension may be rationalised, it is also felt. The strength of this feeling determines her response to the strategy and her confidence in its implementation.

It follows that a teacher's choice of approach in her science sessions involves not just a rational decision, but an emotional commitment. She not only wants to choose an approach that will address her teaching objectives, she also wants to feel good about her teaching. Each time she adopts a certain style, she opens herself to emotional disappointment. Only when her central beliefs about the purpose and nature of teaching are satisfied will she feel the positive emotional response she needs. She therefore becomes engaged in a continual appraisal of her action, based largely on the degree to which she enjoys what she is doing. In her search for emotional reward, she will strive for practice which reflects her beliefs. The rational and the emotional are brought together. This is not to say that the decision to adopt a particular strategy cannot be a solely rational decision. It frequently is. However, without the emotional satisfaction that resonance with beliefs will bring, it is likely that the teacher will be at best emotionally neutral, or report negative feelings of insecurity and lack of confidence. She will not feel she is 'doing it right'. This process will not necessarily apply to all teachers to the same degree; if the level of the teacher's emotional engagement is determined by the strength of the beliefs she has developed about the aims of teaching, children's learning or appropriate pedagogy, it follows that such commitment is likely to be more apparent in those teachers with strong beliefs. These teachers may be older or more experienced, or be teachers of very young children, as were Elizabeth, Carol and Heather.

Since emotions themselves are powerful factors in cognition, it is also probable that teachers' responses to ideas will be rendered hard to predict. This supposition is acknowledged by Helsby and McCullough (1997) as they review the influence of what they term teachers' 'personal biographies' on their practice. Echoing Hargreaves' (1991 p. 251) reminder that 'teachers are people too. They have interests; they have lives; they have selves' (in Helsby and McCullough, p 11), they suggest that teachers' responses to
curriculum innovation may lie in ‘a range of conflicting emotions as much as in rational calculation’ (p.11). Measures to improve the teaching of science in primary schools will therefore be most effective if they have regard for the determining influence of these emotions and allow for their positive expression. This means acknowledgement must be given to the range of beliefs about teaching which teachers hold. They are crucial to success. It does not matter whether the aim is to improve teachers’ understanding of the nature of science so that they recognise a range of possible action within science sessions, or develop their knowledge of a variety of teaching strategies; if the purpose of development is to produce confident and effective practitioners, room must also be given for the expression or development of those practitioners’ beliefs about children, curriculum or pedagogy. The cognitive meaning that teachers will draw from the ideas about science and science teaching they encounter, may depend on those beliefs directly; so, too, might the teachers’ emotional well-being, unless they are given space to adapt.

Yet government policy in England and Wales appears to be based on an approach to teacher development which sidelines teachers’ beliefs in these areas. If this is indeed so, then it is also sideling teachers’ emotions and the importance of their substantial selves. Current policy appears to be sweeping aside the thinking of the three previous decades (for example: Taba, 1962; Stenhouse, 1975; Pollard and Tann 1987), which called for the active involvement of teachers’ selves in the generation of pedagogical and curricular knowledge. When Stenhouse (ibid. p.142) claimed that ‘curriculum research and development ought to belong to the teacher’, he was advocating an understanding of practical knowledge that was fuelled by a penetrating critique of the inadequacies of behavioural objectives and a top down approach to professional development. His understanding was taken up, described and extended by many during the eighties, including Elbaz (1983), Schon (1983), Pollard and Tann (1987) and the growing action research ‘movement’ in education (see Chapter 2). Elbaz’ discussion of teachers’ practical knowledge encapsulated a growing understanding that it was personal and complex. She stated:

The notion of the teacher’s perspective is not to be understood narrowly. It encompasses not only intellectual belief, but also perception, feeling, values, purpose and commitment...the search for knowledge is motivated by the entire range of human feeling, need and desire, and by the perspectives, points of view, system
of constructs, which are elaborated to deal with the world. To characterize knowledge in general, and the teacher's practical knowledge in particular, in this way is to speak less of knowledge-as-product than of knowledge-as-process, the act or acts of creating knowledge.

(Elbaz, 1983, p.17)

But such thinking has struggled against the reforms of the nineties and the increasing centralisation of curriculum and educational control. The publication of a raft of legislation, exemplified by the requirements within Circular 4/98 - Teaching: High Status, High Standards (DfEE 1998b) - has chipped away at teacher autonomy and eroded teachers' ability to make curricular and pedagogical decisions in the classroom. Teachers are not to be educated, they are to be 'trained', presumably to make appropriate responses when presented with particular stimuli.

In her pre-National Curriculum study, Nias (1989) highlighted just how strongly teachers would be 'at pains to protect their substantial selves from change' (p. 204). She claimed that they would strive to ensure that they did not have to behave in ways they did not believe in. With the imminent implementation of the 1988 Education Act, at the beginning of the steady drive towards centralisation, Nias prophesied that the process was likely to lead to a loss of freedom and autonomy, together with an erosion of teachers' professional integrity (p.213). A few years later, this prediction appeared to have been correct. Pollard et al. (1994), in a longitudinal examination of the impact of the 1988 Act on infant and primary schools (the PACE project), released a report on the perceptions of Key Stage One teachers to the change. They commented that although a minority of the teachers appeared to have welcomed more central control over their teaching, the majority felt that same loss of freedom and enjoyment in their teaching that Nias had warned against (p.78 et seq.). Furthermore, the most common response amongst the teachers was one in which they appeared to be striving to protect their core beliefs. Pollard et al. described a common feeling to be one of: 'I'll accept the changes, but I won't allow anything I consider to be really important to be lost.' (p.100). One teacher stated: 'I'll never sacrifice the children. I'll go on doing what I think best for them regardless' (p.100). Interestingly, in the light of the current discussion, Pollard et al. note that where an attitude of compliance towards the imposed changes was present, it seemed mostly to occur in young teachers who had
recently entered the profession, or amongst older returners. Such a finding supports the suggestion made earlier in this chapter that beliefs about pedagogy, and their consequent influence, develop over time.

In a work which describes the response of 'creative teachers' to the increasing control, Woods (1995) presents slightly more conflicting evidence within a general review of research to that date. He describes how Campbell et al. (1991), in a study still relatively close to the implementation of the Act and the introduction of the National Curriculum, considered that the measures had largely found support amongst teachers. Many thought that their professional skills were being enhanced by the change and Campbell concluded that 'primary school teachers' hearts and minds had been won over to the principle of the National Curriculum' (in Woods, 1995, p. 4). However, Woods also lists a large number of studies that found the opposite effect (p.4). He comments how the teachers he was working with expressed attitudes similar to those of Osborn et al (1994) and the PACE project. He notes how the increased control from the National Curriculum appeared to be exerting a negative influence. Pressures were enormous. The creative teachers that were the focus of his book were finding ways to rally against these pressures, and he describes how they appeared to be finding the freedom to 'think their own thoughts', 'express themselves' and 'be original'. ' (Woods, 1995, p.158). They were defending their beliefs in their teaching. In a statement remarkably similar to that of Pollard et al.'s teacher, one said: 'I have arrived at a philosophy of what I feel young children need, and I feel I would not be doing right by my beliefs and my teaching professionalism if I let that go because of the Orders' (p.6).

The changing climate over the last decade can therefore be seen to have exerted significant pressure on teachers' beliefs, especially those based on the child-centredness of early years ideology and the pedagogical autonomy of the reflective professional. The system no longer allows these beliefs to exert as significant an influence on the teachers' pedagogy or the content of their teaching as they may have done before. Yet the findings of this study have reinforced the understanding that the matching of practice with beliefs is an important determinant of confidence and meaningful intellectual engagement with the
content of teaching. There are many dire warnings within the literature as to the long term consequences of the sidelining of central beliefs. Nias (1989) raises the possibility that fatigue and strain will result as a teacher strives to defend her substantial self in teaching, and, in a later work, she emphasises the importance of ensuring that a teacher's emotional commitment to her work is allowed:

Teachers are emotionally committed to many different aspects of their jobs. This is not an indulgence; it is a professional necessity. Without feeling, without the freedom to 'face themselves', to be whole persons in the classroom, they implode, explode - or walk away.

(Nias, 1996, p.305)

6. Change in teachers' beliefs

Up to this point, there has been an implicit assumption throughout much of the discussion that teachers' beliefs are static, that whilst change happens around them they remain a constant within the turmoil. Indeed, it was the relative constancy of the infant teachers' beliefs about why they should be teaching in certain ways as opposed to their understandings about science and science teaching, that pointed to the overall hypothesis that has emerged. Yet beliefs do change, and it has already been noted that they develop and strengthen with time and experience. What is clear, however, is that they also present a strong resistance to change. A teacher's beliefs are a fundamental part of her substantial self, upon which the rest of her practice is built. Both Woods and Nias highlight how far teachers go to 'defend the self in teaching' (Nias, 1989, p.43 et seq.); it is easy to see why change to beliefs does not take place easily. They have a history in teachers' personal biographies, the formative experiences of initial teacher education and the powerfully affective experience of the classroom; they provide the understanding which drives the teachers' action and they form a constancy against which individuals strive to resolve conflict. Referring to Rokeach's (1973) claim that 'the dissonances most likely to precipitate change in an individual arise not at the level of views but of beliefs and values', Nias stresses how teachers protect themselves against such dissonance between values and action (ibid. p.21). Woods (1995) discusses the influence of training programmes in the derivation of teachers' 'personal philosophies of education' and suggests that an important feature of 'teachers'
ensuing practice is action which is designed to validate and consolidate these perspectives (pp164-165). The evidence from the study for this thesis showed this sense of validation to be a strong component of any resolution which occurred in the teachers' science practice; recognition by the teachers that they could defend a way of teaching science which accorded with their beliefs strengthened and validated those beliefs, as well as validating the science teaching approach (see particularly Elizabeth and Carol). Such a process creates an image of an almost impregnable self-referential circle, defying change.

Beliefs, however, are not operational. They are influential within the educational context because they generate an understanding of what is to be valued in teaching; it is the interaction between teachers' actions and these values that becomes the seat of change. Whitehead (1985, p.98) describes the teacher's motivation to engage in reflection on practice as the experience of a negation in her educational values as she teaches. There is a dissonance between aims and reality. Reflection on why this dissonance exists becomes a driving force for change. Yet it is not just action which may change. If reflection becomes reflexive, 'bending back' (Winter 1987) towards the subject, the values themselves lie within the overall dialectic; they define the goals of practice. The principles of dialectical analysis render all elements problematic (see Chapter 3). Elliott (1991) goes further and claims that any new action deriving from such reflection must involve a reappraisal of values; he considers that the ethical dimension of an action which is chosen in order to realise educational values necessarily brings those values under scrutiny. Ethical action, he claims, itself involves interpretation of values. Because of this, he suggests that practitioners engaged in such reflection may be continuously reconstructing their 'concepts of value' (p.51).

If this is so, then it raises the possibility that the self-referential circle may not be completely impregnable. Through critique of values, beliefs may change. Yet such a process of reflection is arduous, in need of strong commitment and, most probably, external support. Dadds (1993) highlights how intense personal reflection, though potentially liberating, may dangerously undermine self confidence. The questioning of fundamental values does not come about easily and even the teachers in this study, though involved in
sometimes painful reflection, did not appear to change their beliefs. It was the relief that they felt whole with those beliefs that provided a resolution for them, when it came at all. Most teachers do not have the time, motivation, opportunity or support to engage in such reflection. In such a situation, it is quite probable that their beliefs will not be seriously questioned.

However, although their beliefs about the way children learn and the aims of their teaching did not appear to change, the teachers in the inquiry displayed an increasing involvement with a complex series of tensions within their practices. It would have been quite reasonable to predict that, as the teachers articulated them, these tensions were going to have a potentially negative influence on their teaching. It is not hard to imagine how the uncovering of so many inconsistencies in their teaching and their understanding could undermine their confidence in the classroom. Yet the teachers emerged from the inquiry with a strengthened confidence and an increased motivation to teach science. This was not achieved by an ultimate avoidance of the tensions; indeed, it can be seen that change and resolution could not have occurred without a recognition of them. The teachers had to be engaged at the level of dissonance between values, understanding and action for meaningful change to any of them to take place. In the case of Carol, who started the inquiry with strong beliefs about the way children learn and how this should affect her own choice of pedagogical approach, her engagement led her to a reappraisal of what appropriate pedagogy might look like in practice. Without changing either her beliefs or what she valued in her teaching, she managed to develop a flexibility which allowed her to see potential in approaches for science teaching she had initially eschewed.

Yet, although such a positive result was forthcoming, there were periods when the teachers experienced severe self-doubt. Carol’s state of mind as she plunged into despondency during the Christmas term exemplifies the turmoil that the uncovering of tensions could produce. It was the support of the study which enabled this potential negativity to have a positive outcome, encouraging a measured process of inquiry which turned the tensions into a fertile ground for change. Far from being negative, the tensions were eventually the most significant factor in the teachers’ development. But without this
help, it is debatable as to whether Carol would have worked through her tensions in the way she did; she was insecure about science at the outset and it is most likely that it would have remained a sideline in her practice. Her insecurity in science derived from intensely significant relationships with her family, producing a complex situation which was easier to avoid, rather than confront. Yet it is hard to consider Carol as significantly different from other teachers; all will have elements from their personal biographies affecting their levels of security and confidence in the classroom. However, most teachers do not receive the kind of assistance the inquiry was able to give to Carol. Tensions in their practice are likely to remain hidden, or partly hidden, operating tacitly within their teaching. It is unlikely that without support – and strong support, given Dadds’ warning – they will be articulated in such a fashion as to promote productive change.

It is perhaps best that the tensions in teachers’ practice remain hidden. To help teachers resolve them requires time, a supportive environment and, above all, a trust that the teachers can take control of their own professional development. Such trust is not a feature of the current educational landscape. A training model based on the imposition of external solutions to the problems of teaching is now operating at all levels of education. From the imposition of the National Literacy Strategy (DfEE 1998b) and the National Numeracy Project (DfEE 1999a) to complement the existing National Curriculum (DES/WO 1989, 1991, DfE/WO 1995, DfEE 1999b) at classroom ‘delivery’ level, to the increasing control over teacher ‘training’ programmes (DfEE 1998a), central direction of what teachers should teach and how they should teach it has become the norm. There is little time for students or teachers to examine their beliefs or explore their consequences. This attempt to control teachers’ professional lives is given even greater force by the inspection regime for schools (Ofsted 1995, 1999) and for courses of Initial Teacher Training (Ofsted 1998a). This regime, when coupled with the level of curricular demand for student teachers set out within Circular 4/98 (DfEE 1998a), makes a transmission model a de facto feature of preservice courses. Although there is a call within Circular 4/98 to ‘consider the standards as a whole to appreciate the creativity, commitment, energy and enthusiasm which teaching demands, and the intellectual and managerial skills required of the effective professional’ (p. 8), the
severity of an inspection regime in which it has to be shown that students can demonstrate their understanding of over eight hundred individual statements, ensures that there is little time for broader or more reflective analysis. The training model can be seen within inservice professional development programmes too. It is becoming increasingly uncommon for INSET activities to recognise the existence of teachers' personal beliefs and values, let alone offer the kind of support necessary for the tensions which derive from them to be resolved successfully. The outcome is a situation which has significant implications for the quality of science teaching in primary schools. If teachers are not able to resolve the many aspects of their science practice before having to accommodate external demands about what they teach, then the increasing burden of requirement upon them is likely to strengthen tensions, rather than clarify practice. This study has highlighted how continual bombardment with information of any kind, be it pedagogical, epistemological, organisational or curricular may have little effect other than confusion and demoralisation.

7. The structure, content and purpose of the science national curriculum

The current technocratic approach within education is based upon an understanding of subject teaching in terms of training and of the teacher as expert. Since the publication of the 'Three Wise Men' report on curriculum organisation in primary schools (Alexander, Rose and Woodhead, 1992), there has been increasing criticism of the subject expertise of primary teachers and a steady pressure to introduce more subject specialist teaching in primary schools. The recent announcement (TTA 2000) that postgraduate trainees are likely to receive payment whilst on a primary P.G.C.E. programme (a trial project will run from September 2000) only serves to emphasise the importance the government places on 'subject' (i.e. anything directly represented within the scope of the National Curriculum) knowledge. Students engaged in four year undergraduate programmes will not receive such payment. Given the structure of the National Curriculum, an epistemology which divides knowledge into discrete subjects and a heavy emphasis on skills and factual understanding, such an approach is, perhaps, understandable. The teaching of discrete subjects requires teachers with subject expertise; the recruitment of subject graduates will strengthen the
knowledge base within primary schools. In time, perhaps, primary schools are to become like small secondary schools, with subject teachers or children moving from class to class. Such a move can already be seen, especially in science. But such change will not be easy; it will (and does) encounter vehement opposition from early years teachers and those who, despite the raft of changes thrust upon them, remain convinced of the advantages of the generalist teacher.

The current science National Curriculum is based firmly on a model of subject training. Putting aside for a moment the important tensions with teachers' beliefs which may exist in the imposition of a mode of the delivery of this curriculum, it must be recognised that teachers' perceptions of the nature and purpose of the curriculum constitute a significant factor in the confidence they feel to teach it. In their report of the recent Nuffield seminars 'Beyond 2000: Science Education for the Future', Millar and Osborne (1998) identify much that is wanting within the present curriculum, much, they suggest, that may be holding back the development of good science teaching in schools. They claim that the current curriculum (DfEE 1995 – in force until September 2000), filled with detail from Key Stage One upwards, represents an old-fashioned training model for future scientists, in which factual learning is paramount. This is emphasised, they suggest, by a content which appears frequently as a catalogue of discrete ideas and an assessment regime which relies heavily on memorisation and recall. Moreover, a well-articulated set of aims is lacking, as is any agreed model of children's development over the 5-16 period (Millar and Osborne, p.5).

There exists, therefore, a strong pressure on teachers to transmit large quantities of factual information to their pupils. Following the introduction of the National Curriculum in 1989, there was considerable unease throughout primary schools from teachers who had little science experience. Low levels of scientific knowledge and high levels of commitment to process-based educational goals combined to create a situation in which the new curriculum generated much insecurity. This insecurity was initially assuaged by the widespread adoption of a 'fair testing' approach in science sessions (see, for example, Harlen and Jelly 1989), in which a predominantly hypothetico-deductive method appealed to the prevalent understanding that, for primary children, processes were more important
than concepts. Such an approach, as well as being open to criticism on epistemological grounds (see Hodson 1985 p.49), could not, however, encompass the range of conceptual demand within the new curriculum and, with the publication of the report by Alexander, Rose and Woodhead (ibid), the pressure on primary teachers to show they have a mastery of science knowledge within their classrooms steadily increased. The result of this pressure has been that teachers who lack confidence in science frequently struggle to convey the meaning of ideas they themselves understand only poorly to children, or tend to implement slavishly a restricted range of activities they feel are representative of 'scientific method' (exemplified by Heather's initial approach to investigation in her science sessions). This can mean that the content of a session becomes little more than an attempt to 'simplify' those already poorly understood concepts, or that children are taught to follow an almost ritualised 'method'. The outcome can be lessons which are likely to be inappropriate in relevance and demand. Very often the experienced teacher's science sessions may be worthwhile experiences for the children not because she has a sound understanding of scientific pedagogy, but simply because the craft knowledge of children and teaching she has developed through her work enables her to sense this inappropriateness and adapt the lesson content.

Millar and Osborne call for a 'fundamental review and reconsideration of the aims and content of the science curriculum' (p.1). They call for a curriculum with specified aims, and a curriculum in which central principles have greater emphasis than potentially confusing detail. Following an analysis which suggests that even those who are apparently successful in their science education have little grasp of the relevance of science to everyday life, they recommend a curriculum which strives for a level of scientific literacy in the population to make them 'comfortable, competent and confident with scientific and technical matters' (p.9) and that makes apparent the major ideas which hold scientific knowledge together. Few children will become professional scientists, yet all children will grow into adults whose lives could be enriched by a knowledge of key scientific ideas, an understanding of the procedures through which science progresses and an appreciation of the contribution of science to their cultural heritage. It is a bold vision. There was an attempt
to highlight elements of the nature of science for older children in the first National
Curriculum (DES/WO 1989, Attainment Target 17), but this was soon abandoned
(DES/WO 1991). Millar and Osborne's recommendations would bring many of these
elements back to the fore. Yet, mindful of the continual pressure on teachers, they caution
against too much change too quickly. They make only three recommendations for the newly
revised curriculum (DfEE 1999b), of which two - a statement of aims and the incorporation
of the section on 'General Requirements' (ScO) into 'Experimental and Investigative
Science' (Sc1) - have, to some extent, happened. At the time of writing, the third, relating
to assessment procedures, has not. Millar and Osborne argue that, although the existing
curriculum (DfE/WO 1995) has limitations, teachers need a period of little movement in
order to 'refine, reflect and develop' (p.28) their existing practice before any greater change.

This last sentiment is understandable. Teachers have had to cope with considerable
upheaval in the nature and content of their working practices over the last decade and further
imposed change could be demoralising. Millar and Osborne are wise to call for a little at a
time. But merely changing the structure of the curriculum document will not be enough.
Teachers will still need the time and space to appreciate the relationship between its content
and aims and their defining beliefs about teaching. The need to translate scientific
knowledge and ideas about the nature of science into their pedagogy will not go away. If
Millar and Osborne are right in considering that teachers need time to 'refine, reflect and
develop' their existing practice, then teachers also need to be given the opportunity for
professional development and the climate of trust they need in order to do it. Ultimately,
change in curriculum structure is only the beginning. It may signify a change in external
approach and attitude, but it is erroneous to think that a curriculum has aims. Aims do not
reside in a curriculum, they belong to the people that write it. The aims of 'Beyond 2000'
were generated, not imposed. It follows that if there is to be confident translation of the
science curriculum into teachers' practice, there must be space for teachers to develop their
own, yet hopefully shared, understanding of its aims. They need to go through the same
process of generation. Despite the current technocratic approach, education is not an
exercise for technicians. Education lies within the actions of individual teachers, with
individual histories, in particular circumstances. As Stenhouse (1975) so clearly argued, the imposition of external objectives will not mean uniformity of outcome; teachers need to be engaged with the professional questions of purpose and means for their children if they are to make sense of and have confidence in their practice. This is not a choice, it is a matter of inevitability. A new science curriculum is no exception.

Yet there is little space within the primary teachers’ life for this professional development to happen. Time for science work has become increasingly scarce through the nineties and, latterly, the Key Stage Two assessment targets for 2002 have ensured that literacy and numeracy fill the greater part of the school week and the content of inservice courses. The result is not disastrous; teachers produce science sessions of which eighty percent are deemed satisfactory or better by Ofsted and development across Key Stage Two is judged to be good (Ofsted 1998b). Yet that is only half the story. It masks the reality of teachers like Andrea, involved in preparing children for SATs, yet profoundly unsure why she ought to be teaching what she was. She was acting as nearly like a technician as possible, going through the motions. Children learnt, but it was in a classroom in which there was little passion or creativity and little commitment to the content of the lessons. The figures also mask the reality of Heather, Elizabeth and Carol, self-admittedly stumbling through their science sessions with infant children. They brush aside the reality of Elizabeth, perhaps the most talented Reception teacher the researcher has experienced, who was ‘getting by’ because of her vast experience of children and their needs, yet was unable to draw her science teaching into the core of her teaching philosophy; they ignore the reality of Carol, whose fear of science meant that it was marginalised and avoided; they, quite appallingly, endorse the reality of Heather, who applied a formula to her teaching because ‘that was what you did’. The fact is that, within these generally positive inspection statistics, at least four out of twelve teachers in the ordinary suburban primary school in the study felt they knew little about what they should be doing in science. Because they chose themselves for the study it could be argued that they were not representative, but even so, a minimum one third of the school staff is a significant fraction. Moreover, one was even the science co-ordinator.
Summary

The findings of the study cast light on the significance of teachers’ understanding of the nature of science in their practice. They highlight how this understanding may be less important in the generation of the teachers’ science practice than their beliefs about key aspects of teaching, for these beliefs generate an overriding understanding of how to teach appropriately. This discussion has identified five major conclusions deriving from these findings:

1. that the reaching of agreement between beliefs, action and understanding of the nature of science is powerful in terms of developing teachers’ confidence in their science practice;
2. that current inspection reports may be masking the reality of science teaching, rather than exposing it;
3. that the direct imposition of curricular demands, expectations regarding subject knowledge or recommended pedagogical strategies is unlikely to result in improved science practice, if the measure of improved practice includes teachers’ confidence;
4. that this lack of change may be most marked in the practice of teachers of very young children;
5. that because teachers need the opportunity to resolve tensions within their science practice, a continued technocratic approach to education may have important negative implications for teachers’ morale and professional development.

The thesis will now pass to its final chapter: a brief overview of the implications of these conclusions for the education of teachers, with some recommendations for action.
IMPLICATIONS FOR TEACHER EDUCATION AND RECOMMENDATIONS FOR ACTION

1) Implications

It follows from the preceding discussion that, in order to generate confident practice in the teaching of science or to change teacher attitudes and approaches, both preservice and inservice teacher education programmes in science need to include space for teachers or student teachers to explore their beliefs about education and the tensions between those beliefs and various pedagogical and organisational positions. The health of science education in primary schools depends on an approach which does not sideline the existence and influence of teachers' wider beliefs about the aims of teaching and the way children learn. The relationship of these beliefs to the strategies teachers' adopt is critical; accordance with beliefs is the key to the teachers' confidence. This section will take the form of a short discussion about the implications of these ideas in three main areas: i) preservice education, ii) inservice education, iii) future research.

i) Preservice education

A heavy onus must fall upon the providers of initial teacher education courses to facilitate student teacher reflection on the relationship between their general beliefs about the way children should be taught and their developing understanding of science and science pedagogy. Although beliefs about children and pedagogy are already present in many eighteen year old undergraduates, students should be open to new ideas. It is essential that student teachers develop the ability to extend the normal critical reflection of undergraduate programmes into reflexive analysis of their own beliefs and values. If this habit of thinking is established at this stage, it should encourage a continual critical feedback between beliefs and action that will promote coherent practice, rather than a mix of mutually incompatible elements. Such action is more likely to be pursued successfully within undergraduate programmes than in the highly pressurised environment of a short postgraduate course.
The design of programmes is crucial. The researcher works as a university lecturer in science education, involved with four year B.Ed. and one year P.G.C.E. students. He has been instrumental in the introduction of a module on the B.Ed. programme which helps science specialist students explore the nature of the subject. This is always well received; students enjoy the intellectual challenge of considering perspectives on their subject which render previously held assumptions problematic. Yet the rationale for the module, that such knowledge of the nature of science will make them better teachers of science, has been shown to be flawed; transmission from ideas to practice does not occur in such a simplistic fashion. For the module to make a real difference, it must include strategies which encourage student teachers to engage in an articulation and exploration of their developing beliefs about teaching itself. To ignore these is to ignore the determining factor in the choices the students will make in the classroom. Teachers must have an understanding of the workings of science if they are to appreciate the significance and potential within curriculum elements such as the promotion of inquiry, the analysis and interpretation of data, the communication of ideas and the progress of scientific understanding, but philosophical understanding must not be treated in isolation. Teacher education programmes must strive to ensure that students are given opportunity to reflect in context on how and why they teach in certain ways, which elements of content appeal to them and where they experience tensions in their overall development. Encouraging this kind of reflection at the formative stage of student teachers' beliefs will help ensure not only that an accord between beliefs and ideas about the nature of science may be established, but that the ideas about science will themselves have an influence on the generation of the beliefs.

Unfortunately, the introduction of the Standards for Qualified Teacher Status in Circular 4/98, has created a situation in which tutorial support on students' school experience has become directed primarily at the setting and meeting of targets relating to externally derived objectives. This is especially so in final teaching experiences, where students are demonstrating their competence in the classroom. Yet it is just at this point that they are mature enough to engage in a truly challenging reflexive dialectic between their crystallising beliefs and the content of the curriculum they are teaching. If students are to
generate an understanding of their science teaching which is in accord with their general pedagogical beliefs, it is essential that their tutorial support also allows for the kind of reflection necessary. Planning and evaluation must not only engage students in analysing their action within the confines of subject perspectives, but it must also challenge them to justify their teaching approaches against wider questions of the children’s overall development. The demands of Circular 4/98 will not go away; curricular demands on preservice programmes in England and Wales are likely to remain similar for the foreseeable future. Establishing an opportunity for the kind of broader reflection needed will require vision and a creative approach to the delivery of the Initial Teacher Training National Curriculum.

ii) inservice education

A similar approach to teacher development should also be a feature of inservice courses, but the task here is even harder. Dealing with experienced teachers who have already formed their beliefs about teaching and are sure of what they value will necessitate a certain kind of inservice programme. It must allow open exploration and discussion; it must facilitate and support the expression of tentativeness and uncertainty, and allow the space for personal growth. Teachers need to be helped to feel their way into the philosophical aspects of the nature of science and be given the opportunity to experience the nature and significance of the ideas within their own practice, possibly through carefully supported action research. Such a methodology, if handled sensitively, promotes the dialectical interchange between beliefs, action and ideas which is essential for the development of consistent practice. However, this also takes time. Teachers will need to be convinced of its value and funding bodies will need to appreciate its effectiveness. Such a move would be action that largely goes against the tide at present. With the nature of so many current primary inservice programmes on literacy and numeracy being one of transmission, it will not be an easy task to achieve. Teachers, once used to Stenhouse’s (1975) call to become researchers of their own practice have become increasingly used to operating in a receptive mode. The recent introduction of the DfEE ‘Best Practice’ research scholarships (DfEE
2000) suggests that, in principle at least, there is a commitment in government circles to teacher research; it is important that this funded research is seen to value personal exploration as well as technocratic efficiency. The health of education depends on teachers maintaining a sense that its goals cannot be precisely defined.

jii) future research

This study highlights a need for further research in two areas:

- Research which systematically elicits the range of teachers’ beliefs about education and children’s learning and then explores the relationship between them and the teachers’ cognitive processes. The conclusions of this study need to be explored further. The focus of this study has been science teaching and it is important that further research is carried out in this area. It is, however, logical to assume that if the teachers’ beliefs are important influences in this area, they are likely to be important in others. The focus of this research might therefore be wide ranging.

- Research which explores the effect of specific philosophical training on teachers’ science practice. It has been acknowledged that the current study did not set out to develop teachers’ understanding of key questions in the philosophy of science through a process of tuition. It is, however, logical to ask the question whether such training in the philosophy of science might have resulted in different dynamics within the teachers’ practice.

2) Recommendations for action

Given the current constraints on education and the fact that teachers and lecturers have to adapt continually to new initiatives, there is little time for radical programme development. The following recommendations for action relate largely to ways in which reflexive dialogue might be maintained in science education programmes whilst addressing and fulfilling statutory elements.
a) Preservice programmes

1. There should be programme elements which deal specifically with developing students’ understanding of the nature of science and the rationale for science education. These must also include exploration of students’ beliefs about the purposes of teaching in general;

2. In the same way, the consideration of pedagogical approaches or strategies for science must be related to students’ own beliefs about children’s learning and the ways they should be taught;

3. Tutorial support during student teacher school experience should be reviewed in order to ensure additional reflection which is not objectives or target based, but which facilitates reflexive analysis between beliefs and teaching.

b) Inservice programmes

4. Using the stimulus of the new science National Curriculum (DfEE 1999b) and the recommendations from Millar and Osborne (1998), inservice programmes should be established which facilitate serving teachers’ exploration of their beliefs about teaching and ways to teach science. Science is not at present a priority area in schools and has little funding. Inservice education providers will need to divert their own funds to ways of promoting involvement by teachers within their normal teaching. The establishment of co-ordinated action research projects would be particularly effective in doing this.

c) General

5. A communication network through which preservice and inservice teacher educators can share ideas and expertise about the provision of programmes could be developed. There is much scope for constructive use of the world wide web in the establishment of such a network, supplementing current provision. Current science sites are concerned predominantly with teaching ideas rather than programme design and implementation.
The researcher intends to disseminate the arguments within this thesis to a wider audience through publication in relevant journals and by giving papers at conferences. Such action is, however, a little distanced from the classroom; his primary means of effecting change through the results of this study will be to return to the promotion of teachers' action research and try to establish local networks of science teachers who will take the work forward.

**Postscript**

This research has changed the researcher's understanding of the dynamics of the relationship between espoused ideas and action in the classroom. It has presented a model of influence which is far less amenable to outside intervention than is the idea of a controlling influence through intellectual understanding. It casts doubt on current approaches to the development of good practice in science education. Yet although it makes the situation more complex, there is a sense in which that is no bad thing. Paradoxically, the complexity and its consequent implication of a multifaceted nature to the development of practice is in some way a celebration of the intricacy of human lives. Teaching is not a technical activity. With a review of Circular 4/98 due to be finished by 2002, it is to be hoped that this message will be reflected in its recommendations.
APPENDICES
APPENDIX 1

The Nature of Science
Appendix 1

A BRIEF OVERVIEW OF THE ‘NATURE’ OF SCIENCE

Introduction

The thesis mentions a variety of philosophical terms and positions. In order to clarify the meaning of these terms, the perspectives that the researcher brings to the inquiry and to aid analysis of the teachers’ actions and comments, this appendix gives a brief overview of major aspects of the nature of science. The overview is short, and the exposition of each position brief; the thesis is not a treatise on the nature of science. More detailed treatment of the issues can be found in many texts, for example, Chalmers (1982), Oldroyd (1986), Gillies (1993) or Couvalis (1997).

It is first important to point out that it is not possible to define a single ‘nature’ of science. Philosophers have for long adopted a range of different positions regarding scientific methodology and epistemology. Whilst the debates have generated new ideas in these areas, the new thinking, as Driver et al. (1996, p. 25) suggest, has not superseded the old ideas; it has merely added complexity. The nature of science deals with questions of procedure (methodology) and the validity of knowledge (epistemology); consideration of these also extend into metaphysical questions relating to the existence of what is known (ontology). New ideas in each of these fields extend debate, but they do not define understanding.

It is more easy to say what characterises science as an enterprise. When viewed in this way, science consists of two main elements: some kind of system of knowledge and a range of procedures for arriving at that knowledge. On a simple level, this broad classification can provide an initial distinction against which teachers’ understanding can be measured. There is evidence to show that some of the teachers in this study held tacit ideas in their practice in which science was seen to consist almost exclusively of a body of knowledge. Procedures were apparently unimportant.
Any further exploration of the nature of the knowledge or the purpose of the procedures begins to open up a range of philosophical debate. A common definition of science is that it is about the generation of explanations for the phenomena of the world; however, the nature of explanation itself is problematic. Explanations in science do not answer the question ‘why?’; such questions imply reason and purpose. Questions of ‘why?’ in science become turned into questions of ‘how?’ and it is within this overall perspective that any causal models within scientific knowledge must be viewed. Science cannot offer reasons for phenomena, except in terms of a logical description of the events which lead to them. These explanatory descriptions are themselves based on a range of differing cognitive devices. There are, for example, laws, which offer a generalised statement of perceived regularities in the universe— for example Hooke’s Law, which describes how a body will deform in a regular manner, proportional to the force applied to it, or Boyle’s Law which describes in a similar manner the observation that the pressure of a gas is inversely proportional to its volume. Then there are theories and theoretical models which postulate mechanisms through which these laws, and other phenomena, can be further explained— for example the particle theory of matter, from which the kinetic theory of gases to explain Boyle’s law derives. This derivation is not straightforward however, for other entities, such as energy and force, neither of which can be observed directly, have to be included to construct an adequate model. They are explanatory tools for the physicist in the theoretical world within which these explanations lie and are presumed to exist in the real one (if there is a real one). This raises a question regarding the reality of the components of these theoretical models which cannot be answered by science. Scientific explanations are important because they allow the safe prediction of the behaviour of the physical world; the question of whether the theoretical components of those explanations actually exist is a question of belief. It is of philosophical interest, but it is not crucial to scientific endeavour.

The belief regarding whether the elements of scientific knowledge actually exist belief extends to the more fundamental questions of whether the objects we perceive have any objective reality at all and, even if they do, whether we can have knowledge of them. The first
question is ontological, the second epistemological. In the context of this study, the following clarification of four categories will aid understanding. It is important to be able to distinguish these positions, not just because of their relationship to the teachers' epistemological understanding, but because they may represent a fundamental attitude towards scientific knowledge in the classroom. The first two are perhaps the most important — and most commonly occurring — categories.

**Realism:**
A realist believes that a real, external world exists. Epistemologically, a realist also considers that it is possible to gain knowledge of this world. Scientific theories are statements about a world that exists independently from the scientist's perceptions. Kant (1781: 1934, p.297), a realist, argued that it is impossible to apprehend an object directly, because perception gave knowledge only of appearances. However, 'naïve realists' consider that our ordinary perception is direct, giving access to the true properties of things.

**Relativism:**
A relativist believes that truth is relative to the norms of the group considering it and to the experimental techniques they choose to test it with. Therefore judgements of scientific theories may vary from individual to individual or culture to culture. At this, the most common level, relativism relates to a variation in the conceptual frameworks used to describe reality and there can be a kind of 'half way house' in which someone can hold a relativist epistemology within a realist ontology. However, 'pure' relativists go further and reject the idea of a reality existing independently from a system of understanding. There are thus links between such radical relativism and:

**Idealism:**
An idealist believes that what is known as the external world is in fact created by the mind. Material objects only exist in relation to an
experiencing subject. Berkeley (1685-1753) generalised that because the perception of the qualities of things, such as taste and warmth, depend on the context in which they take place, they cannot be real properties of things. He generalised this claim to all perception.

**Instrumentalism:**

An instrumentalist (or pragmatist) believes that it is not important to ask whether scientific ideas are true. They are fine if they work and allow predictions to be made. However, they say nothing about the nature of independent reality.

Although the adoption of one of these stances in relation to the existence of the world to which science relates is ultimately a matter of belief, the business of science is to arrive at explanations for perceived phenomena. To this extent, it must be said that there is an implicit realism in the enterprise of science, for scientists do not engage in the study of things they do not consider to exist. The crucial question, however, is to what extent any trust can be placed in the knowledge that science generates. To what extent is it 'reliable'? (Ziman, 1978). The procedures adopted to ensure valid data, the methods of analysis and reasoning employed and the epistemological critique of the various facets of the process, constitute the bulk of the 'nature of science' that is relevant to the study.

**An important consideration regarding the reliability of scientific knowledge**

Science has a problem. The aim of its procedures is to generate valid explanations for phenomena. Such explanations are by their nature general; their validity depends on the fact that they apply to all examples of a phenomenon, not just one. But science does not have access to generalities; it does not have access to 'all' examples of a phenomenon. It can only deal with specific instances—this cat, that chemical reaction, those sounds. Science works with 'particulars', verifiable instances of phenomena which it uses in some way in the generation of 'universal' explanations. It does so in a variety of ways.
Induction

Perhaps the most intuitively acceptable method of knowledge generation in science is induction. It places direct experience of particulars at the heart of the process and underpins what Chalmers describes as the most widely held view of the nature of science:

'Scientific knowledge is proven knowledge. Scientific theories are derived in some rigorous way from the facts of experience acquired by observation and experiment. Science is based on what we can see and hear and touch, etc.'

(p.1)

Induction places direct experience at the starting point of knowledge generation. It is thus fundamentally an empirical process, basing understanding on the observational information of an external world arriving through the senses. The general process is straightforward. A series of observations are made of a phenomenon; these are then compared. From the comparison, similarities or patterns emerge. If a sufficient number of observations are made and the pattern can be seen within all observations, then it is possible to state that the pattern is a general feature of all examples of the phenomenon. A simple example would be that of swans. One swan is white, so are two, so are ten, so are a thousand, so are ten thousand. All swans, therefore, are white. The claim that this process of reasoning is the 'method' of science is usually attributed to Francis Bacon (1561-1626), although use of the process itself can be traced back to Aristotle.

Induction is a powerful idea; it accounts for much of the intuitive knowledge-building of individuals and would appear to be particularly strong in a child's early development. As a method for science, however, it has problems. Ziman's call for science to generate 'reliable' knowledge, knowledge which enables safe prediction of the world has been noted. Induction only partially meets that demand. Its problem lies in the fact that general statements are based on a series of singular observations. The Scottish philosopher David Hume (1711-1776) pointed
out that there is no logical connection between singular observations and such generalisations; no matter how many observations are made, it is impossible to be certain that the next one will not contradict the pattern (news of the colour of Australian swans upsets the conclusion in the example given above).

This problem has dogged induction. It is an example of the application of an epistemological critique to a methodological recommendation for the process of science. However, the criticism does not negate induction as a method, it merely highlights the limitations of knowledge generated by the method. All methods have limitations. Philosophers have attempted to strengthen the epistemological position of induction by recourse to mathematical probability theory. Although it is not possible to state that a generalisation is true, it is, they claim, possible to make a judgement as to the probability of the generalisation being true, given the observational evidence for it. This line of thinking was pursued by Bertrand Russell and Alfred North Whitehead and later developed by others, including the future economist John Maynard Keynes. Adherents to a defence of generalisations based on probability became known as Bayesians, after the English mathematician Thomas Bayes (1702-1761), who made an important contribution to probability theory.

**Positivism**

The epistemological basis of inductive reasoning was also explored by the philosophical movement known as ‘logical positivism’ (see Ayer, 1936). Logical positivists set out to clarify the meaning of statements, categorising them as either analytic (those which follow logically from a previous statement or assumption) or synthetic (those which propose a link between things which is not a direct result of logic). Analytic statements tell us nothing new about the world, for they are logically contained within the preceding assumption; synthetic statements — the stuff of science — can only be verified by observation. Therefore the logical positivists held an empiricist viewpoint; new knowledge (that contained within synthetic statements) could only be verified through sense-experience.
The term ‘positivism’ or ‘positivist’ is taken to mean an adherence to an unwavering empiricist stance. The term was originally introduced in the nineteenth century by the French philosopher Auguste Comte (1798-1857). His use of the word ‘positive’ was to reject metaphysical or theological claims that valid knowledge could be formed from non-sensory experience. Comte’s philosophy was based on a powerfully optimistic belief in the ability of science to solve major practical problems and it originally had wide appeal. Within the twentieth century, its certainty (some would say dogmatism) has been frequently criticised, to the extent that, as Carr and Kemmis (1986) suggest, the ‘attractions of positivism have now declined to such an extent that the word has become a derogatory epithet’ (p.61). Poole (1995) suggests that positivism is best summed up by these words of Bertrand Russell: ‘whatever knowledge is attainable, must be attainable by scientific methods; and what science cannot discover, mankind cannot know’ (Russell, 1970, p.243, in Poole p.35). Positivism is not dead, however; some very influential scientists, for example the Oxford zoologist Richard Dawkins, still subscribe to a positivist position within their work.

The place of logical reasoning in scientific thinking

As it has already been suggested that impossibility of deriving generalisations logically from singular observations is a crucial epistemological limitation of induction, a brief reflection on the role of logic in scientific reasoning is important. This reflection will lead into a consideration of the second powerful mode of reasoning within science – hypothetico-deduction.

Logical reasoning depends on premises. Its fundamental unit is the syllogism, used by Aristotle (Oldroyd, 1986, p.17) as a way of clarifying his way of reasoning by categories, or classes of things. A syllogism involves two premises and a conclusion:

All cats are furry (major premise)
My pet is a cat (minor premise)
Therefore:
My pet is furry (conclusion)

The content can be quite absurd, or false as a statement of fact, but still be logically correct:

All lecturers play golf
Golf players are not boring
Therefore:
Lecturers are not boring

However, the following:

All lecturers play golf
Fred is playing golf
Therefore:
Fred is a lecturer.

is an example of a logical fallacy, regardless of whether Fred actually is a lecturer. For the conclusion to follow logically, it must be contained within the premises. A syllogism has nothing to say about the truth or falsehood of premises, it is a device for examining the validity of reasoning.

The syllogism becomes of particular importance for the philosophy of science with the development of the 'hypothetical' syllogism. Oldroyd p. 26 attributes this to another Greek philosopher, Chrysippus (280-206BC. It allows the logical handling of possibilities, rather than categories. There are two main forms of the hypothetical syllogism:

If P implies Q
And P is true,
Then:
Q is true
(known as the *modus ponens* argument);

If P implies Q
And Q is false
Then:
P is false
(known as the *modus tollens*, or ‘taking away’ argument)

Two important fallacies relate to the hypothetical syllogism. The first is known as ‘affirming the consequent’:

If P implies Q
And Q is true
Then:
P is true

This is not necessarily true. For example:

If cats are furry
And my pet is furry
Then:
My pet is a cat

Merely to observe the consequence of a hypothesis does not demonstrate the hypothesis itself.

The second fallacy is known as ‘denying the antecedent’:
If P implies Q
And P is false
Then:
Q is false

For example:

If cats are furry
And my pet is not a cat
Then:
My pet is not furry

Hypothetico-deduction:

The role of logic in the generation of knowledge has been a continual preoccupation in the philosophy of science. It can be seen that it is perfectly possible to reach logically valid conclusions in a deductive manner, but also that these conclusions are themselves dependent upon premises which are impossible to verify logically. The philosophy of science has often been characterised as a search for a way to complete an 'arch of knowledge' Oldroyd (1986), leading from observations to generalisations and then, through logical deduction, back to the prediction of observable phenomena. In general terms, induction can be characterised as constituting the first part of the arch, with the process of hypothetico-deduction constituting the second.

The term hypothetico-deduction refers to the process of reasoning through which it can be predicted from a general hypothesis that certain phenomena will be found. This prediction follows logical rules. For example:
Red balls are the bounciest (hypothesis)
Here is a tray of different coloured balls, including red ones (conditions)
Prediction:
The red balls in this tray will bounce higher than the rest.

The scientific importance of this is that the prediction can be tested through observation. It may not be possible to guarantee the veracity of the hypothesis (the initial premise), but it is possible to see whether the prediction that follows from it works.

Falsification

In his critique of induction, Karl Popper (Popper, 1934) argued that it was too flawed to constitute the process of science. Furthermore, he later stated that the idea of pure observation, upon which inductivist reasoning rests, is absurd; observation is directed by the observer (Popper 1963, p.46). Observation is selective, it needs a focus and depends on a descriptive language for its communication. It is untenable to expect knowledge to be generated from such subjective elements. Popper’s alternative was to propose a version of hypothetico-deductive reasoning, based on the testing of hypotheses. As verifiability through testing is impossible (the fallacy of affirming the consequent), he claimed that the purpose of testing is to try to disprove or falsify a hypothesis. It is only in falsification that logic will lie. A hypothesis can never be proved, but its logical consequences can be tested. It will only need a single anomalous observation to falsify it (the modus tollens position). Science for Popper therefore proceeds through a series of ‘conjectures’ and ‘refutations’:

‘The way in which knowledge progresses, and especially our scientific knowledge, is by unjustified (and unjustifiable) anticipations, by guesses, by tentative solutions to our problems, by conjectures. These conjectures are controlled by criticism; that is, by attempted refutations, which include severely critical tests. They may survive these tests;
but they can never be positively justified: they can neither be established as certainly true
nor even as 'probable' (in the sense of the probability calculus).

(Popper, 1963, preface, p.vii)

Popper argued that testing adds empirical content to hypotheses and that science progresses
through the replacing of refuted hypotheses with newer ones which have a stronger empirical
base. For Popper, it did not matter how conjectures arose; they might quite justifiably be the
result of pure speculation as much as inductive inference. The method of science did not depend
on the way ideas were conceived, but on the way they were tested. The criterion of a scientific
idea was that it was possible to conceive of a way of testing it. Falsification does not solve the
problem of truth; the process of conjecture and refutation gives no account regarding the truth or
otherwise of hypotheses. At best, they are simply those which have not yet been falsified. To
deal with this, Popper developed the conception of 'verisimilitude', with which he claimed it
was possible to identify how close to the truth a hypothesis might be. Popper was a realist, both
ontologically and epistemologically, claiming that his falsificationism would slowly generate
knowledge which was closer and closer to reality.

Falsification is not without criticism. It could be argued that all science is not
hypothetico-deductive in character, that much early exploration of an area is inductive and not
informed by a general theory. Furthermore, falsification is strongly counter-intuitive as a
description of scientific practice. Few scientists set out to prove themselves wrong. Most
importantly, falsification also appears to face severe problems when one considers the 'theory-
laden' nature of observation (Hanson, 1959). Hanson argued, much as Popper did himself
(1963, p.46, above), that observation is an active process, shaped by one's theoretical
background. As a result, the idea that a hypothesis can be refuted by observation becomes
problematic; the problem may not lie in the hypothesis, but within the theories informing the
observation statement. Popper accepted this argument and proposed that all observation
statements should be viewed as conjectural. Whether or not they provided a basis for the testing of a hypothesis was ultimately a consensual decision for the scientific community.

**Scientific research programmes**

In response to criticism of this brand of what he termed 'naïve falsificationism', Lakatos (1970) developed a 'sophisticated' version of the idea. He suggested that it was rare for the scientific process to involve the testing of only one idea at a time. He considered that the history of science showed that 'tests are – at least – three-cornered fights between rival theories and experiments' (Lakatos 1978, p.31, in Driver et al, 1996, p. 34). Importantly, he claimed that scientists do not reject a theory simply on the basis of a single contrary observation; they hold on to it, hoping that further work will enable it to accommodate the observation. He developed the idea that science proceeds through a series of 'research programmes', in which there is a central core of assumptions which cannot be modified, surrounded by 'auxiliary' hypotheses. These auxiliary hypotheses, Lakatos claimed (1970, p.136), are bound to change during the development of the programme. He cited Newton's struggle to explain planetary motion as an example; Newton continually met with anomalies which resulted in changes to his model, but he did not reject the central explanatory theories driving his work.

In addition to Lakatos, a further criticism of Popper's 'naïve' falsification can be found in what is termed the 'Duhem-Quine' thesis. Duhem stated the idea boldly as a section heading in his major work 'The Aim and Structure of Physical Theory' (Duhem 1906):

>'An experiment in Physics Can Never Condemn an Isolated Hypothesis but Only a Whole Theoretical Group'

(p.183, cited in Gillies (1993) p.98)
Duhem went on to explain that it is impossible to subject an isolated hypothesis to experimental test. The hypotheses of science interlocked and could not logically be separated. If, therefore, an observation is in contradiction with predictions, the scientist learns that at least one of the hypotheses constituting the group under study is not right, but the observation does not show which one should be changed. This makes the effect of one anomalous observation problematic; it is illogical to reject a whole theoretical group on such uncertain evidence.

**Scientific revolutions**

Kuhn (1970) considered that a sociological analysis of the history of science itself could shed light on the nature of science and the way that scientific ideas change. His work drew attention to the role of context and belief in scientific knowledge. He claimed that two different kinds of scientific activity could be identified: normal science and revolutionary science. He suggested that science proceeds in a series of 'scientific revolutions'.

For most of the time, scientists practise 'normal science'. This is work which takes place within the accepted framework of ideas and practices in that particular branch of science. The scientist's role in normal science is both to explore and clarify understanding within the framework and to examine the limitations of its application. Kuhn originally used the term 'paradigm' to describe the theoretical background and the set of beliefs within which scientists worked in normal science, but on criticism that he had made the term too vague, he restricted its use to mean a specific concrete exemplar of a practice. These exemplars were then guides for the practice of normal science and one could study how to practise science in that field by learning them. He went on to call the conceptual framework within which the research community operates, along with their rules of inquiry and their set of underlying beliefs, the 'disciplinary matrix', which, in general terms, ensured that a consistent interpretation of reality was reached by workers in the field. Within normal science, theories are produced from within a paradigm or disciplinary matrix; Kuhn termed the process 'puzzle-solving', the puzzles originating from within the accepted paradigm and soluble within its terms.

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However, Kuhn argued that as researchers attempt to solve puzzles, they continually run into difficulties. These difficulties may not be important at first, but eventually there will be many puzzles which the dominant theoretical framework cannot solve. These become ‘anomalies’ in the field. Eventually, a state of affairs may develop when there are too many anomalies to be ignored. This Kuhn described as a state of ‘crisis’. At this point, the research community begins to lose faith in the theoretical framework of normal science and starts searching for alternatives. The crisis is resolved when the old framework is abandoned and a new one which attracts the support of the research community takes its place. Normal science resumes once again, as researchers apply the new understanding to the field. They initially have to go through a period of ‘mopping up’, as anomalies and old ways of looking at the field are translated into the new framework. Kuhn’s idea is particularly stimulating from the position of the philosophy of science because he claimed that scientists displayed no particular logical necessity for choosing one framework over another. Rather, it was more a case of persuasion, ‘conversion’ and ‘allegiance’: a ‘scientific revolution’. Significantly, the new mix of paradigm examples and disciplinary matrix changes research in fundamental ways, so that the nature of the puzzles within normal science change, as does the way in which the research community interprets reality and defines truth. They represent a new way of looking at the world. The term ‘contextualism’ is sometimes given to the idea that reality can be interpreted in different ways depending on the context from which it is viewed. There are obvious links with relativism (c.f. Koulaidis and Ogborn, 1995, p.276).

What nature of science?

No overview of major positions regarding scientific methodology and epistemology, no matter how brief, would be complete without a mention of the work of Paul Feyerabend. In his two major works (Feyerabend, 1975, 1978), he cast an irreverent (he claims ‘anarchistic’) look at the methods and epistemology of science. He claimed that science does not have a special method of its own which gives it a privileged position in terms of knowledge. He further
claimed that it is erroneous to think of science as strictly rational, something which is also suggested by Kuhn’s idea of 'scientific revolutions'. Feyerabend suggested that important theoretical advances are often based on ideas which are irrational according to the thinking of the previous position. Progress, he suggested, is thus dependent on people thinking in ways that are at odds with established norms of thought.

The upshot of this, Feyerabend claimed, is that there is no privileged methodology of science which will lead successfully to the acquisition of knowledge or that, in Lakatosian terms, will allow secure decisions to be made between competing theories. He highlighted the epistemological difficulty that such a perspective suggests, stating that it leaves a situation in which the only 'rule that survives is that anything goes' (Feyerabend, 1975, p.296). In an extreme example of relativism, he further suggested that science should lose its special position within the school curriculum. There are many forms of rationality and science has no greater claim to be taught than any other:

'And yet science has no greater authority than any other form of life. Its aims are certainly not more important than are the aims that guide the lives in a religious community or in a tribe that is united by myth. At any rate, they have no business restricting the lives, the thoughts, the education of the members of a free society where everyone should have a chance to make up his own mind and to live in accordance with the social beliefs he finds most acceptable'

(Feyerabend, 1975, p.229, cited in Oldroyd (ibid.) p.338)

Summary remarks

The intention of this brief overview has been to identify major positions regarding scientific methodology and epistemology in order to aid clarity in the thesis. Each has been dealt with briefly, but, it is hoped, with enough detail to convey the general meaning of the
The discussion of the participating teachers' understanding of the nature of science deals largely with general categories; their understanding was unsophisticated. However, as much understanding lay at the tacit level in their practice, a sound grasp of key ideas is necessary to identify the positions indicated here.

The table below indicates briefly how key ontological and epistemological positions may appear in teachers' practice:

**Table 4: Possible indicators of major positions regarding the nature of science**

<table>
<thead>
<tr>
<th>Position</th>
<th>Common indicators within teachers' action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realism</td>
<td>transmission of a message that the body of science knowledge has authority; may or may not emphasise provisionality within science knowledge-building; portrayal of science as producing unquestionable, certain knowledge of the world; adherence to constructivist principles in children’s learning potentially at odds with ontological understanding.</td>
</tr>
<tr>
<td>Naive realism</td>
<td>'naive realism':</td>
</tr>
<tr>
<td>Relativism</td>
<td>a greater emphasis on provisionality in scientific knowledge; adherence to constructivist principles promoting questioning and debate.</td>
</tr>
<tr>
<td>Induction</td>
<td>promotion of the use of observation as a starting point for scientific inquiry; encouraging children to compare, contrast and look for patterns.</td>
</tr>
<tr>
<td>Hypothetico-deduction</td>
<td>Encouraging children to generate ideas for testing; promotion of the 'fair test'; testing as a way of showing that scientific ideas work. Emphasis on right and wrong answers in tests; emphasis on building understanding based on the approach that 'my idea seems to work at the moment; let's see whether it will work in another situation'</td>
</tr>
</tbody>
</table>
This portrayal is simplistic. The categories are not exclusive of each other; in reality, the teachers held complex mixes of the positions, with espoused and tacit ideas frequently in contradiction.
APPENDIX 2

Characterisations of Action Research
Source: Ebbutt (1985)
My enquiry questioning is disrupted by my need to keep control in ways the class expects.

Record questions and responses on tape for a couple of lessons to see what is happening. Keep notes of my impressions in a diary.

Enquiry developing but students are more unruly. How can I keep them on track? By listening to each other, probing their questions? What lessons help?

Record on tape questioning and control statements. Note in diary effects on student behaviour.


Shift questioning strategy to encourage students to explore answers to their own questions.

Try questions which let students say what they mean, what interests them.

Continue general aim but reduce number of control statements.

Use less control statements for a couple of lessons.

Source: Kemmis and McTaggart (1982)
Source: McKernan (1991)
Source: McNiff (1988)
APPENDIX 3

Ethics Protocol

Version agreed with participating teachers at the outset of the inquiry, showing original draft title.
Primary teachers and science: considering the importance of epistemological understanding

ETHICS PROTOCOL

(Based on the guidelines published by the University of Plymouth: ‘Ethical principles for research involving human participants’)

Informed consent / Right to withdraw

1) The permission of the Head teacher will be sought prior to entry to the school. The nature of the research and role of the researcher will be explained clearly to members of staff before any data gathering commences.

2) It will be emphasised at the outset that involvement in the research by members of staff is voluntary and that they have the right to withdraw at any time, should they so wish. If children are to be involved, either those acting in loco parentis or the children themselves, if it deemed that they would have sufficient understanding, will also be informed of the right to withdraw at any time.

3) If staff members are to be interviewed or asked to complete questionnaires, they will be told of the nature of the content in advance and that they have the right to refuse to participate or to withdraw at any time.

4) The focus of the research will be teachers. However, should it be appropriate to talk to, work with or interview children, consent will be obtained from those acting in loco parentis. It is not anticipated that the research will deal with sensitive issues, however, should a potentially sensitive topic arise, written informed consent will be obtained from parents.

Openness and Honesty

The researcher undertakes to be open and honest in all matters concerning the purpose, method and application of the research. This will take the form of an initial briefing session, coupled with more detailed discussion of methodology and access with participating teachers. It may be inevitable that the researcher will not be able to explain every focus of his own reflections, but he commits himself to the discussion of all aspects honestly, should he be asked.
Confidentiality

1) The researcher undertakes to maintain the confidentiality of participants at all times, unless they have specifically given written consent for him to do otherwise.

2) Participants will be assured that information gathered from observations, interviews, questionnaires or other instruments will not be shared with any other person in such a way that their identity might be recognised.

3) Every effort will be made to anonymise evidence used in any documents based on the research. It is anticipated that this will entail the use of pseudonyms or the use of titles, e.g. Head teacher. If it should be appropriate to convey something of the character and geographical location of the school, this will be done in general terms, without specific references that may enable identification by others.

Protection from harm

The researcher will be working in a variety of modes whilst in school, from non-participant observer to participant teacher. The researcher is a qualified teacher. He may at times be working in a position of responsibility with children; permission for such activity will be sought from the Head teacher prior to the research commencing. If the researcher finds himself in a situation where there is a potential for harm to children and there is no member of staff present to intervene, he recognises his responsibility to respond to such an incident in accordance with school policy. The implications of such action will be discussed with the Head teacher prior to the research and agreement reached that such action is permitted.

Debriefing

On the conclusion of the study, the researcher will provide an account of the main findings of the research to the participating staff and the Head teacher of the school. Such a report will acknowledge the requirements already mentioned for the protection of confidentiality.
APPENDIX 4

Lesson observation – Heather 4.10.95
Teacher

Do you think everything will float?
(Gets some paintbrushes) What about these?

(Goes over to the water)
Which bit comes up first?

Why is the metal making it go down?
(Gets a block of wood)

What did you say before, D?
(Gets a ruler)
Why?

What if we covered the hole?

Ca has a light piece. What this like?
Let’s put the wobblers to one side...

What did you say before?
What does that tell you about your ideas?
Does the hole make a difference?

Try standing it upright
This is an interesting one – a pencil

(Recaps what they have done). Did anything sink?

Children

No

J – It might sink because it’s got a much harder bit.
D – The metal bit will pull it down, but the wood’s heavier, it will pull it up.
Ca – The wood will float, even though it’s heavy.
(J tests brush)
J – The wood, the metal’s going down.
D – ‘cos it’s heavier.
J – a little bit stops over the water.

No answer
J – It wobbles as it comes up
Ca – ‘cos it’s light.
J – The water’s making it wobble. It’s got a curvy bit.
The wheel wobbles as well – it’s got that shape.
D – the hole would make it float
D – It would sink

(D goes off to cover hole)

(D returns with hole covered)
I think it’s going to float
(Wheel floats)

(D tries to push it down)
No
J – It wobbles – it wobbles sideways.
(Ca has wooden horse)
(Still floats)

(J is holding the wheel) Wait a minute, let’s see if it wobbles

Thoughts

Exploration of the phenomenon of floating and sinking – what actually happens

Exhibits logical sequence in thinking

How many refutations needed?

Why? Is the children’s attention drawn to the composition?

Lead to other work on forces?
| (Paints out the hole in the wheel) | D - No. |
| Will it make a difference, D? | (Paintbrush floats) |
| (Goes back to the paint brush) | D - 'cos they're both the same weight |
| What did you think before, J? | (wood and metal) |
| Why? | (J wants to compare with other |
| (Gets some plasticene. Weighs it in her | paintbrush – has different composition) |
| hand). It's...heavy! Do you remember | Ja - All these wooden things float. |
| what we were saying last time? – heavy | Ja - The fir cone's spinning cos it's a |
| things sink. | ball shape. |
| What will happen to it? Feel it. | D embarrassed |
| D - if you put a hole in it, what would | Why? |
| happen? | All engaged in looking at |
| (Gives the children one piece each) | how to make it float using |
| Test out whether they sink or not. | wood. |
| How are you going to change it, D? | Change of idea |
| Even with a hole? | |
| Why should that make a difference? | |
| You're using the wood to help you. | |
| Anyway, can you make it float without | |
| using the wood? | |
| Try making it into a flat shape – really | |
| flat | |
| (T. attends to the rest of the room) | (All still sink) |
| | (Ja makes a ring – sinks) |
| | D - That's 'cos it's got a hole in it |
| | (J's boat shape floats then sinks) |
| | J - it sinks because it gets more water |
| | in. (Fascinated by it, tries to show it to |
| | the others). |
| | (No-one seems to take up J's boat |
| | shape). |
APPENDIX 5

Lesson observation - Elizabeth 8.11.95
<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>We are putting things together that fit. If I wanted to sort them, how would I sort them? Let's look first, before we touch. (Lays out objects) Now, touch. Look at them with a friend if you wish.</td>
<td>(3 – focuses on animals – play. 4/5 – building bricks). 5 –(frame) This is funny – it's made of metal and glass. (general exploration)</td>
<td></td>
</tr>
<tr>
<td>Put them back. We'll play a game. It's going to be difficult – I don't want you to touch at the moment. A thinking time. If they were yours, which would you put together? Think of an idea. The rest of us will try to work it out when you have sorted them.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 – Why? 1 – Why? That makes them different. We want to focus on what makes them the same. But these are different materials. Did you choose because they were small? Can you make smaller sets? (Thanks 3) (Asks 1) Remember, how they belong together Any ideas? That makes them different. Was it because they were small? To begin with, I thought hard... 2 – Your turn Can you sort them out more? 4 – Your turn. What would you like? 5? There's one thing that is a little different? (Focuses on train) It's a special kind to make it look like wood.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3 – coral/ cow/frame/weight/mouse/sheep/ necklace/flat animals) 1 – 'cos they're the same; cos one stands up and one doesn't. 'Cos they're both wood? 3 – No. Because they're the same colours 1 – flat mouse/ coin/ key/ wooden circle/ mouse/ stone/ peg 6 – It goes little, middle sized, big, long 1 – Yes. 4 – and wooden things. 2 – sheep/ marble/ ruler/ apple (plastic). 1 – big things and small things? 4 – cotton reel/ plastic train/ cork All wooden things</td>
<td></td>
</tr>
</tbody>
</table>
5's turn

(Suggests magnifying glass)

Anyone?

Can I have a turn please?
Frame/ spoon/ key
We’re going to be thinking about what things are made of – not colour, but made of and what they can do – (shows bendy, not bendy plastic)

Take a clipboard, walk around the room and look at different things. Work out what they are made of.
Write down and draw.
See how many different materials you can find.

5 - frame/paperweight/mirror
1 - (suggests key)
1 - he wants all glass things
2 - they’re metal
1 - they sound like glass
5 - coral/mouse/pencil/tape box/ruler
1 - I think he’s thinking about glass and hard.
5 - adds box, bricks, sheep, cow, egg cup, cotton reel....

2 - wood, plastic, metal
1 - glass, boxes, metal and hard things

5 - Yes...
4/5 - Metal!

4 - paperweight - Metal
No, glass!!
5 - bricks, wood
6 - key - metal
3 - sheep - wool
2 - magnifying glass - metal/glass
1 - mouse - wool, string, wood

Keeping then focus a difficulty?
But, is focusing on properties of materials anyway!
APPENDIX 6

Lesson observation – Andrea 12.11.96
<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Let's recap on what we did yesterday. What do you have to do before we start?</td>
<td>-Date, title</td>
<td></td>
</tr>
<tr>
<td>What title?</td>
<td>- Light</td>
<td>- What materials light goes through</td>
</tr>
<tr>
<td>We wrote down our question. Someone else?</td>
<td>- We had to do a plan. All the materials you were going to use.</td>
<td></td>
</tr>
<tr>
<td>(Follows up). Make a list. Then?</td>
<td>Test it.</td>
<td></td>
</tr>
<tr>
<td>Before that?</td>
<td>Think how we can record.</td>
<td></td>
</tr>
<tr>
<td>What does that mean?</td>
<td>In your book, draw a chart, put all the materials in one section and then estimate.</td>
<td></td>
</tr>
<tr>
<td>So it showed ideas. Why should we think of recording before we start? Why do we need a plan?</td>
<td>So you know what stuff is going to work.</td>
<td></td>
</tr>
<tr>
<td>Any other ideas? Why don’t I just say – there’s a list, get on with it.</td>
<td>- So you know what you’re trying to do. - So we’ve got a record - So you know what light goes through and doesn’t go through.</td>
<td>Seems to indicate some understanding of the purpose of planning</td>
</tr>
<tr>
<td>So you know what happens. Make sure you’ve got a list of things you’re going to use and a way of recording your results (Gives out books) (Sends the planners to their desks)</td>
<td>(Children test the materials)</td>
<td></td>
</tr>
<tr>
<td>What is the torch for? (Gives a reminder about the use of equipment)</td>
<td>It's for investigating</td>
<td></td>
</tr>
<tr>
<td>If you think you’ve finished investigating, write down what you think you’ve found out. Who thinks they’ve found out something they’d like to share?</td>
<td>- It only goes through see through things and thin stuff - Glass, cos it’s see through</td>
<td></td>
</tr>
<tr>
<td>Who thinks that thickness has something to do with it?</td>
<td>- I think thickness has something to do with it, cos thin stuff it will go straight through</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>- The thinner it is, the more you can see through.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- No...some thin stuff it won’t go through.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Like wood.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- I had wood this thin and put the torch on it and you could see it.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I'd like to see that.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Why didn’t it go through the bluetak?</td>
<td>- Cos it’s sticky</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>If you haven’t managed to write down, write it down at another time.</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>General – the plan:</th>
</tr>
</thead>
</table>

The children had a little lack of clarity as to exactly what was intended in the initial list they were making - some a full list / no predictions, some a full list / with prediction, others splitting the list into 2 separate lists based on predictions. All using a tick or yes / no way of recording the tests.

Children unsure about the exact nature of the materials to test – ‘nylon’ / ‘sheet’ / ‘cotton’ etc. Much choice in the boxes – any mileage in giving them a much reduced and pre-determined set of materials to avoid confusion?
APPENDIX 7

Completed bi-polar semantic differential scales

There follow copies of the original scales completed by the teachers. In order to accommodate the formatting, the page numbering has been moved to the right.
Teachers' understanding of science project 1995/1996

Within the following table, each of a range of attributes that could be applied to science, its nature and the kind of knowledge that it produces is presented in the form of a continuum, with what could be considered as opposite poles located at either side. The attributes I have chosen originate partly from the evidence you have so far contributed about what you consider to be important aspects of science and partly from my own ideas.

Each continuum is itself divided into five points. I should be obliged if you would consider each and indicate by ringing a number where you would place your understanding of science on the continuum, e.g.:

<table>
<thead>
<tr>
<th>(Strongly)</th>
<th></th>
<th></th>
<th></th>
<th>4</th>
<th>5</th>
<th>(Strongly)</th>
</tr>
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<tbody>
<tr>
<td>Rigorous</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>Laissez faire</td>
</tr>
</tbody>
</table>

Thanks!

So, Science is:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th>4</th>
<th>5</th>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>Descriptive</td>
</tr>
<tr>
<td>Certain</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>Provisional</td>
</tr>
<tr>
<td>Sure</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>Tentative</td>
</tr>
<tr>
<td>Systematic</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>Unsystematic</td>
</tr>
<tr>
<td>Cohesive</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>Unconnected</td>
</tr>
<tr>
<td>Rigorous</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>Laissez faire</td>
</tr>
<tr>
<td>Exploratory</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>Lacking</td>
</tr>
<tr>
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<td>2</td>
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<td>4</td>
<td>5</td>
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</tr>
<tr>
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<td>2</td>
<td>3</td>
<td>4</td>
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</tr>
<tr>
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<td>4</td>
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<td>4</td>
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<td>Questioning</td>
<td>1</td>
<td>2</td>
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<td>4</td>
<td>5</td>
<td>Unquestioning</td>
</tr>
</tbody>
</table>

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<tbody>
<tr>
<td>(Strongly)</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

Thanks!

So, Science is:

|  | Explanatory | 1 | 2 | 3 | 4 | 5 | Descriptive |
|  | Certain     | 1 | 2 | 3 | 4 | 5 | Provisional |
|  | Sure        | 1 | 2 | 3 | 4 | 5 | Tentative   |
|  | Systematic | 1 | 2 | 3 | 4 | 5 | Unsystematic |
|  | Cohesive   | 1 | 2 | 3 | 4 | 5 | Unconnected |
|  | Rigorous   | 1 | 2 | 3 | 4 | 5 | Laissez faire |
|  | Exploratory | 1 | 2 | 3 | 4 | 5 | Lacking Exploration Objective |
|  | Subjective | 1 | 2 | 3 | 4 | 5 | Objective |
|  | Verified   | 1 | 2 | 3 | 4 | 5 | Unconfirmed |
|  | Public     | 1 | 2 | 3 | 4 | 5 | Personal |
|  | Imprecise  | 1 | 2 | 3 | 4 | 5 | Precise |
|  | Discovered | 1 | 2 | 3 | 4 | 5 | Constructed |
|  | Changing   | 1 | 2 | 3 | 4 | 5 | Unchanging |
|  | Questioning | 1 | 2 | 3 | 4 | 5 | Unquestioning |
### Teachers' understanding of science project 1995/1996

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<table>
<thead>
<tr>
<th>Attribute</th>
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<tr>
<td>Laissez faire</td>
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</table>

Thanks!

So, Science is:

<table>
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<tr>
<th>Attribute</th>
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<td>5</td>
</tr>
<tr>
<td>Precise</td>
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</tr>
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</tr>
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</tr>
<tr>
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APPENDIX 8

Questionnaire responses.

There follow responses from Elizabeth, Carol and Heather. No response was obtained from Andrea.
I am interested in exploring a little about the way you feel when you are teaching – the kind of focus or concentration you might have, how it might change, etc. I should be very grateful if you could share some thoughts in reply to this questionnaire.

Thanks in anticipation,

Steve

Name: Elizabeth

1) What would you say motivates your teaching?

Several things I think:

- the desire to do it well;

- the huge responsibility of the job, in terms of affecting the children’s happiness, learning potential, safety…;

- a fairly deep interest in the job. When it’s going well and I’m not hassled I find it really stimulating. I enjoy talking about my work, reading about it, and planning my lessons;

- I never feel satisfied with my work; I think I am also motivated by wanting to improve my practice. I suppose this is linked with my first statement.
2) We all have an idea of what characterises our best teaching. What do you see as the main characteristics of your best teaching? (Please, your own thoughts, not necessarily what Ofsted, etc. might want!)

- respect for the children’s ideas;
- valuing what they do;
- that children have needs and interests which they bring to each learning situation and that what I plan must take account of this;
- the quality of the relationship between the children and myself (and their families);
- being well prepared in terms of knowing what I want to teach and how;
- trying to provide high quality materials where I can;
- being reflective and self critical;
- being stimulating (or rather being able to stimulate children’s interest);
- making activities developmentally appropriate (linked with 3 above).

3) What does it feel like when it’s happening?

Wonderful! Stimulating and totally absorbing. It has a kind of momentum to it; one thing leads to another and it feels really exciting, especially when something is sparked off that perhaps I hadn’t planned for. It’s totally rewarding too, although it feels ‘corny’ to say it. I keep thinking of myself as a learner and how great it feels to have learnt something new or achieved something I couldn’t do previously. In the same way it feels good to be instrumental in making things happen for children. I feel education can be instrumental in changing people’s lives; how good to be involved in being part of this process.
4) How easy do you find it to feel fully engaged with your teaching, hour to hour, day to day, etc.?

I don’t find it easy to be fully engaged all the time, and I don’t think I am. Being fully engaged, however, is definitely linked with my interest in the subject I am teaching. I can often generate an interest too by planning more carefully, reading about the subject, or talking with others. And because I feel committed to my work, this is, I think, how I try and maintain a level of engagement. Lots of things can impinge on my day to day teaching in a negative way, and interfere with total engagement – how the children are, the way my colleagues are feeling, my own energy levels, even the weather!

5) To what extent do you feel like a teacher?

I’m finding this question difficult to answer. In many ways I feel very like a teacher because I have been one for so long, but in some ways I don’t feel like a typical teacher (whatever that may be). I don’t feel like a controlling kind of teacher, more a facilitating kind of teacher; someone who is responsible for creating the best kind of environment, and interacting with the children in the best possible way for learning to take place.
I am interested in exploring a little about the way you feel when you are teaching – the kind of focus or concentration you might have, how it might change, etc. I should be very grateful if you could share some thoughts in reply to this questionnaire.

Thanks in anticipation,

Steve

Name: Carol

N.B. A quick note to say all this is off the top of my head due to severe time constraints!

1) What would you say motivates your teaching?

In the first place: I went into teaching because I enjoy ‘young minds’. I am fascinated with their fascination. I am motivated by their motivation, I am enthused by their enthusiasm.

Watching a young child with their hands immersed in clay (water/sand etc. etc.) you see how in touch with the world they are...in that they are fully absorbed in the experience.

As a teacher I am able to provide opportunities to extend their experience, to raise their awareness and deepen their thinking – i.e. not to necessarily to provide answers for them but to instil an investigative attitude in which they start to ask their own questions.
2) We all have an idea of what characterises our best teaching. What do you see as the main characteristics of your best teaching? (Please, your own thoughts, not necessarily what Ofsted, etc. might want!)

...This is a continuation of the previous page really. I'm not much good at the finer details of planning and recording...but I think I can enthuse children...probably because if I see that they are interested in something it makes me feel that I'm doing my job well...and so it goes on - a perpetual cycle of finding out what works. Now then, no one ever told me that there is no magic formula - since every child is different ( & each 'group' is different) there is no one way of teaching...thus to get it right, i.e.) inspire your class or an individual – means that you have to know your children well.

3) What does it feel like when it's happening?

I can answer this in reverse – when a session is dire - i.e. the work is not matching the children’s ability or grabbing their interest, or whether you haven’t organised the time/space/resources well...I feel that it’s a ‘waste’ of time. Small group times are precious these days, I only see each group twice a week – so I feel deflated if the task is mismatched or dull. I believe that every experience in school should be purposeful, whether child initiated, teacher directed or supported by other adults or children in school. When things go well I know because the time flies by, and there are usually lots of avenues to continually explore. This is immensely satisfying, and makes the enthuse - learn - enthuse model continue.
4) How easy do you find it to feel fully engaged with your teaching, hour to hour, day to day, etc.?

This very much depends on what I’m teaching. For example, Dance, Science, Art, History – are relatively easy to become absorbed in. The social/behavioural aspects are now easily managed (circle time etc.) but there are vague parts of the day – one simply cannot ‘give’ all day long without lapses of concentration...well I can’t. I did once witness M.S. with a class and was amazed at how much she teaches without knowing it. I aspire to this great height – one day!. Anyway, I hope that this answers your question.

5) To what extent do you feel like a teacher?

Well in spite of all this grand stuff I’ve written about how and why I went into teaching, I’m sorry but I never think of myself as actually having made it to that elusive teacher status! Honest! (No, apart from at Monday staff meetings). During class time I have to say that whilst I set out the framework for what we are going to do – and aim to ensure that we cover all the required areas – (monitor & record etc.) But on a day to day basis, the class share with me the responsibility for the day’s learning. Teaching needs to have a framework – ‘a trellis for the vine’ but many of the most enhancing experiences have been instigated by the children.
I am interested in exploring a little about the way you feel when you are teaching – the kind of focus or concentration you might have, how it might change, etc. I should be very grateful if you could share some thoughts in reply to this questionnaire.

Thanks in anticipation,

Steve

Name: Heather

1) What would you say motivates your teaching?

The desire to see success;

A fascination for watching children discover/learn.

2) We all have an idea of what characterises our best teaching. What do you see as the main characteristics of your best teaching? (Please, your own thoughts, not necessarily what Ofsted, etc. might want!)

Holding the children’s interests – being able to keep the majority focused and interested. Using children’s questions to keep children’s thoughts moving without demanding ‘set’ answers.
3) What does it feel like when it's happening?

Easy when it's actually happening – sometimes hard getting there.

Things flow naturally when the children show genuine interest and keeping this ‘moving’ becomes easier the more it happens. Fascinating when you hear what ideas they – it's like unlocking a secret door! Listening to their thoughts out loud.

4) How easy do you find it to feel fully engaged with your teaching, hour to hour, day to day, etc.?

Depends on the other demands being put on you in that particular week/day.

Sometimes it’s nice to be able to forget Ofsted/planning/staff meetings and bury oneself in a teaching session – it's like showing yourself what it’s really all about. Other times there are so many other demands on your thinking time that it is very difficult to become ‘engaged’ in teaching you find that you’re so tired it just won’t happen.

5) To what extent do you feel like a teacher?

However hard you try not to let teaching take over your life I think it is a way of life. You are always looking for answers to questions, furthering your own knowledge/learning, looking for resources. I feel like a teacher all the time, even when at home, etc. Sometimes at school I think to myself what have I ‘taught’ today and it is almost impossible to say nothing – even on a really bad day I know I have at least disciplined and taught somebody about right and wrong even if the lesson plan went out of the window!
APPENDIX 9

Portraits of the teachers

These short portraits of the teachers are intended to add contextual depth to the case studies. They give supplementary biographical information and present an image of the teacher at work in her classroom. They derive from observational and other data collected during the course of the inquiry and have been modified from initial drafts following respondent validation by the teachers.
Of the four teachers involved in the project, Elizabeth had been teaching for by far the longest time. In 1995, this amounted to twenty two years experience, all of it spent as a class teacher, albeit with a range of curriculum and managerial responsibilities. At the beginning of the project, Elizabeth was Infant co-ordinator and had recently held a position as subject leader for mathematics within the school. She originally qualified with a Certificate in Education, which she had upgraded by taking a B.Ed degree. By 1995, she also held a Certificate of Applied Professional Study (CAPS) in the leadership of the mathematics curriculum.

Elizabeth was an enthusiastic teacher who applied herself with great commitment to her practice. An early years specialist, she had developed a pedagogical approach which was consistent with strong beliefs about the nature of young children, learning and education. During the time of the project, Elizabeth taught a Reception class. Her organisation of this class followed a fairly common pattern for such age groups, with a mixture of group work and whole class discussion times, with much practical activity. However, it was in the special flavour that she imparted to this common organisation that her individuality and pedagogical values became apparent. She would treat the children with a calmness and tenderness that was remarkable and displayed a deep concern for the well-being of each child. The school day was punctuated by events that were designed to encourage and deepen the children's self-esteem and their understanding of how to respect each other. She had introduced to the two Reception classes the daily institution of designating a ‘special person’, about whom the children would be encouraged to identify positive, likeable qualities. The idea was not new, but the sincerity and genuine warmth for the children which she brought to the activity could not fail to impress an observer.
This concern for the children was matched by a deep interest in teaching and education. She considered herself to be a mathematics and language specialist and had regularly attended courses related to these areas of the curriculum. Despite the often intense pressure of change that was affecting schools at the time, her commitment to teaching never faltered. In written reflections about her teaching, she considered what motivated her, commenting simply: ‘...I find it really stimulating. I enjoy talking about my work, reading about it and planning my lessons’. Her further responses to a short sequence of questions show just how deeply she enjoyed the experience of teaching, drawing parallels between her own motivation and that which she wanted to pass on to children. She saw her best teaching as being intensely satisfying:

Q. What does it feel like when it’s happening?

A. Wonderful! Stimulating and totally absorbing. It has a kind of momentum to it; one thing leads to another and it feels really exciting, especially when something is sparked off that perhaps I hadn’t planned for. It’s totally rewarding too, although it feels ‘corny’ to say it. I keep thinking of myself as a learner and how great it feels to have learnt something new or achieved something I couldn’t do previously. In the same way it feels good to be instrumental in making these things happen for children. I feel education can be instrumental in changing people’s lives; how good to be involved in being part of this process’.

(see appendix 8)

One almost wants to add an exclamation mark after the last sentence, such is her enthusiasm.

The general pedagogical ideals she articulated reflected this interest in children’s well-being and her excitement with what she understood as the process of learning. She
was strongly committed to the principle of developing children's conceptual and
cognitive abilities through experience, advocating an 'emergent' approach to the teaching
of both mathematics and language. Much of her practice was structured around practical,
investigative tasks. She thought deeply about the nature of children's learning and how
to encourage it. Her description of the kind of teacher she wanted to be is illuminating:

Q. To what extent do you feel like a teacher?

A. I'm finding this question very difficult to answer. In many ways I feel very
like a teacher because I have been one for so long, but in some ways I don't feel
like a typical teacher (whatever that may be). I don't feel like a controlling kind
of teacher, more a facilitating kind of teacher; someone who is responsible for
creating the best kind of environment, and interacting with the children in the
best possible way for learning to take place.

(see appendix 8)

She passionately wanted to structure her classroom and her teaching so that she
could develop children's thinking ability. She was a member of a local group of the
Society for the Advancement of Philosophical Enquiry and Reflection in Education
(SAPERE) and regularly attended discussion meetings. She wanted to design activities
for the children that promoted enquiry and investigation. Stating that 'thinking ....has
been seriously neglected in the past', she considered that she provided 'quite a lot of
opportunities for thinking' in her classroom (interview 10.7.95).

Much of her practice did reflect these ideals. She would frequently structure the
children's activities so that they would be challenged to make decisions for themselves,
allowing them space and time to act independently. The overall organisation of the
classroom aided this process; through her constant reminders, the children were
sensitised to the needs of others and to the necessary restrictions on behaviour that
would enable the classroom to function. She strove to develop their attitude and
approach to their work; activity in her classroom nearly always appeared to be
purposeful. Not that this meant children were sitting all the time; Elizabeth would
frequently set tasks which required them to move around the room, gathering
information or data for themselves, practising emerging recording skills. When such an
activity was an integral part of a session, she would help the children to identify and
focus on the kind of behaviour they needed to show to each other, contextualising her
wish to develop their respect for others and their own sense of value and worth. A
characteristic of her practice here was that she tried to let the ideas come from the
children, not wanting to impose her own expectations about behaviour, but striving to
help the children generate their own understanding of a rationale for their conduct.
Within the curriculum areas she felt most confident in, the style of session and her own
interaction with the children could be seen to be closely aligned to these pedagogical
values. Particularly within mathematics, she would promote the children's
understanding of sets and sorting, encouraging understanding of number through the
classification of experience. She seemed to have the ability to make her interaction with
the children open and a stimulation for their ideas; she gave the impression of having a
great interest in listening to what the children actually said.

Elizabeth was strongly interested in home-school links. She held a holistic
picture of what she described as the child-family-school situation, seeing all elements as
partners in one enterprise. Her classroom truly felt inviting to outsiders. This link with
the 'outside' did not stop at strong relationships with parents; Elizabeth was interested in
being as involved with research into education as possible. Aside from this inquiry, she
had frequently been involved with researchers from another local university, gladly
welcoming them into her classroom. Such action reinforced her profound philosophical
interest in education and she would seek out conversation that dealt with ideas.
However, though able to discuss educational matters at a deep level and though widely read across a range of educational literature, especially in child development and learning, Elizabeth was a quiet and gentle person, with a self-effacing character. In the natural deferment to others that was obvious in her demeanour, she mirrored and lived the values she had for the children in her class.

Of all the teachers in the inquiry, Elizabeth was the most diligent planner. Notes and session plans, as well as medium and long term planning, would all be written up thoughtfully and in considerable detail. The strength of her commitment to personal professional development was evidenced by her normal practice of engaging in written reflection on issues of practice, prior to any of the specific demands of the inquiry. When it came to her involvement in the inquiry, she was full of enthusiasm. Of all areas of her teaching, however, science took the longest to plan. It was an area in which she did not feel confident to take the kinds of risks she felt able to in other areas, especially English and mathematics. She felt she did not have the kind of overview of the subject that allowed her to do this. Her commitment to the philosophy of ‘emergence’ within English and mathematics in the early years had led her to apply the principle in theory to science, only she had no real idea what this might look like. This meant that she was far less inclined to take risks in her science work than in the other two areas. She wanted to know if ‘emergent science’ was possible, or a reality. Sensing that it might be possible to chart children’s development in science in their play or in the other areas of learning within the classroom, she wanted to develop a secure overview of the area to help her identify this development if it happened. Her involvement in the project, she hoped, would help provide this.
At the start of the inquiry, Carol was the most newly qualified teacher of the four. She had been teaching for nearly two years, returning as a mature student to take a Drama/Education and Community studies degree and then a P.G.C.E. Both of her two years' teaching experience had taken place at the same school, in which she taught a Reception class alongside Elizabeth. She had been designated as the school’s subject leader in art and, in addition to the inquiry, was also engaged in trying to co-ordinate staff development in this subject.

Carol was a strong minded and committed teacher. Although relatively inexperienced, her maturity had given her strong ideas about what was important in life, influencing both her educational philosophy and her practice. She had a well-developed sensitivity to environmental issues and would seek opportunities both to relate her work in the classroom to them and to introduce them directly. Her sense of care and concern for the ‘environment’ could frequently be seen to influence the content of her sessions and her interaction with the children. When one coupled this with her perception that she was most comfortable in those subjects which could be called ‘expressive arts’ (something powerfully endorsed by observation of her teaching), it could be seen to explain the strong sense of creativity that was always present in her classroom.

Carol’s classroom was filled with children’s activity. The results of it adorned the walls or hung from the ceiling in colourful and stimulating displays. Her practice seemed to be designed on the basis of ‘discovery’. At the same time, she was passionately committed to the promotion of children’s independent activity and to the importance of teacher contact with them. Children would frequently be given work that was aimed at promoting exploration and in this she would spend much time working alongside groups on the carpet. Many times, sessions began or finished with a variety of songs or action rhymes which she would accompany on the guitar.
Carol described herself as having a holistic attitude towards the education of young children and the nature of their conceptual development. It underpinned her teaching style and influenced her decision to adopt the ‘discovery based’ classroom described above. Children’s lives, she claimed, did not fall into discrete subject areas and she found that kind of conceptualisation limiting. She considered that when children were engaged in investigative or self-initiated activities, specific understanding could emerge from integrated, non-differentiated experience. She did not feel she should restrict the possibilities by focusing the activity, as would be inevitable if a subject perspective was adopted. She stated frequently that she was glad she taught Reception children, in that they were not covered, as such, by National Curriculum requirements, thus lessening the pressure upon her to reduce their experience to discrete subject areas. She was very sceptical of the benefit of the National Curriculum, especially its assessment, feeling that its content was somewhat arbitrary and limiting. In a preliminary interview, she stated:

As you’ll find out, I have a very holistic sort of thing about education and that is my philosophy, my personal philosophy which spills out into what I’m doing, which is probably why I have to stay in Reception, because after Reception, once you’re playing with, you know, curriculums and guidelines and deadlines....Even if you’re looking at the SAT things; I’ve looked at the questions and said sort of ‘Well, there’s more than one answer to that!’ And there are so many questions and there are so many answers and I just don’t believe that any one ever finds them...

Her answer to a question about what motivated her teaching captures some of this understanding when applied to the children themselves:

I went into teaching because I enjoy young minds. I am fascinated with their fascination. I am motivated by their motivation, I am enthused by their enthusiasm. Watching a young child with their hands immersed in clay (water/sand etc.) you see how in touch with the world they are...in that they are fully absorbed in the experience.

(interview 7.95)

Carol was a dancer. She ran a dance club for the children in the school and tried to involve staff in her enthusiasm for dance in the curriculum. Her statement above identifies
children's 'minds' as more than just intellectual activity; to her, thinking, feeling and physical activity were inseparable. Dance was an illustration of this kind of 'holistic' understanding in action. The understanding was also responsible for her enthusiasm in the role of subject leader for art in the school. She had worked with the local advisor for art and was involved in courses exploring children's development in the subject. Now she wanted to enthuse her colleagues and was in the process of carrying out a review of children's achievements in art throughout the school, planning and organising staff development sessions. Carol naturally incorporated much art work in her own classroom. It was where she felt most at home. It was here that she felt that she really knew where she was going, what strategies worked and what children needed. It allowed her to exercise her desire to work alongside children most effectively; her practice introduced the children to a wide variety of techniques and she would engage confidently in modelling action for the children, drawing, painting or sticking with them. Results were often stunning, with four and five year olds producing work of impressive detail or sophistication.

Carol was very committed to helping children develop an ability to inquire and investigate. She wanted children to ask questions about their world and she would frequently plan activities which set children challenges and encouraged this kind of thinking. In support of this, she saw the development of children's independence as crucial to their overall development, wholeheartedly embracing the 'Plan-Do-Review' strategy introduced throughout the early years classes in the school, making it a strong feature of her work. Such a strategy was designed to encourage children to make decisions and act systematically, letting them take the responsibility for the planning of their own activities before they did them and helping them to reflect on their effectiveness afterwards. Each afternoon in the Reception classes was devoted to this. Children were allowed free choice of planned action within a limited number of options. Much of her role in any self-initiated or 'investigative' activity she saw as being purely facilitative. Describing her teaching, she said:
As a teacher I am able to provide opportunities to extend their experiences, to raise their awareness and deepen their thinking - i.e. not necessarily to provide answers for them but to instil an investigative attitude in which they want to ask their own questions.

However, no matter how strong the commitment to investigative work, she admitted to feelings of uncertainty as to her role during such activity by the children. She would frequently start the children off and then find herself unsure about the best way to help them. This could at times lead to a slightly frenetic feel to the classroom, in which there was much activity but an uncertainty as to its direction. Her general philosophy led her to state that in this kind of work she saw the teacher as rather superfluous once the children were engaged in a task, but this wish not to ‘interfere’ with the children’s ‘explorations’, was also a source of tension in her teaching. She felt the pressures of curriculum accountability that seemed to be forcing her to try to identify discrete structure within the experiences.

This tension was exacerbated because Carol was still rather insecure about her role. The idea that a good teacher became rather superfluous once children were engaged on this kind of was fine if one was confident with what the children were doing. Carol frequently wasn’t. For although her holistic philosophy made her sure of her justification for this kind of approach, she knew that her pedagogical framework for handling the children’s inquiry work was unsound. Frequently, she was unsure of the purpose of her sessions and where the children ought to be going. The result was that she was left with a distinctly uneasy feeling of insecurity. It was one thing to ‘remove’ oneself when one was confident about the purpose and direction of the children’s task; it was simply another when one was very unclear about why they were doing it. Carol wanted the project to help her with this. She wanted it to help her develop a way of interacting with the children so that she could monitor what children were doing effectively and she wanted it to help her develop a framework of understanding in science teaching that would enable her to place the children’s actions within a more general picture of development.

Fundamentally, however, she wanted it to help her validate the children’s own development, for in her terms, that was the driving force of the curriculum:
...that's my thing - am I asking the right sorts of questions to see whether or not I'm extricating what the children really know, to access what they know because they know a lot and it's very often their ideas and explanations are far more than we give them credit for...

(interview 7.95)
Heather had been teaching for five years at the beginning of the project. She had entered teaching after taking a BA Combined Studies, specialising in Human Geography and Education. Her subsequent P.G.C.E. had trained her to teach in the early years and she had taught either Year One or Year Two since qualifying. She had a curriculum responsibility for geography within the school.

At first sight, there was little that was very distinctive about Heather’s classroom or her practice. It was not a drab classroom, but their was nothing of the flamboyance of colour and display that might have been seen in Carol’s. Heather worked steadily at completing her displays, but they took time to complete and tended to be functional, with a considerable amount of teacher directed work. There was a slight air of scruffiness to the room, with children’s resources - books, pencils, rulers, etc. - spilling out of their allotted storage places, just enough to indicate that this aspect of their self-reliance was not a priority. When the children were working, her classroom usually appeared well ordered, with a variety of group work going on. Sessions were generally introduced with a calm lack of flamboyance with, by and large, this calmness transferring to the children in the class. These characteristics of her practice were true of her as a person; she was an even-paced, thoughtful personality who, though deeply interested and committed to teaching displayed thoughtful engagement, not passion.

Heather would normally seat herself with one of these working groups, handling enquiries from other children as and when they approached her. These enquiries tended to be few in number, with classroom structures helping children to help themselves when they had problems. It is probable, however, that underlying this aspect of her practice was a significant distinctiveness; for it was within the relationship of her classroom organisation to her aims for a session that many of the tensions in her practice were found to lie. Heather wanted to encourage independence in the children and the classroom structures she had set up could be seen to be
encouraging free and responsible movement and independence in use of resources. To consolidate this, she would frequently organise sessions which involved practical challenges, hoping to develop the children’s self-reliance. It was within the organisation of these practical sessions that tensions frequently lay.

Heather had a real flair for constructive interaction with children. This was possibly just as well, for the planning behind some of her sessions was frequently only very sketchy, with poorly articulated objectives. Thus, although she often said she was driven by the aim of encouraging children’s independence, there could often be contradictions between the amount of independence she wanted for the children and her planned structure for a session. Conversely, even if her planning were articulated more fully, she had a tendency to make it look potentially limiting, with much anticipation of a rigid structure to the session and little sense of the promotion of the independence she wanted. In either case, the impression was that such planning could have reduced the children’s autonomy, either through too much direction or lack of purpose. However, once the activity was underway, she could display a truly impressive ability to ask focused, productive questions which helped children to explore their experience more deeply. These questions appeared to come naturally to her; they were rarely anticipated in her planning. They also did not seem to depend on the general effectiveness of any particular session, there being many occasions where, even though the activity itself had potentially lost its way through insecure conceptualisation or overload, she managed to salvage the learning experience through her sense of the right question to ask. This hinted at a major contradiction in her practice; some of her most effective teaching was actually manifested in these open sessions, sessions about which she may well have felt a lack of confidence.

The sequence of interaction in an early science session (appendix 4) gives a flavour of this ability. In a session looking at floating and sinking, her planning had lacked focus and the children’s activity was becoming random, with little sense of direction to their experience. However, although one could sense that she felt this (and she acknowledged the fact afterwards), she was still able to react and respond to the immediate feedback from the children.
and create meaningful learning experiences for them. In this abridged sequence from the session, she manages to produce a good example of a child learning in science through her ability to identify and respond to these signals from a child:

(Child D has been exploring what will float or sink and has decided (from observation) that a hole in something will make it float. Working with child J, he has just been looking at how a pair of scissors with plastic handles act when placed in a tank of water. Heather notices this. Child D investigates a wooden wheel with a central hole.)

**Heather:**

What if we covered the hole?

(Interaction with other children)

What did you say before? What does that tell you about your ideas - does the hole make a difference?

....(Recaps for all children): Did anything sink?

....(Points out the hole in the wheel) Will it make a difference, D?

(Looks at other objects, then gets some plasticene.) It's heavy. 
.....What will happen, Feel it. D, if you put a hole in it, what would happen?

(Gives them one piece each). Find out whether they sink or not How are you going to change it, D?

Even with a hole?

**Children**

D The hole would make it float. 

D - It would sink. (Goes off to cover the hole)

(D returns with hole covered) 
D - I think it's going to float (the wheel floats)

D - (tries to push it down) No.

D - (a little embarrassed) No.

(D says nothing, but looks a little embarrassed).

D - Make it into a flat shape. It always sinks.

D - Yes.

(D and others make the plasticene float by putting it onto pieces of wood)
You're using the wood to help you
Can you make it float without using
the wood?
Try making a flat shape, really flat.

(All sink)
(I makes a ring - it sinks)
D - that's because it's got a hole in it.

(D has changed his idea because of the evidence of his observations. This thinking probably
would not have occurred had the teacher not engaged in the right kind of open, but focused
interaction).

Although at first sight, therefore, there could often be a random feel to the independent
or investigative activity undertaken by the children in Heather's classroom, on closer
observation it could be seen that much meaningful learning was taking place. However, the fact
that her planning notes were often brief and that she was frequently hesitant in articulating what
her exact focus was for this kind of session, suggested that she often worked from an intuitive
appreciation of what the children needed that arose as she was working with them. This sense
that teaching was about the intuitive reaction to children in the action of the classroom is
reflected in this response to a question in which she is reflecting on the level of her engagement
with teaching from day to day:

Sometimes it's nice to be able to forget OFSTED/planning/staff meetings and bury oneself
in a teaching session - it's like showing yourself what it's really all about. Other times there
are so many other demands on your thinking time that it is very difficult to become
'engaged' in teaching you find that you're so tired it just won't happen.

(appendix 8)

Other responses to this sequence of questions convey a similar attitude. For example, when
asked what her best teaching 'feels' like when it is happening, she gives a reply that again
draws attention to the importance of spontaneity:

Things flow naturally when the children show genuine interest and keeping this 'moving'
becomes easier the more it happens. Fascinating when you hear what ideas they have - it's
like unlocking a secret door!

(appendix 8)
Heather acknowledged the deficiencies in her planning. In the interview at the end of the reconnaissance period, she realised that it would be one aspect of her practice that would have to change if she were going to achieve the most from her involvement. She traced part of her reticence about her planning in science sessions to her own feelings of inadequacy in the subject, but just as real was a feeling that carefully articulated plans could actually represent too much control on the children. As she did not want this, the net effect was that she planned little.

As she approached the inquiry, therefore, Heather wanted it primarily to give her a sense of security and confidence in the management of practical, enquiry based activities like science. In order to help her focus, she decided to begin by exploring the nature of her interaction with children; this, she felt, could give her insights into exactly how she might respond to children’s questions and actions in order to promote their investigative work. Only when she understood this would the messages for her planning become clear.
ANDREA

Andrea had been teaching for two and a half years when she joined the project. She had taken a B.Ed. as a mature student and had transferred to the project school at the beginning of the autumn term, the term in which the other participants had begun to engage fully with their reflections on practice. She took up the post of subject leader for science and teacher of a Year Six class. She had previously been teaching Year Two children. She began her involvement with the project after Christmas, moving in the following autumn to a Year Five class.

At the start of her involvement in the project, Andrea often displayed a tension and concern in her teaching that could make it appear as though she were worried. Her general personality and demeanour may have exacerbated this appearance, for she was usually quiet and unsmiling, with a slightly tense air. There was frequently a sense of uncertainty both in her own planning and teaching and in the classroom generally. Children were usually well engaged with whatever task they had been set, but appeared often to be unsure of its purpose. Part of this apparent uncertainty may have been due to her unfamiliarity with both the school and the age of the children she was teaching, or to her initial lack of detail in her written lesson planning, but there were also possibly deeper, more complex reasons.

Andrea's classroom was paradoxical. Although she herself wished for order and structure within the children's activities, the classroom itself frequently appeared disorganised and mildly chaotic. Within it however, although aware of what was going on, Andrea would maintain a calmness that allowed the activity around her to continue without indicating frustration. Only occasionally would she respond forcefully in an attempt to refocus the children. Both the classes she taught during the project she described as 'difficult' and she would employ a classroom organisation that involved strong differentiation within tasks without overt grouping by ability. It was difficult to motivate many of the children and she frequently found their lack of engagement with tasks tiring.
This classroom structure was possibly significant; it may have been a direct result of Andrea attempting to follow the main driving force of her teaching at that time. Although quiet in manner and with a level, dispassionate voice, Andrea displayed a passion towards some aspects of her practice. She considered the development of children’s ‘life skills’ a central part of her role. Working with older children now, she was extremely concerned that they were approaching the next major change in their life - a move to secondary school - having little sense of autonomy or self-reliance. Moving from infant teaching, knowing the expectations she had made on six and seven year old children and seeing the structure within the Reception classes in her new school, she was shocked that many of the children in her class seemed so dependent on others for their actions and their thoughts. She was determined to do something about this.

Despite reservations and uncertainties about how to proceed in some subjects with children of this age, she undertook to introduce as much teaching centred on inquiry and the development of children’s thinking skills as possible. This was one reason why she allowed so much practical activity. She felt she was compensating for experience and challenge that the children had missed in the last few years.

This approach, however, had developed tensions within her. Although she of course knew they were not going to (otherwise the action would not have been so necessary in her eyes), the children did not respond or act as she wanted. Driven by a desire to help the children become self reliant, she also had a low tolerance level of those children who were not. At times she viewed her frustration with them as inevitable, for, although she had been successful, she had mixed feelings about teaching and her post at the school. This was not to say that she was not professionally committed to her job and, indeed, found it important and something she wanted to do, but she was still finding it hard to identify her place within the profession. She had remarked that she had not much liked teaching six and seven year old children (although she had obviously done well enough with them to ensure the kind of reference that would have helped her secure her new post). She had stated that she much preferred the ten and eleven year olds she was now teaching. They were, she claimed, more challenging; she had found the Year
Two children too 'simple'. However, there were still frustrations. She found them within her new class, with children whom she thought were still operating at what she described as a 'simple' level. These children were difficult to deal with, especially within the areas of science or mathematics, areas that although replete with opportunities for inquiry and self-directed activity also need structure and systematic action. The frustrations within her had developed to the point that she had seriously wondered whether she should have trained to teach at secondary level.

Andrea did not promote much in the way of art or other expressively creative work in her classroom. It was relatively bare, with displays taking a long time to be put up and more focused on English, science and mathematics than other areas of the curriculum. There was little sign that the children actually used them subsequently. Andrea did not consider herself to have much expertise in the field of art and tended to be rather dismissive of it. She claimed that work in science or mathematics was much more creative for children than that it was in English or art, stating that 'there was no challenge in art; it was start, do, finish - that's it'. This was borne out in her classroom, with most creative demand seeming to come more from the challenges she would give the children for designing and making in technology sessions and in their science sessions.

As a new appointee, Andrea was still finding her place within the school. At the start of the project she was still very much an outsider, with one main confidant, a newly qualified male teacher who had joined the school at the same time. They initially taught parallel Year Six classes and were a source of support for each other. Andrea was forging relationships with other staff members, but found the internal relationships within the school sometimes hard to cope with. From her perspective as a relatively new entrant to the profession, she had a strong interest in, and strong views about, education, but she stated that there seemed to be no real forum within the school to promote the discussion of ideas. This disappointed her. She could see that there was no real sense of educational debate within the staffroom and in fact she felt the opposite, that she was almost positively discouraged from talking about ideas. She knew about
Elizabeth's interests, but as yet had not managed to strike up a relationship with her that would allow such dialogue. She was very concerned that the school should be investigating ways of injecting a sense of purpose into the curriculum and the children's experiences there.

As a result, Andrea was feeling her way with her role as subject leader for science. Liaising with few people, she had, however, come to some strong conclusions about the state of science teaching within the school. Much of her evaluation had come from her experience of the children in her class and the implications that their ability at year six gave about their previous experiences. Given a sizeable budget to spend, she was preparing to introduce a new set of science resources into the school and considering how to deal with any possible opposition to them. She appreciated the tensions within her position and wished for more complete relationships with her colleagues that would have enabled her to identify more accurately their needs and their attitudes. However, she approached the job with a stoical resolve to succeed whatever the opposition. In this sense, she felt a little like a missionary.

Andrea's initial foci for reflection could be seen to reflect the general concerns reflected in her classroom, her practice and her thinking at the time. With the children already engaged in focused study for the SATs, she was preparing to make the forthcoming spring term one of general revision. However, she appreciated that with such a wide range of ability in her class any general sessions would be problematic and that specific differentiated teaching would be desirable. This itself was a problem. As the class science sessions tended to follow much the kind of organisation already referred to, with much free, often seemingly unfocused activity, she was uncertain as to whether her provision was actually meeting individual or group needs. Although there was little sense of pressure from the Headteacher, whose expectations were tempered by her acknowledgement of Andrea's newness in the school, she herself felt very strongly the responsibility for each child's performance. She wanted them to succeed but had severe doubts as to whether her provision was adequately differentiated. This became a strong initial focus for her own enquiry. With the emphasis on the children's conceptual understanding of science, she acknowledged that this focus might take her away from her overriding aim of
promoting the children’s ability to enquire, but was prepared to delay her focus on this until later in order for the children to have the best possible chance with their SATs.

At the outset of the inquiry, therefore, Andrea found herself a little cut off from the rest of the school but with a big job to do. She felt she had inherited a class that did not think, act or respond as she might have expected or wished and was in the process of trying to guide them towards success in their forthcoming SATs in the summer term. She was keen to enter the inquiry, with high hopes for what it might offer her. As a non-specialist and a relatively newly qualified teacher, she saw it as a way of helping her own development in science teaching and as a demonstration of her commitment to the post. The Headteacher strongly encouraged her to take part.
APPENDIX 10

Lesson planning – Elizabeth 12.5.95 / 19.6.95 / 16.6.95
Lesson planning notes - 12.5.95

Programme of Study – Life Process and Living Things

1 a) the differences between things that are living and things that have never been alive.

3 a) that plants need light and water to grow;
   b) to recognise and name the leaf, flower, stem and root of flowering plants;
   c) that flowering plants grow and produce seeds which, in turn, produce new plants.

4 b) that living things can be grouped according to observable similarities and differences.

5 a) that there are different kinds of plants (and animals) in the local environment.
   b) that there are differences between local environments and that these affect which
      (animals) and plants are found there.

Systematic enquiry:

1 b) .....focused exploration
   c) .....first hand experience

Science in everyday life:

2 c) .....consider how to treat living things and the environment.

Nature of scientific ideas:

3 a) .....evidence
Communication:
4 a) .....use scientific vocabulary
   b) .....present information in a number of ways

Health and Safety:
5 a).....recognise hazards
   b) .....control risks themselves

Experimental and Investigative science:
1. Planning:
   1 b) .....think about what is expected to happen

2. Obtaining evidence:
   a) .....explore using the sense
   b) .....make observations
   c).....make records of...observations

3. Considering evidence:
   a) .....to communicate what happened
   b).....to use drawings
   c).....make simple comparisons
   d) .....use results to draw conclusions
   e) .....indicate whether evidence they collected suggests a prediction
   f) .....to try to explain what they found out.
Lesson planning notes - 19.6.95

Assembly: prompt start. SWA in.

9.30: Circle, supported by adults.....Intro. new focus.

- Some people in our class are dressed differently today.
- Today and tomorrow are special days for us.
- Why is that? Where are we going?
- I want you to think about that for a moment. Don’t say anything, just think.

- I would like you to try and have a picture in your head of what you think a forest looks like.
- First of all think about what you might see all around you (on the ground, up high, in front and behind you) as you walk around.
- Now, what you might hear? Keep having this picture in your head.
- Now, what you might smell?
- Now turn to the grown-ups near you and talk about your ideas.
- You are predicting. Adults scribe. Write names.
Back together: Now small group time.

Me: Dinosaurs: continue environments theme:

We are going to call it an environment. ‘The forest environment’. But for a moment I want us to think about the school environment – that is our school and its ground. You know a lot about this environment because you come here every day.

Two groups:

A group thinking about the forest environment – listing all the things you think that forests have – things now that you think are there, grow or live there, even though you might not see them.

A group thinking about the school environment.

5-10 minutes to make a list on separate cards. Now sort – which occur in both environments. Remember we are predicting. How can we know?
Lesson planning notes - 26.6.95

Programme of Study Life Processes / Living Things in their environment

- Do you remember last week when we thought about the animals and plants you might find in the forest, and (one group of us) thought about all the things we find around us at school, and we played a sorting game of which things we’d find in both places.

- I’ve made a picture of what this looked like at the end....

- We’ve been to the forest now, we’ve listened to Adele who told us about the animals, plants and birds that live in the forest.

- Think about what you know about the forest now.

- We are going to play another sorting game now, using the same list (words on cards). We are going to sort into:
  
  living things     things that have never been alive

- Whole group discussing together: SWA to write down any interesting comments – names.

- We are going to look at our living things set now and sort it again.
  
  Just think about living things in the forest; in the school grounds.
• What do you notice about the two sets?
  (Forest set has more specified living things in it).

• Read them out.
  
  Are there any other living things we could add to the forest set now that we have been?
  Plants/animals. Deer, frogs.

• We are going to be finding out more about the living things we might find in our school
grounds, but I would like you to think about why we might find these living things in the
forest.

• In pairs, looking at three things each. Come back as a group with ideas.

My aim for this activity:

To build on the previous activity where the children were predicting what might be found in a
forest environment and a school environment. To ‘tidy it up’ really; give the thinking more
focus. To gauge their understanding of living and non-living things. To re-sort in relation to
the forest/school environment, having given the activity the focus of living things. To begin to
lay the foundations (and also gauge their understanding of) a habitat, by asking them to think
about why certain animals and plants are found in the forest.
APPENDIX 11

Lesson observation – Elizabeth 29.2.96
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<thead>
<tr>
<th><strong>Teacher</strong></th>
<th><strong>Children</strong></th>
<th><strong>Thoughts</strong></th>
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</thead>
</table>
| (Has old teddy – shows to the children. Tells a story about it. Children have their own. Asks children why toys are so special). 6? | Cos it’s cuddly  
Cos it’s mine and it’s soft | 7 – Why don’t we close our eyes then guess what our teddy is?  
(Children reach out – eyes open!)  
5 – it’s nice and soft and it’s hard | (Children choose a bear) |
| 8? Why is yours special?  
We going to play some games – feeling our teddies. | | |
| That’s a good game. Let’s try. | | |
| Show us how you played, 5.  
4 – you said something interesting... You said it was a small bear.  
Just choose a bear you like. (Splits children into pairs to work together)  
You need a teddy each. Listen. We’re going to talk – you’ve got to find something out. Find 3 ways your teddies are different. | 5 – yours is soft, mine has hard bits.  
Mine sucks its thumb, yours doesn’t  
Yours doesn’t have spots.  
6 – mine doesn’t have toes.  
5 – yours doesn’t have ears.  
6 – yours has feet, mine doesn’t  
6- mine is brown fur, yours is white fur. | |
| (Pulls together). We’ll go round the circle now.  
6?  
5? |  - white eyes / 5’s doesn’t  
- mines got red / 6’s doesn’t  
- mine sucks thumb / 6’s doesn’t  
- mine’s got a black nose / 6’s hasn’t  
- mine has hard bits / 6’s hasn’t  
4 – buttons  
3 – broken leg  
- hard bit – nose / eye  
2 – bow tie / hasn’t  
1 – brown paws / hasn’t  
2 – black eyes / hasn’t  
1 – fluffy / knitted  
7 – black nose / not  
8 – black footprints / hasn’t | |
| 3/4? | 7 – black nose / not  
8 – black footprints / hasn’t | |
| 1/2? | 7 – it’s got clothes on / hasn’t | |
| 7/8? |  | |
| You noticed something about what it was wearing...  
This time find ways they are the same | | |
Come together....
3/4?

How?

5/6?
7/8?
What do they feel like?

They are both soft and furry.
1/2?

We're going to play a game now. It's called 'Bear Dominoes' - the same game.
Make a line of bears.
Don't play with them now. We're doing our science now: we're thinking.

And they're about the same size. Now it's my turn. How can I go?

4 had a good idea - putting it in a different place in the line

I want you to think now... Just hold it. Look and see what you think it's made of.

Squashy.... What do you call it? Look at the different parts (indicates clothes / fur). What do you think it's made of? Look at the eyes

Focuses on 7's knitting. What do you think this is made of? 6?
How does it feel? Anything else hard?

5/6 - ears, fur, black noses, arms/legs
(Much feeling)

- they move their ears
4 - putting them backwards and forwards
- move their head from side to side
- both furry
5/6 - fur, ears, arms/legs, black noses
7 - indicates label
8 - both soft

2 - they sit up
1 - they lay down,
- they move their legs

(Reasons given for the bear line up).
- nearly match - white/nearly white
- both got ears
- both blue/white and black eyes
- both black eyes
- both move their hands
- both black eyes

6 - by its clothes
4 - they are both fluffy
- their ears are the same

4 - when it's hard (5's bear)

Soft / squasy
Nothing
- Fur

Getting the focus difficult - why?

5 - (feeling her eyelashes) My eyes are made of cotton wool (to 6)

- cotton
- soft
- eyes

Developing the ability to discriminate.
- specifically science?
- incidently science?

Wants focus on materials?
| What are they made of?  | - cardboard  
|                         | - wool  
| (Many focusing questions) |  
| 5? What about the clothes – they’re different aren’t they? |  
| 1? |  
| 2 thought of what’s inside |  
| (Children starting to call out spontaneous ideas, but off target) |  
| - they’re made of plastic  
| - they’re soft  
| 5 – if a heavy thing falls on the glass (eyes) they would smash.  
| 2 – plastic.  
| - that’s made of wood |  
| 3? |  
| What’s inside the pillow?  
| We’re going to pretend this bear is lost in school. It would be important to tell other people what it looked like. I’ll write down ideas about L’s bear. Tell me some things. |  
| 3 – it’s made of pillow |  
| Of what? |  
| (Reads out the list. Corrects ‘neck’ – collar.) Smooth – is that the best word? Someone thought it was soft – is that the best word? Now – you’re going to choose a bear and do the same for that. Draw your teddy carefully. I’ll help you to write down your ideas. |  
| 4 – it’s soft  
| 5 – it’s lost  
| 5 – it’s got clothes with birds on  
| 6 – it’s brown  
| 5 – it’s L’s  
| 1 – it’s got a white neck  
| 8 – it’s got glass eyes  
| 8 – it’s got clothes made of  
| - material -  
| - it’s smooth |  
| Soft... |  
| (Children draw and dictate to teacher) (Some drawings are very careful and well observed.) |  
| Amount of teacher focusing and children’s response. How much do they come up with by themselves? Why explore? Why not tell them? |  
| Why not both? |  
| Assessment of what the children have seen or their ability to focus? How draw this together into a consolidation of ideas about kinds of materials? Over time? During the session? Not important? |
APPENDIX 12

Lesson observations – Carol – 10.5.96 / 13.6.96
<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Has flowers in a vase. Conducts a general discussion about them. Communicates enthusiasm and focuses the children’s attention. Tells the children that they are going to do some drawings of the flowers)</td>
<td>(Children comment of the colours and the shapes)</td>
<td>What is the relationship between this kind of observational drawing and science?</td>
</tr>
<tr>
<td>What do you notice about the shape? The size? The colours of the flowers? I want you to use your eyes – I want you to be really looking at them. Choose one flower near to you and draw it.</td>
<td></td>
<td>Increasing focus. Developing focus in a comparative way?</td>
</tr>
<tr>
<td>(Models the drawing - does it herself).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Now, show your drawing to the person next to you. See if they can guess which one you have drawn.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Now, choose a different flower. This time, I more closely. Count the petals (shows). How many flowers on the stem? Look at the parts. (Encourages vocabulary)</td>
<td>(Children’s interest in dandelion seeds)</td>
<td></td>
</tr>
<tr>
<td>How many different types/ shapes can you see? (Focuses attention on the way the flowers are attached – dangling/ stiff etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Distributes fineliners)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draw the vase in pencil. With the fineliner start by drawing the plant nearest to you. (Corrects S/R for drawing in a stem when they cannot see it.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Reinforces / reiterates the need to look closely, not just draw what they think they see.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>The activity promotes children’s discriminative abilities in observation. It also has developed / consolidated vocabulary. It has focused on differences / similarities in structure. Does this make it science?</td>
</tr>
</tbody>
</table>
### Record only of teacher interaction

<table>
<thead>
<tr>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>I want you to put on your scientist’s hats and become really good investigators</td>
</tr>
<tr>
<td>Where will you see lots of trees? Look and see how many kinds of trees you see.</td>
</tr>
<tr>
<td>(Setting up session)</td>
</tr>
<tr>
<td>Put your scientist’s eyes in.</td>
</tr>
<tr>
<td>Shut your eyes and feel your hand.</td>
</tr>
<tr>
<td>What does it feel like?</td>
</tr>
<tr>
<td>Is it smooth all over?</td>
</tr>
<tr>
<td>I can feel bumpy bits on mine.</td>
</tr>
<tr>
<td>What about your nails – are they the same as your skin?</td>
</tr>
<tr>
<td>Some parts may be squidgy.</td>
</tr>
<tr>
<td>Are there any pointy bits?</td>
</tr>
<tr>
<td>I find when I shut my eyes it helps me know more what I’m feeling...</td>
</tr>
<tr>
<td>We’re going to play a noticing game. I’ve got some things under this cloth. (Shows):</td>
</tr>
<tr>
<td>Stone – I expect some minibeast somewhere will be saying ‘I expect you’ve taken a bit of my garden away...</td>
</tr>
<tr>
<td>Bark – Can you see one side it’s hairy – on the inside. It’s like a bit of the tree’s skin.</td>
</tr>
<tr>
<td>Grass seeds – Just look at those – do you remember, every single one of those is a seed. (Actions) When it gets all dry it flies off into the ground.</td>
</tr>
<tr>
<td>Stick – It looks like a knobbly, wobbly finger – look, it’s bumpy</td>
</tr>
<tr>
<td>Rose – (no comments)</td>
</tr>
<tr>
<td>Daisy – There you are, there’s the beautiful daisy. Which has more petals, Daisy or Rose? Are they the same, look, if you turn it over? They’re not the same, are they? Pass it round.... They’re a slightly different shape, aren’t they?</td>
</tr>
</tbody>
</table>
APPENDIX 13

Lesson planning – Heather, 18.6.96
18.6.96 – Lesson planning notes

Materials

- Know that some materials can be stretched / squashed
- Describing properties of materials
- Materials – names and groups

- Asking questions / answering questions
- Talk about what they have found out

- Focused exploration and investigation
- Use of previous knowledge to relate to environmental context

Define the terms: materials and sorting

Give out feely bags – get each child to describe what is in it – can others guess?
Look for common language.

Take out and get children to group wherever possible, using sorting rings:
   Squashy / hard
   Smooth / rough etc.

What are they made out of?
What might you use it for?
APPENDIX 14

Lesson observation – Andrea, 17.1.96
<table>
<thead>
<tr>
<th>Teacher</th>
<th>Children</th>
<th>Thoughts</th>
</tr>
</thead>
<tbody>
<tr>
<td>(VIDEO – light. Direction, filters, colour. Mixing white light)</td>
<td>- pyramid / prime colours in painting</td>
<td>- pyramid / prime colours in painting</td>
</tr>
<tr>
<td>(Stops video). Can anyone remember doing anything like that?</td>
<td>- red, green, blue...</td>
<td>- red, green, blue...</td>
</tr>
<tr>
<td>Mixing? Why white?</td>
<td>- cos that’s the way light is</td>
<td>- cos that’s the way light is</td>
</tr>
<tr>
<td>(comment on reflection)</td>
<td>(Children organise themselves. A few yawns)</td>
<td>Motivation factor with videos? – in terms of follow up work?</td>
</tr>
<tr>
<td>(VIDEO finishes)</td>
<td>(Children organise themselves. A few yawns)</td>
<td></td>
</tr>
<tr>
<td>Now, get your science books and a pencil.</td>
<td>(Children organise themselves. A few yawns)</td>
<td></td>
</tr>
<tr>
<td>Find a fresh page, write the title 'Light'</td>
<td>(Children observe effect. Can draw effect)</td>
<td></td>
</tr>
<tr>
<td>Has 6 activities on the board, to do with:</td>
<td>- refraction</td>
<td>How much explanation required?</td>
</tr>
<tr>
<td>- refraction</td>
<td>- reflection</td>
<td>Link between seeing and light?</td>
</tr>
<tr>
<td>- reflection</td>
<td>- passage of light</td>
<td></td>
</tr>
<tr>
<td>- passage of light</td>
<td>- making a periscope</td>
<td></td>
</tr>
<tr>
<td>- making a periscope</td>
<td>(All relate to aspects of the video).</td>
<td></td>
</tr>
<tr>
<td>I want you to have a go with these. See if you can write down what is happening</td>
<td>(Refraction) (B’s group)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- it bends cos of the way the light’s shining on it – that’s what it said in the video.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Children observe effect. Can draw effect)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(S’s group with refraction)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Closely observing effects, playing with position of stick – strongly motivated. Observes multiple sticks, phantom sticks)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B – back of head- reflection)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Correct explanation of how he sees the back of his head, including detail of light bouncing from mirror to mirror, then to eye and originating from window.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gives one to one help with questioning and explanations</td>
<td>Kinds of understanding?</td>
</tr>
</tbody>
</table>
| Goes from group to group questioning | (Seeing back of head – D, K)  
(Show how to see back of head with mirrors. Diagrams in explanation appear a little uncertain)  
- Light comes from window and bounces off one mirror onto another.  
- You can see one mirror in the other and the window through it.  
(S.M. – mirror image writing)  
(Able to work out how to get effect. Explanation shaky.) | Time for extension/consolidation?  
Need understanding of a mechanism for explanation? How appropriate / necessary at this stage?  
Activities are giving a good exploration of effects – time for future development? |
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