An evaluation of a practitioner’s approach to the initial and inservice education of teachers in primary science based upon a constructivist view of learning

Ritchie, Ron

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AN EVALUATION OF A PRACTITIONER'S APPROACH TO THE INITIAL AND INSERVICE EDUCATION OF TEACHERS IN PRIMARY SCIENCE BASED UPON A CONSTRUCTIVIST VIEW OF LEARNING

submitted by

Ron Ritchie

for the degree of PhD of the University of Bath

1993

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[signature]
I wish to acknowledge the support and encouragement given me by those with whom I have collaborated in this research, but especially...

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... to colleagues at Bath College of Higher Education and the University of the West of England who were directly and indirectly involved in this research

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... to Anna, Kate and Lucy, for being my favourite young scientists - I hope one day you'll think it was worth all the effort.
TITLE
An evaluation of a practitioner's approach to the initial and inservice education of teachers in primary science based upon a constructivist view of learning.

ABSTRACT
Implementation of the National Curriculum for Science has implications for the initial and inservice education of primary teachers in terms of improving their scientific knowledge and understanding as well as their competence to teach science. Recent research indicates many primary teachers and entrants to initial teacher education lack an adequate scientific knowledge base. Consequently teacher education requires trainers to develop adults' scientific knowledge and understanding alongside the development of their competence to teach science. A constructivist view of learning, and approaches to teaching based upon it, are evident in the literature concerning secondary and primary science education. This thesis examines the effectiveness of such an approach with adult learners.

Through the use of action research I have addressed the question 'How can I improve the quality of my teaching through the use of a constructivist approach?'. Close observation and analysis of my practice with undergraduate students enabled me to identify a number of concerns about my teaching. These were addressed by making modifications to my practice in collaboration with colleagues with whom I was team-teaching. Evaluation of these modifications, in the context of my work with teachers on Department for Education designated 20-day science courses, involved collecting and analysing detailed evidence from teaching sessions and post-course interviews. I looked for evidence of improvements in the teachers' scientific knowledge and understanding and for evidence of impact upon their teaching. This evidence was used for self-evaluation of my use of a constructivist approach and an evaluation of the approach and the course during which it was used.
In order to address systematically the variety of concerns that arose during my enquiry I developed the use of a framework for analysing multiple concerns and a multi-levelled approach to analysis. I have addressed the extent to which a constructivist epistemology can be used to understand my own learning during the enquiry and explored the way in which my own enquiry could be regarded as 'constructive action research', in that it paralleled the constructivist teaching approach I used, involving phases of orientation, structuring/elicitation, restructuring/intervention, review and application.

The enquiry provides evidence of the success of a constructivist approach both in terms of changes in teachers' classroom practice and in terms of improved scientific knowledge and understanding, although the complex nature of the way adults develop scientific knowledge and understanding was highlighted. The outcomes have been analysed using an existing typology of INSET outcomes which I modified to recognise the significance of metacognition to adult learning. The adoption of epistemological assumptions which underpin the learning of adults on the course, the learning of their children in the classroom and my own learning, together with the use of an approach to teaching which was used with teachers and could be adopted by them for use in the classroom was an apparent strength of the approach.
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1.1 Introduction

Wonderful ideas do not spring out of nothing. They build on a foundation of other ideas. ... The more we help children to have their wonderful ideas and to feel good about themselves for having them, the more likely it is that they will some day happen upon wonderful ideas that no one else has happened upon before.

Duckworth 1987, p14

Science is a curriculum area in which teachers can encourage learners to develop wonderful ideas. This thesis focuses upon my work in initial and inservice teacher education which is aimed at helping teachers to become more effective teachers of science. The introduction of science as a core subject in the National Curriculum has had implications for the initial and inservice education of primary teachers. It is now a requirement of all teachers to teach science to children at Key Stages 1 and 2. However, according to research findings many primary teachers and entrants to initial teacher education courses lack an adequate scientific knowledge base for teaching the subject. Consequently, teacher education in primary science has to address the development of adults' knowledge and understanding alongside the development of their competence to teach science. My thesis documents an action research enquiry which evaluated my use of a particular approach to meeting these aims.

The thesis is based upon a constructivist view of learning. This regards child and adult learners as the active constructors of their own knowledge and understanding. It is an epistemological assumption of constructivists that personal knowledge is tentative and provisional and the process by which this knowledge is constructed is dynamic. Changed or 'restructured' understanding is the result of existing understanding and attempts to deal with new experiences or ideas. Consequently, my first point must be that this thesis is not offered as 'a right answer' but as a tentative contribution to the literature which represents a practitioner's attempt to tell the story of an aspect of his professional development and the insights he has gained through evaluating his own practice. The very notion at the centre of this thesis,
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concerning the nature of knowledge, is in itself best seen as a working hypothesis to be
tested against challenges made to it by others and through my experiences.

This chapter provides an overview of the thesis, the background to my enquiry and the nature
of the account I have produced. It begins by setting the enquiry in the context of the National
Curriculum for Science and the demands this is making upon primary teachers. The aims of
the enquiry are established and my approach briefly outlined. This is followed by a section
discussing the criteria that the reader may wish to use to evaluate the account. The difficulties
of writing a thesis based upon a practitioner-centred enquiry are discussed and the structure
of the account justified and explained.

The next section provides a brief professional biography to locate the enquiry in terms of my
continuing professional development. This section highlights experiences and influences
that I consider have been significant in terms of my enquiry. Failure to contextualise the
enquiry in terms of this biographical information would suggest this enquiry was somehow
separate and divorced from the process of professional development in which I have engaged
and intend to engage throughout my professional life. This section includes a set of
statements about the educational values I hold and these are again of fundamental
importance in the context of the enquiry.

As initially stated, this thesis is based upon a constructivist epistemology and a particular view
of the nature of science. These have informed my teaching of science and my approach to a
practitioner-centred enquiry. Section 1.9 introduces these epistemological assumptions and a
view of science which are referred to in several later chapters.

The chapter concludes with a brief introduction to some of the outcomes of my enquiry and
the insights I gained.

It should be noted that this chapter was the last to be written and the problems of chronology
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and the disadvantages of producing a 'tidied up' account of a complex enquiry are significant and are explored later. Crucially, the perspective I now have of my enquiry has evolved and was not evident at the outset. This account tells the story of a 'journey' of professional development. The final destination was unclear at the outset, but I was clear about the direction in which I was heading and the purpose of the journey. This overview, written in retrospect, must be seen in this context.

1.2 Background and aims

Implementing the National Curriculum for Science (DES, 1989a, 1991c) requires primary teachers to develop pupils' knowledge and understanding in science, particularly through pupils' use of scientific process and skills, and assess their progress. For many teachers this is proving difficult because they lack appropriate background knowledge and understanding in science themselves. Research (Kruger & Summers, 1988) has indicated that many primary teachers hold ideas about the world which do not correspond to accepted scientific explanations. Many primary teachers have no formal qualifications in science. Current recruits to initial teacher education are not required to have a qualification in science and existing cohorts in institutions include many students with limited scientific backgrounds.

Consequently, the initial education of new teachers and successful INSET requires tutors/trainers to adopt approaches that will develop scientific knowledge and understanding in teachers as well as their competence to teach science to primary children. Considerable research in the secondary sector, notably in this country through the Children's Learning in Science Project (CLIS, 1984-91), and more limited research in the primary sector through initiatives such as Science Processes and Concept Exploration Project (SPACE, 1990-92) have indicated the potential of adopting approaches to teaching science based upon a constructivist view of learning (Driver and Oldham, 1986; Scott, 1987). Scott outlined a 'constructivist teaching approach' that involves orientation (arousing the learner's interest and curiosity), elicitation/structuring (helping the learner find out and clarify what they think),
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restructuring (encouraging the learner to test out ideas to extend, develop and replace them) application (encouraging learners to use new ideas and integrate them into everyday thinking) and review (helping learners clarify changes in their thinking). The apparent success of using a constructivist view of learning to inform approaches to teaching science has led to its endorsement in the National Curriculum Non-statutory Guidance (NCC, 1989, page A7).

The aim of my thesis is to examine the effectiveness of my use of an approach with adult learners similar to that introduced above. Through observation and analysis of my own practice, and that of others, I made modifications to my teaching and evaluated those changes, in collaboration with colleagues with whom I was co-teaching. Effectiveness was evaluated in terms of improved knowledge and understanding of scientific ideas in the adults I taught and impact in terms of the changes in the practice of these teachers when working with children. I looked for evidence of whether their improved understanding of science and of pedagogy had an impact on the learning opportunities provided for children in their classrooms.

There are two strands running through this thesis. The first concerns my practice and my understanding of it. This strand leads to considerations of the extent to which my practice has been modified and whether these changes have led to improved learning opportunities for the adults I have taught. It has therefore been an attempt to answer the question, ‘How do I improve the quality of my teaching through the use of a constructivist approach?’

The second strand of the thesis is concerned with my use of action research as an approach to improving my practice and my understanding of it. This strand has led me to an improved understanding of the nature of action research and how multiple concerns that arise for practitioners during an enquiry can be addressed.

My thesis involves a self-evaluative dimension, as outlined above, but is also intended to provide an evaluation of the constructivist approach to teaching that I used with adult learners.
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and the Department of Education and Science (DES)\(^1\) designated 20-day Science Course during which it was used.

1.3 Scope and outline of the enquiry

I used a constructivist approach with B. Ed students and with teachers on courses that I run at Bath College of Higher Education (BCHE), where I am a tutor. I collected detailed evidence of my work with two student groups on a science course in their final year of initial teacher education and used an analysis of sessions to inform decisions about subsequent changes to my practice. The work with practising teachers on INSET courses has involved work with two cohorts on DES 20-day courses at BCHE. I have collected and analysed data from three out of five cycles of the courses for both cohorts, covering twenty-four teaching days. The data I have used for analysing these sessions has included transcribed tapes, field notes (my own and those of other tutors co-teaching the course), student outcomes (including posters, floor books, concept maps, other written material and assignments) and various outcomes of evaluative activities. I have also observed B.Ed. students, who were in the taught group, working with children, and interviewed them and a of sample teachers on the inservice courses (several months after the courses finished) to evaluate outcomes from the teaching sessions. The scientific content covered during these sessions has been electricity, materials, and forces.

My analysis of sessions included consideration of the nature of my teaching approach, the nature of science implicit in the sessions, alternative ideas held by individuals that did not correspond to accepted scientific ideas and evidence of restructuring of those alternative ideas. When analysing the nature of the teaching approach I considered the extent to which the students and course participants had been adequately orientated to the content and provided with opportunities to structure their existing ideas, the means by which I elicited

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\(^1\) The Department of Education and Science (DES) became the Department for Education (DFE) in 1992. Throughout this thesis the DES title is used for all activities and publications prior to the change.
Chapter 1 - Introduction and background

those existing ideas, challenged them if appropriate, encouraged restructuring and facilitated application of restructured ideas. My reflections on sessions also addressed my role and the input offered as well as the balance between unstructured exploratory activity and more systematic investigative work. The analysis of the nature of science implicit and explicit in the sessions involved consideration of the relationship between science processes and content, the provisional nature of scientific knowledge and the social context in which scientific knowledge and understanding was developed.

Detailed analysis of sessions enabled me to identify a range of concerns about my teaching. These concerns and my attempt to address them helped clarify the strengths and weaknesses of the approach I had adopted. I attempted to devise a ‘framework’ in order to analyse these multiple concerns so that I could make decisions about how they could best be addressed and consequently my practice made more effective. This framework involved three sets of categories. The first concerned the time scale required to address the concern, the second concerned the nature of the change required to address the concern and the final set indicated the relative difficulty of these changes.

The research has involved evaluation of this framework as I engaged in further action research cycles. In the final phase, I looked for evidence of the extent to which the teachers involved in the INSET course have retained and used restructured scientific ideas some months after the teaching sessions and the extent to which the improved understanding of scientific ideas and teaching strategies has impacted on their classroom practice. I revisited my analyses and evaluations using the framework in order to look for significant aspects, in the light of my further reading of relevant literature and discussion with others. Therefore my enquiry involved a multi-levelled approach to analysis through a series of reviews, over three years. The first three of these reviews focused upon self-evaluative aspects of the enquiry. The final one also provided an evaluation of the approach and the DES 20-day Course during which it had been used.
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1.4 Criteria for evaluating the thesis

The first set of criteria that I have been aware of when writing this thesis are those used to examine it:

i. Does it show evidence of industry, application and scholarship?
ii. Does the work form a distinct and original contribution to knowledge?
iii. Does the research contain matter worthy of publication?
iv. Has the candidate displayed knowledge and understanding of the relevant literature?

The extent to which the thesis provides evidence of these criteria being met is for the reader to judge. However, I consider these criteria need supplementing with additional ones in order to evaluate the particular enquiry I undertook and for that reason I have also set my own criteria. The rationale for these criteria, and the extent to which I consider them met are addressed later in this thesis (Chapter 11). They are indicated at this stage to alert the reader to key questions I had in mind during the period of my research. These are formulated as general questions, which are subdivided into further more detailed criteria later (Chapter 11, Section 11.5). These key questions are:

i. To what extent is my enquiry scientific?
ii. To what extent is my enquiry educational?
iii. To what extent is my enquiry ethical?
iv. To what extent was my enquiry collaborative?
v. To what extent has my enquiry been communicated effectively?

These criteria are based upon the work of Whitehead and Foster (1984) and Winter (1989) although I consider there to be original aspects to the way I have conceptualised and formulated them.
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I consider effective learning to involve the fostering of attitudes as well as the development of new skills and knowledge and understanding. Therefore, alongside these two sets of criteria already outlined I also invite the reader to consider the extent to which the thesis provides evidence of other personal qualities which I consider necessary for a practitioner engaging in a research enquiry related to their own practice. These include a personal commitment to the enquiry and its outcomes; an open-minded approach; curiosity and a desire to find out more; resolution and perseverance to maintain an enquiry over a long period of time; confidence in my own ability to improve my practice and take risks in order to do that; the honesty and integrity to communicate my enquiry to others in order to invite their constructive criticism.

The significance of how I communicate my enquiry is the focus of the next section.

1.5 The structure of the thesis

Writing a thesis which tells a personal story of professional development requires considerable thought to be given to its structure and style. In using the notion of a story I am drawing upon the influence of Denley (1987) who faced a similar problem. He, like me, was writing a thesis which was concerned with science education and he drew upon the view of a scientist to offer a rationale for the nature of his account. I can do no better than draw upon the same source:

The purpose of scientific enquiry is not to compile an inventory of factual information, nor build up a totalitarian picture of Natural Laws in which every event that is not compulsory is forbidden. We should think of it rather as a logically articulated structure of justifiable beliefs about nature. It begins with a story about a Possible World - a story which we invent and criticise and modify as we go along, so it ends by being, as nearly as we can make it, a story about real life.

Medawar, 1969
Chapter 1 - Introduction and background

My intention is to provide an accessible account of my professional development which does justice to the complexity of that personal learning. I recognise that my account needs to convince the reader of my integrity as a teacher and as a researcher. In that context, it is therefore necessary to alert the reader immediately to a problem concerning chronology. As noted in the first section, this chapter was almost the last to be written and a reader who wants to gain a more 'authentic' account of my enquiry would need to be prepared to sift through my journal and the various notes, reports, plans, diagrams, questions, quotes and doodles rather than reading this thesis which 'tidies' all those elements and brings them together in what I hope is a coherent whole, but inevitably involving some post-hoc rationalisation. It is through my journal that the 'messiness' of the enquiry and my thinking is evident; it is in my journal that I can identify significant periods when my understanding was changing and developing.

The reader may be helped in her/his approach to my account by recognising, as I came to during the enquiry, that it could be conceptualised in terms of different phases which paralleled the phases of the approach I was using to teaching. A period of orientation occurred prior to the submission of a proposal (September 1989) during which I was beginning to think about the enquiry and its direction. As a result of relatively unsystematic reflection upon my existing practice, talking to others and doing background reading I identified the direction for my enquiry, which can be best described by the question, "How can I improve the quality of my practice through the use of a constructivist approach?". A period of structuring/elicititation followed (October 1989 - December 1989) during which I began to clarify my existing understanding of my practice. This was an exploratory period when I began to look at my practice in a more systematic way. The first two case studies (included in Volume 2 of this thesis) cover this period and it was through analysis of data from those early teaching sessions that I identified a range of concerns, as a series of questions, which became the focus of my consideration of changes to my practice. A review of those case studies (April 1990) signalled the beginning of the investigative phase of my enquiry. This parallels the restructuring/intervention phases of my teaching approach. Over the next year, through
Chapter 1 - Introduction and background

cycles of ‘plan/act/observe/reflect’, I evaluated a variety of new teaching strategies and used the framework for analysing concerns to review my progress (December 1990 and March 1991). An application phase followed (from March 1991 to December 1992) during which I applied new insights to my practice to other contexts and teaching. I also conducted follow-up interviews linked to earlier case studies in order to collect further evidence to inform my evaluation of the constructivist approach and the course during which it had be used. A final review in January 1993 drew upon the range of data available to discuss the tentative insights gained from the enquiry.

The collection, transcription and analysis of data contained in Volume 2 is the core of my enquiry. At the time I was collecting the early data I was also drafting Chapter 2 which establishes the epistemological and pedagogical foundations of my practice. Therefore the story of my professional development can be read by starting with the case studies and referring back to the main thesis or more logically starting with Chapter 2 to set the scene and justify the assumptions I have made. Figure 1.1 represents one way of conceptualising the rest of the main volume of the thesis. From this it can be seen that the story of my enquiry is told through Chapters 2, 7, 8 and 9. The diagram also indicates that the two strands, related to the ‘content’ of the enquiry (concerning primary science and teachers’ professional development) and the research approach or ‘process’ strand, are covered by different contextualising chapters. Chapters 3, 4 and 5 address the content and Chapter 6 addresses approaches to practitioner-centred research and in particular action research. These two strands are also the focus of Chapters 10 and 11 which discuss insights gained in those two areas. These chapters are contextualised by the earlier ones and refer the reader back to those previous chapters. The two strands of the thesis are brought together in the final chapter in terms of conclusions and pointers for future action.
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Figure 1.1: The structure of the thesis
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The almost 'modular' aspect of my original conceptualisation of the thesis led me to consider other ways of presenting the information. In particular a computer database, such as HyperCard (Macintosh), would have allowed me to present the material in a way that would have enabled the reader to access it in a variety of ways. It would have given the reader control over how they approached the thesis in a way that a sequential report does not. However, a more traditional format was required for examination purposes and 'alternative' means of communicating an enquiry will have be explored at some other time for a different audience. I consider the inclusion, as part of the thesis, of the extensive data and analysis as a second volume is essential to allow the reader to judge the nature of the claims I am making and to indicate the nature of my teaching and how I evaluated it. Further advice about accessing this data is given at the beginning of Chapter 8. Any reader wishing to get straight into the body of the enquiry is advised to finish this chapter and read Chapter 2 before she/he skips the contextualising chapters and begins reading from Chapter 7. Use of the case studies (Volume 2) alongside the main thesis will begin when Chapter 8 is reached. It should be noted that Volume 2 also contains the appendices.

The following section provides a brief description of the contents of each chapter to orientate the reader to the rest of the account. The style of writing varies between the contextualising chapters (2 to 7) and the chapters dealing directly with the enquiry. The latter are written in a more personal style to reinforce the nature of the enquiry as a personal account of one practitioner's professional development. My reasons for adopting a propositional, rather than dialectical style of communication are discussed in Chapter 11.

1.6 Purpose and content of chapters

Chapter 2, Constructivism which was drafted at the time I was collecting data for Case Studies 1 and 2, discusses the constructivist epistemology that underpins the thesis. The work of Piaget, who advocated a constructivist view of learning focused upon the individual, and that of Vygotsky who emphasised the social construction of knowledge and placed greater
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emphasis upon the role of instruction in learning are outlined. A discussion of developments of their ideas leads to a consideration of the relationship between the individual and social factors related to learning. The chapter then focuses upon science education and the significance of children’s existing ideas. The ‘alternative frameworks’ research is outlined and the nature of common alternative ideas explored. This leads on to a description of and justification for the ‘constructivist approach’ to teaching that I have used. It is an approach to teaching based upon a constructivist view of learning and recognises the significance of learners’ existing ideas and the importance of eliciting and challenging those ideas in order to enable learners to restructure actively their understanding of the natural world. The chapter concludes with a brief section on the way in which a constructivist view of learning might be applied to teachers’ professional knowledge.

Chapter 3, Science in the primary school traces the history of science in English primary schools throughout this century. It identifies the significance of key curriculum initiatives and addresses the question of the relationship between content and process in the curriculum and knowledge and understanding and skills in terms of children’s learning. The National Curriculum for Science is outlined and discussed as is the extent to which primary teachers have been able to meet the challenge of implementing it. This chapter provides a significant context for the teaching that is the focus for my enquiry. It highlights the fact that issues high on the science education agenda at the present time are not new and have been identified and addressed in a variety of ways over the last thirty years. In particular the need to improve teachers’ background knowledge and understanding of science has been raised by curriculum developers and HMI for many years. The means of doing this on the scale needed have not been forthcoming. Chapter 4, Primary teachers and science, considers factors related to primary teachers’ confidence and competence to teach science. It reviews research that has investigated their attitudes towards science and the nature of their existing scientific knowledge base. The crucial work of the Primary School Teachers and Science Project (PSTS) is introduced in this chapter. Factors such as teachers’ understanding of the nature of science and their professional needs in terms of implementing science are significant in
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contextualising the teaching which is the focus of my enquiry. Primary teachers' needs in terms of science are complex and not simply about an increased knowledge base.

Chapter 5, Initial and inservice education in science, begins with a brief history of primary science education in initial teacher education and indicates that until the late eighties it was a fairly low priority for course developers. The quantity and quality of primary science support for students varied considerably from one institution to another. The influences upon the changes that then resulted and the nature of more current courses is discussed. The attention is then turned to parallels in the provision of inservice education for qualified primary teachers. This section looks at the nature of INSET activities intended to support teachers in introducing and developing science in primary classrooms and includes reference back to initiatives introduced in Chapter 3, again highlighting the extent to which some inservice providers had previously addressed similar concerns to the current ones under discussion. The role of advisory teachers as INSET providers is discussed. The background to the DES designated courses is outlined before the BCHE course (developed in collaboration with colleagues at Bristol Polytechnic\(^2\)) is treated in more detail. It is this course that provided the majority of the data during this enquiry and therefore its aims, intentions and structure are of significance. Two national evaluations of these designated courses were carried out, one by HMI and the other by the National Foundation for Educational Research (NFER). The BCHE course was part of the HMI evaluation but not included in the NFER survey. The findings of these evaluations are discussed and other examples of DES course models, that have been documented, explored. This chapter concludes with a more general section raising issues from the literature concerning the evaluation of INSET.

Chapter 6, Practitioner-centred research, reviews some of the literature concerning action research which was the methodology I chose for my enquiry. The nature of action research, essentially viewed as self-evaluative cycles of plan, act, observe, reflect, is discussed and its relationship to other approaches to research explored. The variants of action research in

\(^2\) Bristol Polytechnic became the University of the West of England, Bristol in 1992, but is referred to throughout this thesis by the title it had at the time of the data collection.
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Educational contexts and the intellectual basis for the approach are introduced and key issues related to theory and practice; the use of schema; the validity of action researchers' claims; the extent to which action research can be 'inward-looking'; the ethical concerns and the relationship between 'process' and 'content' are addressed. The concluding section of this chapter considers the relationship between action research and evaluation, in the context of my enquiry, as noted, being both self-evaluative and an evaluation of an approach. Action research has the potential to facilitate both. This chapter is the final background one, intended to contextualise my enquiry.

Chapter 7 provides a treatment of methodological considerations related to my enquiry. It offers a rationale for my choice of methodology, based upon the ontological and epistemological assumptions made, which refer back to Chapter 2. The scope of my research is discussed in some detail before a treatment of the various data collection techniques I used during the enquiry. These included a research journal, field notes, verbatim collection techniques, collection of student outcomes, other student originated data, interviews, classroom observation data and other 'informal' data. The approach to analysis is then discussed and justified and the specific techniques used to validate my work outlined. This emphasises the significance of the collaborative aspects of my enquiry. The nature of evidence of impact in terms of changes to teachers' classroom practice is discussed in the final section.

Chapter 8 tells, in a more personal style, the story of my enquiry through three key reviews carried out in April 1990 (Review 1); December 1990 (Review 2) and March 1991 (Review 3). The relationship between these reviews and the case studies they refer to is illustrated by Figure 1.2. This diagram is discussed in more detail in Chapter 7.

The first review includes a rationale for the framework I developed for analysing my range of concerns. These concerns are included in Volume 2 as Appendix 17, so that they can be read alongside the reviews. In the review each concern is then addressed in turn. This approach to
analysis contrasts with the analysis of each session (included in each case study) which used the themes for analysis outlined in Section 1.2. Reviews 2 and 3 revisit each concern through the use of the framework in order to evaluate progress and set new targets in terms of future action. Chapter 9, Review 4, completes the reviews and includes an analysis of course assignments and evaluation forms as well as the interview data collected some months after the teaching sessions. Chapter 9 includes an evaluation of the approach and course together with further self-evaluation. The latter is structured around the phases of the constructivist approach and focuses upon two key concerns identified through the use of the framework during Review 3. These address the time available for exploratory and investigative work (Concern 13) and the relationship between children and adult ideas in science (Concern 14).

Figure 1.2: The research process showing the relationship between case studies and reviews.
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Chapter 10 summarises the insights gained through the enquiry related to adult learning. It considers the outcomes of the teaching sessions in terms of improved scientific knowledge and understanding and in terms of impact upon practice. These outcomes are analysed using a typology produced by Kinder and Harland (1991). My own learning that resulted from the enquiry is discussed and the extent to which I have been able to apply my new understanding in novel contexts is outlined. Chapter 11 is a reflection upon my use of action research and includes an evaluation of the enquiry against the criteria introduced in Section 1.3.

The final chapter draws together the two strands of the enquiry and is described in more detail in the last section of this chapter.

The reader should also be aware that my use of a constructivist approach did not begin at the start of this enquiry and the story told here covers a relatively short period of my professional development. In order to help the reader locate this phase of my learning the next section offers a brief professional biography.

1.7 A brief professional biography

This outline of my professional career to date is to provide an indication of the experiences and influences I brought to my enquiry. Inevitably, significant experiences and influences will have been missed in such a brief history but I have attempted to provide a reasonably rounded picture. It is included in the main body of the thesis rather than as an appendix since in producing an account of my professional development within a constructivist epistemology, what went before and its perceived influence on my thinking played a vital part in understanding subsequent learning. It should be noted that this biography makes little reference to an major aspect of my professional work which is related to science. Primary technology has always been a significant part of my classroom, advisory, initial teacher education and inservice education work. It is in many ways very closely linked to science,
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particularly in areas like problem solving. However, this thesis has a clear focus upon science and the exclusion of technology from the discussion (especially in Chapters 3, 4 and 5) was a conscious decision to avoid confusion by trying to address both. My own perspective is that the purposes and processes of these two areas of experience for children are distinct and that in the context of this thesis it is appropriate that I should focus exclusively upon its main concern - science.

After a period of work in the aircraft industry, I completed a first degree in aeronautics and astronautics. However, dissatisfaction with many aspects of a career in an industrial context and an interest in work with children led to a PGCE course in primary education. My experience of work in industry and my degree have been significant in terms of the insights they provided me into the nature of science and technology.

1975 - 1980

Although trained as a primary school teacher, I failed to secure a primary post and was given the impression in interviews that my background in industry and my engineering degree were not ‘relevant’ to primary teaching. My first teaching post was consequently in a comprehensive school and I spent my probationary year teaching mathematics in the middle and upper schools (14 - 18 year olds). During the next three years I taught combined science and mathematics in the lower school (11 - 14 year olds). I had no training for teaching science, although my degree in engineering was of some use. A significant influence on my teaching during this period was the work of the Resources for Learning Development Unit (RLDU) which is described by Denley (1987) and Foster (1979). I used the RLDU materials to develop an approach to individualised resource-based learning and was invited to join one of the writing teams working on materials for the *Microbes* pack (RLDU, 1980). This period also provided me with my first experience of classroom observation and collaborative evaluation. As part of an evaluation of the work of the RLDU, John Graystone, a researcher from the University of Bristol, observed a number of my lessons during which the materials were used.
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(University of Bristol, 1985). The outcomes of his observations were discussed after each session and I found the insights provided by a systematic observation of my practice very helpful in enabling me to identify aspects that needed changing. This experience led to me inviting colleagues from the science department to spend time observing my lessons and discussing what they observed. This happened on a number of occasions but the observations were unsystematic and the data collected was superficial and tended to lead to discussions based on impressions rather than evidence. It was, however, my first experience of a type of professional collaboration which was to become a feature of later work.

1980 - 1984

I obtained a primary teaching post in 1980 and was given responsibility for science as a result of my secondary experience. I found the transition to teaching eight year old children challenging but rewarding. My initial approach to primary science was to ‘water-down’ my secondary approach. I found my experience with the RLDU material extremely helpful and often adapted the materials for use with younger children. I tended to plan and implement separate science lessons involving teacher-directed ‘experiments’. I was gaining an awareness of the benefits of working in a more integrated manner through a topic approach as a result of talking to primary colleagues. However, during this initial period in a primary school I lacked the experience and knowledge of how to plan and organise an integrated approach.

After the first two years, my classroom organisation had improved and I was happier about the experiences and learning environment I was providing for the children. However, science was seen by my headteacher to be my area of expertise and I was aware that, although I was enjoying my science work with this younger age range, my approach and understanding of the nature of science in the primary school was still poor. Consequently, in 1982, I enrolled for a year long course, Science for the Younger Child, at Bristol Polytechnic. This course was run by John Griffiths and Sheila Jelly and the regular Tuesday evening sessions provided me with an excellent introduction to primary science. The course emphasised a process-based
approach to primary science within an integrated curriculum. The tutors had both been involved in the Science 5-13 Project (Ennever & Harlen, 1972, see Chapter 3, Section 3.9) and the course reflected the project's aims and objectives. It was an approach that I found immediately appealing and it had a considerable impact on my practice. No longer were all the science activities in my classroom teacher directed and I recognised the variety of experiences that children should be offered that supported their scientific achievements but were not necessarily 'experiments'. For example, I organised many more opportunities for the children to observe and sort everyday artefacts and materials. I encouraged them to raise questions and plan their own investigations. The enthusiastic course tutors and the committed group of teachers I worked with during the year inspired me and helped me develop an enthusiasm and commitment for primary science which I hope I still retain. This was the period when I came to appreciate the value of independent learning and gained a greater respect for children’s own ideas. My growing confidence allowed me to give them more control of their own learning.

As a result of my work on the course I was invited to get involved in inservice work with Avon's advisory teacher for primary science, Mary Horn. This work involved me in a wide variety of activities and provided me with my first experiences of delivering INSET and working with adults. I found the experiences challenging although I was offered little support in dealing with adults as opposed to children. The assumption seemed to be that if you could work effectively in the classroom with children you would be able to adjust to an adult audience easily. I found this was not the case. The role model I was offered by the advisory teacher was of an 'expert' sharing her knowledge, in an enthusiastic way, with her audience. There was little attempt to draw on teachers' previous experiences or strengths. I helped run a number of Inservice days for primary school staffs during this period. Most involved an initial input from the advisory teacher on the nature of primary science and this was followed by a practical workshop involving tasks that the teachers could take back to the classroom and use. A plenary discussion usually dealt with issues like resources and classroom organisation.
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1984 - 1985

About this time, the issue of the relationship between ‘content’ and ‘process’ in primary science (see Chapter 3, Section 3.13) was being discussed within the LEA and there was a growing concern that many primary teachers' background knowledge and understanding of science was inadequate for teaching primary science in a way that addressed content and process in a balanced manner. The primary science INSET panel, of which I was a member, identified the need for a course which would help teachers develop their scientific knowledge and understanding. It was agreed that a pilot 10-day course be planned, through Bristol Polytechnic, for those teachers who were already confident in terms of organising practical science in their classrooms. I was invited to participate in the planning and delivery of the course. It was to be directed by John Griffiths (Bristol Polytechnic) who was to be supported by LEA staff. These included the advisory teacher, secondary science teachers and me, as a primary teacher. A number of half day meetings were held during which the year long course was planned. The approach was to provide a ‘watered-down’ secondary combined science course for primary teachers. Although the content covered was to be loosely related to the primary classroom the sessions essentially involved science activities at the teachers' own level. I remember I shared the concern, expressed by others on the Primary INSET panel at the time, that using secondary teachers who had no experience of primary classrooms to deliver such a course might prove problematic. However, I had no other approaches to draw upon and felt fairly confident about teaching on a course where I could use my secondary science teaching experience. The approach was modified over the next few years but the first cohort, in the spring of 1985, were offered a fairly conventional secondary science course, using resources and typical laboratory activities from secondary science text books. Sessions included energy changes, electricity & magnetism, heat, light & sound, water, rocks & minerals, forces, fibres & fabrics and woods & metals. I taught sessions related to heat and kinetic theory and acted as a link primary tutor on several other sessions. The significance of this course, for me, was that it was my first experience of working with adults in trying to develop their knowledge and understanding of science. The subsequent course was called...
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Science Enrichment for Primary Teachers and was offered as one of Bristol Polytechnic's courses that led to a Certificate in Advanced Professional Studies in Education (CAPSE 14). It was a second level course for further professional development of those teachers who had already done a course like Science for the Younger Child.

During this period I was a fairly active member of the Association for Science Education. I had first joined in 1977 and had found its publications and meetings a valuable source of information and discussion about science education. However, at this time there were far fewer primary members than secondary and its activities were biased towards the secondary sector despite the fact that it had produced policy statements on primary science as long ago as 1963 (ASE, 1963). I found its publication, A Post of Responsibility for Science (ASE, 1981) particularly helpful because of my role in school.

1985 - 1988

In September 1985, I was appointed as an advisory teacher for primary science in Avon through Educational Support Grant (ESG) funding. This allowed me to develop my interest and expertise in the area of the primary curriculum I had found most satisfying in the classroom. The post involved working collaboratively alongside teachers in their classrooms, providing INSET and producing materials (British Gas, 1986; Ritchie & Smith, 1987a and b). I worked within a team of six primary science advisory teachers and found the opportunities this provided for discussion about issues in science education and collaborative teaching very stimulating.

I continued my involvement with CAPSE 14 and during the second year the format changed from ten full days over a few weeks to the same number of days spread over a year with regular evening sessions. The approach remained similar to the pilot course although some individual sessions were modified in the light of the previous year's evaluations. I also planned and ran a Further Professional Studies (FPS) Course at the University of Bristol on Problem Solving
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Across the Primary Curriculum. This seven session course addressed the process of problem solving within a range of curriculum contexts. My awareness of the nature of problem solving and its potential as a process for unifying primary work had been developing gradually throughout my teaching career and was grounded in experience I had in industry prior to deciding to teach. The significance of this initiative in the present context is related to the similarity between the problem solving process and the action research process of which I became aware a few years later. The FPS course continued to run annually until 1988. It provided me with opportunities to work collaboratively with colleagues with other curriculum strengths such as museum support staff, a drama specialist and an urban studies expert. We were united in our commitment to the use of a problem solving approach in education (County of Avon, 1986).

It was in 1985, that I was first introduced to the work on the Children's Learning in Science Project (CLIS, 1984-91) and a constructivist approach to teaching science, at a seminar held at the ASE Annual Meeting at the University of York.

In the following year, the influence of this project and the approach adopted began to show itself in my work as an advisory teacher. I started to introduce the notion of children actively constructing their own ideas and the importance of commonly held alternative constructs into my INSET activities and teacher support materials. At that time, I had yet to grasp its significance in terms of teaching strategies. I was talking to groups of teachers about constructivism as a model for looking at children's learning and stressing the implications in terms of their classroom work but not using it to inform my own teaching strategies with adult learners.

A colleague in the advisory team, Chris Ollerenshaw, had begun an M.Ed in 1986 at the University of Bristol and was introduced to action research. We began to discuss the possibilities of using such an approach on INSET and planned a Classroom Research Course to use action research as a means of supporting teachers in exploring the nature of children's
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learning in science (Ritchie and Ollerenshaw, 1989). Work on this course throughout 1987 and the subsequent discussions that arose as a result of dissemination were very influential on my current understanding about the nature of children's conceptual development and the use of action research approaches, although as I will explore in Chapter 6, the work of the teachers on this course is more accurately described as action enquiries rather than action research.

Other significant events in this period included a seminar held at the Primary Science and Technology Advisory Teachers Group (PSTATG) conference in July run by Chris Ollerenshaw (Ritchie, 1987) and seminars held at the ASE Annual Meeting in January 1988. One of the ASE seminars was on action research in primary science to which I contributed a presentation on the classroom research course and another included an outline the work of the Science Teaching Action Research Project (STAR) and Science Processes and Concept Exploration Project (SPACE). These were significant in moving my thinking forward and are discussed in later chapters.

1988 - 1990

In May 1988, I took up a post at Bath College of Higher Education as a Senior Lecturer in Primary Education. The debate about the National Curriculum for Science was in full swing at this time and the issue of primary teachers' capability to deliver a science curriculum with a broad and balanced content was high on the agenda (see Chapter 5, Section 5.2). I was given responsibility for leadership of the science course on the B.Ed course at Bath. I inherited a course which involved over sixty hours contact with students in the professional part of their degree. This was higher than that provided by many other institutions but was still a very limited time to deal with professional issues about teaching science whilst at the same time coping with the students' lack of background knowledge and understanding of science. During my first year I delivered the course as planned by the previous course director, and attempted little development. During the following year, I looked critically at the way students'
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background knowledge and understanding was tackled and introduced more sessions with an explicit science content. I introduced the other staff who taught on the course to a constructivist approach and attempted to ensure such an approach permeated our work with students.

During 1989, the college was reviewing the B.Ed degree and I was asked to write a new course proposal. This included more hours for science and technology (eventually 130+ hours) and I ensured a constructivist approach was one of the principles underpinning the course.

I continued to be involved in the delivery of INSET and took on the Course Directorship of an Inservice course in Science and Technology based at BCHE. This was a ninety hour course that lasted a year and was similar to the CAPSE 6 course that I had attended at Bristol Polytechnic. I introduced a number of changes. The course included three full days which had been used for college workshop sessions. I used these days for collaborative classroom work, allowing two course members to work together, in one of their classrooms, with a small group of children. I also increased the number of sessions with an explicit science content and again adopted a ‘constructivist approach’ to delivery of these sessions.

My interest in courses that were based on action research and collaborative classroom enquiries led me to put a proposal to the Digital Equipment Corporation for sponsorship of an Information Technology initiative using these approaches. This bid was successful and led to the appointment of a member of staff who directed an INSET course on Information Technology that involved extensive opportunities for collaborative work. The bid also involved the new appointee in supporting Initial Teacher INSET (IT/INSET) activities which involved college staff, students and classroom teachers working collaboratively in classrooms.

IT/INSET and action research was being used by other college staff (eg. Whitehead (Joan), 1987) which meant that there were opportunities to discuss the developments I was
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interested in exploring.

My colleague from the Avon science team, Chris Ollerenshaw, took up a post at Bristol Polytechnic in September 1988 and took over the course directorship of CAPSE 14. This led to a significant change in direction for that course. In particular, school-based sessions that allowed course members to work intensively with a small group of children were introduced. Chris Ollerenshaw also introduced a constructivist approach to the workshop sessions of the course. I continued to be involved in the course and led sessions on energy in 1988 and 1989.

My links with Chris Ollerenshaw also involved work on a National Primary Centre (SW) project on Assessment in Primary Science (Ollerenshaw et al., 1991). This project was funded by Avon LEA and involved two and a half full time researchers who were seconded from primary schools to work alongside other classroom teachers in developing their assessment skills. Chris Ollerenshaw was the Project Co-ordinator and worked on the project one day a week. I was appointed as the project consultant and worked with the team for half a day a week. This project was based on the principles that action research is a powerful tool for classroom evaluation and that constructivism provides a practical model of how children learn. My work on this project and with the INSET materials that were produced were a significant influence on my present research.

My collaboration with Chris Ollerenshaw led to a joint proposal (Appendix 3) to the DES to run 20-day science courses at our respective institutions. The story of this proposal and the implementation and evaluation of the course is taken up later in this report (Chapter 5).

1.8 My educational values

A teacher's educational values are often implicit in the way they work and are rarely made explicit. However, in the context of this enquiry, although I hope my educational values will
become evident in the case study evidence and in the discussions about my practice, it is appropriate to make a statement at this stage of the thesis about the nature of those values. Attempting to put complex and interdependent values into a set of simple statements is fraught with difficulties and can lead to slogans of limited value in terms of communicating meaning. My intention is to set an agenda for the reader of values I hold which will be evident in the subsequent case study material. The origins of these will also be apparent from the previous section. These beliefs are:

i. I should give all learners responsibility for their own learning;

ii. I should support learners in the process of actively constructing their own scientific knowledge and understanding - knowledge is not a 'commodity' that I can transfer or transmit from me to them;

iii. I should ensure learning is provided in a secure and unthreatening social context;

iv. I should give learners the time and opportunities to address their own individual needs;

v. I should give learners the highest quality teaching I can offer;

vi. I should respect all individuals and ensure they are treated with respect by other tutors and their peer group;

vii. I should ensure learning in science involves learners in firsthand practical activities;

viii. I should ensure learners' existing ideas are always valued;
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ix. I should offer my ideas as worth consideration alongside their own and not as ‘right’ answers to be accepted without question;

x. I should treat individuals’ learning in science as more important than the ‘scientific ideas’ I intend them to develop;

xi. I should ensure my science teaching is based upon recognition of the inextricable links between scientific processes and scientific knowledge and understanding;

xii. I consider working in collaboration with others is more desirable and more effective in terms of learning outcomes than individual activity;

xiii. My teaching should offer a model of good practice that teachers can adopt for their own teaching - I should ‘practice what I preach’.

xiv. I should make decisions about my teaching based upon explicit epistemological assumptions;

xv. I should make decisions about my practice based upon evidence not impression.

These personal values are ones I strive to live out in my professional practice. This enquiry provides evidence of the extent to which they are sometimes denied by actual behaviours and actions in the teaching situation. This thesis describes my attempts to ensure my practice allows me to live out those values more fully.

1.9 A view of knowledge and of science

This thesis is based upon explicit epistemological assumptions which have informed my
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decisions about the nature of science, the nature of my view of learning, the nature of my teaching approach and the nature of my approach to research. These assumptions will be discussed in Chapter 2, but at this stage of the thesis I intend to outline my view of the nature of science which will be referred to throughout the subsequent chapters. To do that, I need to make clear my epistemological position, which will be justified later. Throughout this thesis knowledge is regarded as best viewed as tentative and provisional. Its acquisition by individuals is taken to be an active process of construction on the part of that individual. New understanding is the result of individuals' existing ideas as well as experiences and ideas offered by others.

This epistemology is incompatible with a commonly-held view of scientific knowledge as proven knowledge and scientific theories as "derived in some rigorous way from the facts of experience acquired by observation and experiment" (Chalmers, 1982, p1). In contrast an epistemology that recognises knowledge as tentative leads to a view of science as a process of developing provisional theories about natural phenomena. Scientific knowledge, as it can be 'known' by scientists, has a permanently conjectural nature. The construction of such knowledge by scientists takes place in a social context and this has significance to the nature of that knowledge and the process by which it is constructed. Such a view allows for more than one theory to be acceptable at any one time - it is therefore pluralist.

The view of scientists as neutral observers of the world around them is also fundamentally flawed. All observations by scientists are "coloured by our expectations and prior experiences" (Medawar, 1979). All observations are 'theory-laden' and this has implications for scientists and those learning about science (Driver, 1983). Acceptance that observations cannot be strictly objective provides a challenge to empiricist views of knowledge as essentially based on observations. It also highlights the inadequacy of inductive methods in science. Inductive logic would allow scientists to generalise from specific instances. Medawar (1969) identified the shortcomings of such a view:
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i. it confuses the processes of discovery, or the formulation of scientific ideas, and justification;
ii. observations can never be objective;
iii. it does not explain the origin and prevalence of error;
iv. it is illogical, no number of instances of an event can logically lead to the idea that that event will always happen.

There is no simple answer to the question of what method describes the way scientists work. Indeed the way scientists actually operate may well be different from the way philosophers of science explain their activities and attempt to identify a logic to explain the nature of scientific knowledge. There are also considerable differences between the ways scientists work and the way children are encouraged to work ‘scientifically’ in school (Millar, 1989, p40). Popper provided one of the most influential contributions to the philosophy of science in recent years through his development of a hypothetico-deductive view (1963, 1972) which addresses the criticisms of inductive methods cited above. Popper recognised scientists’ knowledge as having a permanently conjectural nature (influenced by his recognition of the nature of Einstein’s challenge to Newtonian theories) and advocated that scientists should formulate their theories as unambiguously as possible and expose them as clearly as possible to refutation. His notion of falsification rather than proof when considering scientific theory is crucial to his approach. He, in the simplest terms, described a process for scientific activity which can be seen as:

i. problem concerning our understanding of the natural world
ii. proposed solution - a new theory or conjecture
iii. deduction of testable propositions from the new theory
iv. tests of those propositions to attempt to falsify them;
v. preference established between competing theories.

Popper’s account of the logic and history of science is not intended to address the
psychology of scientists - to him how a theory is arrived at has no bearing on its logical and scientific status. His approach allowed for the extent to which dreams, flashes of inspiration, misunderstanding and mistakes can all lead to scientific theories.

Medawar (1969) claimed Popper's approach provides a clear distinction between discovery and justification and recognised that "the initiative for new understanding comes from an imaginative preconception of what might be true". Observations can now be seen as confined to those that have a bearing on the hypothesis under investigation and the approach allowed for "rectification or running adjustment of the hypothesis". Even 'luck' now made sense and due weight was given to the critical purposes of experimentation. To Medawar, the hypothetico-deductive approach "gives a reasonably lifelike picture of scientific enquiry, considered as a form of human behaviour ... it makes science very human in its successes and its fallibility" (p58).

This approach, whilst considerably more satisfactory than earlier justifications for a scientific methodology, is still problematic. In particular it does not account for the theory-laden observation of scientists if they claim to refute an hypothesis. As Popper himself recognised, "In point of fact, no conclusive disproof of a theory can ever be produced .." (1972, p50). Popper deals with this by suggesting a scientist must state in advance under what conditions she/he will consider the proposed theory to be falsified. Another approach to the issue of the nature of scientific methodology is to consider the social context of the scientists' work.

Kuhn (1970) attempted to approach an understanding of science from the historical record of scientific research activity. He, in contrast to Popper, adopted a sociological perspective. He recognised science does not develop through the accumulation of individual discoveries and inventions. He introduced the notion of scientific paradigms to describe the "general theoretical assumptions and laws and techniques for their application that members of a particular scientific community adopt" (Chalmers, 1982, p90). Workers within a paradigm (such as 'Newtonian mechanics') practice what Kuhn called 'normal' science. Normal science is
predicated on the notion that scientists know what the world is like and will defend that assumption. However, when the community of scientists can no longer evade anomalies that challenge and subvert the existing practices and understanding, a new phase begins. “Extraordinary investigations take place which lead to a new set of commitments” (Kuhn, 1970) and a new set of assumptions. This discontinuous change is called, by Kuhn, a ‘scientific revolution’ and leads to a qualitative transformation of the scientists’ world. Kuhn’s contribution reinforces the notion of science as a human activity and recognises the importance of the social context in which scientists operate. Kuhn and others adopting sociological perspectives to science (eg Lakatos, 1974) go further than Popper and claim that a significant criterion for the acceptance of scientific theories is that they are “scrutinized and approved by the scientific community” (Driver, 1983, p4).

This brief discussion of the view of science which has informed my approach (based, in particular upon the work of Brown et al., (1986), Chalmers (1982), Driver (1983) and Magee (1982)) will be revisited at various points in this thesis.

1.10 Nature of the outcomes

The outcomes of my enquiry can be grouped in terms of the content strand, related to adult learning resulting from the use of a constructivist approach, and the process strand in terms of action research. However, the final chapter of my thesis brings these two strands together and considers outcomes in a more integrated way.

There are several issues addressed through the background chapters and the enquiry where educationalists and teachers tend to emphasise one aspect over another where both may more appropriately be seen to play an essential part. This holistic resolution of such issues and the apparently opposing perspectives of educationalists concerning them is in discussed in Chapter 12. For example, learning, as discussed in Chapter 2, involves both individual and social aspects. However, there is a tendency for one of these aspects to be emphasised by
teachers or those writing about education. Their preferred emphasis leads to pedagogical decisions, which may not, necessarily, be in the best interests of learners. Work on this enquiry has led me to recognise the importance of both factors and understand that viewing learning in a more holistic way where the role of the individual and the significance of social context are identified is the most appropriate conceptualisation of learning in science. In some senses a false dichotomy is set up by educationalists concerning these issues. Similar examples, where apparently 'opposing views' are articulated, include the place of content and process in the science curriculum; the development of skills and knowledge and understanding in terms of learning in science; the relationship between educational theory and practice. The way in which I have constructively resolved these issues is discussed and the parallels between science education and action research are explored.

The final chapter also revisits the outcomes discussed in Chapters 10 and 11 in terms of their implications for teaching primary science, in a context where proposals for more specialist teaching, more subject teaching and more whole-class teaching are emanating from the DFE; for inservice education, in the context of further designated courses in other curriculum areas; for initial teacher education, in the context of increasing staff-student ratios, increased use of directed time and moves towards school-based training. The particular significance of metacognition in adult learning is highlighted. There is evidence through the enquiry of the success a constructivist approach with adult learners in terms of outcomes related to gains in scientific knowledge and understanding and in terms of teaching science. However, there are a number of insights into the use of a constructivist approach which deserve the attention of tutors and providers of inservice education related to the way in which children's alternative ideas are introduced to teachers; the significance of social context and the extent to which adults develop alternative ideas as a result of discussions with their peers; the complex nature of restructuring in different conceptual areas.

The extent to which a constructivist approach is one which can be applied to learning in different areas is discussed and this leads to a section in which the notion of constructive
Chapter 1 - Introduction and background

Action research is explored in terms of epistemological and pedagogical assumptions. The conceptualisation of action research in terms of orientation, structuring, restructuring and application is revisited and the other innovative aspects of my enquiry is summarised. These include the use of a framework for analysing multiple concerns and a multi-levelled approach to analysis through structured reviews.

The thesis concludes with a discussion about the coherence of my approach and the extent to which the holistic approach has been beneficial. The coherence is justified through the common epistemological assumptions which apply to the learning of children in the classroom, teachers and students on courses and to my own learning through the enquiry. The same epistemological assumptions also apply to the view of science which underpins my teaching and my approach to this enquiry through action research. There are therefore three 'key ideas' which provide coherence to the thesis - a constructivist epistemology, a constructivist approach to teaching and a constructivist view of the nature of science.

1.1 Conclusion

During the period of data collection for this enquiry the key researchers in the area of primary teachers' scientific knowledge and understanding stated:

Most primary school teachers are completely outside the science paradigm. The implementation and evaluation of a constructivist programme for primary science INSET would therefore be particularly challenging and innovative.

Kruger, Palacio and Summers, 1990c, p140

My enquiry attempts to meet this challenge and in doing so provides an example of a constructivist approach to adult learning which I hope will encourage others to recognise the potential of such an approach and explore it in their own teaching contexts.
Chapter 2 - Constructivism

2.1 Introduction

This chapter discusses a constructivist view of cognitive development and learning upon which the teaching approach being evaluated in this research is grounded. It is a perspective which has also enabled me to clarify and develop my understanding of my own learning as I engaged in the process of my enquiry. My current acceptance of a constructivist view of learning is a result of my previous professional experience, discussed in Chapter 1, and my tentative understanding of knowledge as discussed below. I regard this position as one which resulted from a constructive process in which I engaged, and am engaging. It is therefore, as I stated at the outset, not postulated as a 'right' answer or as a definitive personal perspective. It is, and, logically, can only be regarded as a view of learning which best matches my experience at this time of child and adult learning. It is therefore the most appropriate view of learning upon which to base decisions about strategies for teaching science. The acceptance of epistemological assumptions (and ontological ones, discussed in Chapter 6) restricts subsequent decisions about teaching strategies, as it does decisions about appropriate research methodologies. There are, for example, other views of learning, such as behaviourism (Pavlov, 1927; Skinner, 1968) and rationalist notions of being able to transmit or transfer 'objective' knowledge from a teacher to a passive learner, which are incompatible with the view of knowledge I currently hold.

The chapter begins by looking at fundamental questions about the nature of knowledge in order to indicate the epistemological basis for a constructivist view. The discussion should, however, be seen in the context of science education and therefore focuses upon a learner's knowledge of the physical and natural world.

Constructivist theory has its origins in the work of Piaget. In its simplest terms it regards a learner as the active constructor of his/her own knowledge and understanding. These origins have led to constructivism being viewed, particularly within science education, as a theory focusing upon the individual and her/his attempt to construct knowledge about the world.
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around her/him. The significance of the social context of that individual's experience has been emphasised by social constructivists, who have had much less influence on science education.

The chapter discusses Piaget's contribution to the field of child development, criticisms of his theories, and the influence of his ideas on personal constructivists. The contribution to my understanding of learning made by Vygotsky and others who informed the thinking of social constructivists is then considered. The relationship between cognitive development and learning will be discussed and the significance of the social dimension of learning considered. This leads to a third school of thought which brings together the individual and social perspectives and reflects my own view of learning.

The research that has been carried out into children's learning in science will be discussed and the nature and significance of children's common alternative ideas and explanations outlined. This will be followed by a discussion of the implications of constructivism in terms of appropriate teaching strategies.

The chapter will conclude with a section considering the relevance of this view of learning to my own learning and approach to this research.

The use of key terms, which are used in a variety of ways within the literature, is problematic when dealing with epistemological issues. At this stage of the discussion, the term 'knowledge' is used broadly to describe how an individual can know something about their world. 'Concepts' are taken to be elements of knowledge or ideas which an individual can know. These might be a regularity in events or objects designated by a label (Novak and Gowin, 1984, p4). These, it is assumed, are organised by individuals into cognitive or conceptual structures which can be used selectively to explain specific experiences.
2.2 A constructivist view of knowledge

We cannot be certain about how children's or, indeed, adults' ideas about the world develop or how they are organised by the brain. However, the work of philosophers, psychologists, sociologists and educators provide theories which offer teachers some insights to inform their approach to teaching. The following treatment outlines my own tentative understanding which is offered in the context of Gessell's recognition that, "our present-day knowledge of the child's mind is comparable to a fifteenth century map of the world - a mixture of truth and error ... vast areas remain to be explored" (Gessell, quoted in Fisher, 1990, p1).

To understand the nature of constructivism, which is essentially a theory about learning, it is necessary to address the fundamental question of what is it to know something, since learning is a process of gaining knowledge. There is, of course no simple answer to this question and epistemological issues such as the source, basis and certainty of our knowledge have been addressed by philosophers for centuries. Rationalists (such as Descartes) have tried to find a completely sound foundation for our knowledge in terms of certain procedures of human reasoning and found that such knowledge cannot be discovered in experience based upon sensory information. In contrast, empiricists (like Bacon, Locke and Hume) looked to find the basis for knowledge in sense experience, again with limited success. Analyses of these philosophical positions are common and the ones which have informed the present discussion include Carr and Kemmis (1986), Chalmers (1982), Medawar (1969), Popper (1963, 72).

Perhaps the first consideration should be whether knowledge is something which can exist independently of the individual knower. This will lead to the related concern of how knowledge can be transferred from one individual to another.

If knowledge is considered as objective and somehow 'out there', to be known by an individual, then knowing something to be true must be dependent upon achieving a perfect
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match between an individual's cognitive structures (their mental picture of the world) and the external structures (the 'real' world) that they are supposed to represent. This poses a dilemma, since an individual cannot 'know' whether such a match has been achieved without basing such a decision upon their own unique experience of the world. An individual cannot, as Putnam recognised, adopt a 'God's eye view' (Putnam, 1982, quoted in von Glasersfeld, 1989, p6), and see the 'real' world. There is no way in which the knowledge an individual has can be tested against absolute reality (Sinclair, 1989, p55). Of course, this is not a claim that some knowledge is not objective, there may indeed be some form of 'absolute' knowledge. It is a claim that an individual cannot know knowledge to be absolute with certainty. This is a view that has been held, in different terms, for many centuries as the following reminds us:

The gods did not reveal, from the beginning,
All things to us, but in the course of time
Through seeking we may learn and know things better.
But as for certain truth, no man can know it,
Nor shall we know it, neither of the gods
Nor yet of all the things of which I speak.
For even if by chance he were to utter
The final truth, he would not know it:
For all is but a web of guesses.

Xenophanes, quoted in Magee, 1982

A different view of knowledge is to reject, or at least avoid, the need for absolute knowledge, and regard it as more tentative and useful in terms of the extent to which it fits with our observations or experience of the world. In this view, knowledge is seen as something that an individual derives from experience and which makes no claims to represent the 'real' world. Its value lies in the extent to which it is useful to the knower; the extent to which it enables an individual to structure and organise their experience and solve experiential problems (von Glasersfeld, 1989, p7). The means of assessing knowledge is no longer in terms of 'match' with an absolute reality, but with 'fit' to the world as it is experienced by an individual. From this perspective individuals are not striving to replicate a 'correct' conceptual framework, or cognitive representation, of the world, but actively engaging in a process of constructing
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contemplative structures which enable them to make sense of their experience and make predictions and decisions that allow them to function effectively. It is a process about which the knower can be aware; and in that sense, it involves the individual in reflecting upon their own mental operations. This is metacognition (Fisher, 1990, p11) and is a process which will be revisited later in this thesis.

If it is 'tentatively' accepted that personal knowledge about the world is tentative and individually constructed, can it be communicated from one individual to another? Language is the means by which humans generally communicate and based on the above treatment of knowledge it is inevitable that each individual will have constructed a unique and subjective meaning for many, if not all, of the words they use. The meanings attached by individuals to words are not somehow contained within the words themselves. This leads to the conclusion that if communication is regarded as the conveyance of absolute meaning from one individual to another it is not possible for us to communicate. However, if it is accepted that communication is possible without the words used meaning exactly the same to those communicating then it is possible.

For communication to be considered satisfactory and to lead to what we call 'understanding', it is quite sufficient that the communicator's representations be compatible in the sense that they do not manifestly clash with the situational context or the speaker's expectations.

von Glasersfeld, 1989, p9

The process of communication will sometimes lead to one or more of the communicators needing to modify or reorganise their cognitive structures, or mental view of the world as experienced. In this way, communication can be regarded as one of the means by which an individual becomes better 'adapted' in cognitive terms to the world. The concept of adaption is used here in a way that is similar to its biological meaning and is a theme that is central to Piaget's view of cognitive development as will be discussed later. As von Glasersfeld stated, 'the cognitive organism tries to make sense of experience in order better to avoid clashing with the world's constraints. It can actively modify ways and means to achieve greater viability'
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(p11). He suggested that learning involves individuals in drawing conclusions from experience and basing future actions on those conclusions. This raises another philosophical issue since it implies that an inductive process is involved. For an individual to make predictive decisions would require them to accept that there are regularities involved in experience and that future experience will probably conform to these regularities. The use of the term 'probably' is crucial in this context since the widely held criticisms of inductivism (Medawar, 1969; Popper, 1963) are based on the illogicality of assuming that because something has been observed to happen regularly (such as the sun rising in the east) it is sufficient grounds for stating that will always be the case. Popper claimed that individuals were not merely looking for patterns in their experiences but, 'actively try to impose regularities upon the world' (Popper, 1963, p46). To him, this was achieved through a process of trial and error, whereby an individual proposes conjectures or hypotheses to test against experience, which may be 'refuted' and rejected or tentatively retained if evidence is found to support them. This avoids acceptance of a pure inductivist explanation since conjectures may be based on single observations, or, according to Medawar (1969), on intuition. It does however, assume that theories so devised are probable, not certain (Popper, 1963, p53). It also accepts a principle of empiricism in that conjectures are accepted or rejected by observations, testing and experimentation. Popper's view of knowledge acquisition, or construction, explains how we can make predictions about everyday experiences, such as 'knowing' it will get light tomorrow morning because the sun will rise, without recourse to a 'pure' process of induction. It involves the recognition that the identification and use of a set of regularities is one way of cognitively organising our experience and there may be others. Popper's treatment of knowledge acquisition, in terms of the significance of falsifying, rather than verifying, theories, and criticisms and developments of his view (Feyerabend, 1975; Kuhn, 1970; Lakatos and Musgrave, 1970) offers a view of the nature of science which has significantly informed my thinking in this area as was discussed in Chapter 1.

Von Glasersfeld's treatment of knowledge (1989) recognised that an individual's interpretation of experience and language have in common the reliance upon the conceptual structures that
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the interpreter already has (p11) and this is fundamental to the view of knowledge which informs constructivism generally and the present research in particular. Interpretation requires an awareness of possibilities and an active and deliberate choosing between possibilities for rational reasons.

If our interpretation of experience allows us to achieve our purpose, we are quite satisfied that we ‘know’; and if our interpretation of communication is not countermanded by anything the communicator says or does, then we are quite satisfied we have ‘understood’.

von Glasersfeld, 1989, p11

Before summarising the view of knowledge outlined so far it is appropriate to note that there are other perspectives which have been considered and have influenced the perspective adopted. These, to some extent, will be explored in more detail when addressing the nature of teacher knowledge (later in this chapter) and the nature of action research in Chapter 6. In particular, the significance of ‘critical theory’ proposed by the Frankfurt School, articulated by Habermas (1972) and discussed by Carr and Kemmis (1986), is acknowledged. Habermas attempted to establish different forms of knowledge shaped by the different human interests that they serve. These he called ‘knowledge-constitutive interests’. To him, knowledge was, as discussed above, the result of activity, but he postulated that the activity is motivated by natural needs and interest which ‘guide and shape the way knowledge is constituted in different human activities’ (quoted in Carr and Kemmis, 1986, p134). These interests are a priori, pre-suppose any cognitive act and consequently constitute the possible modes of thought. Habermas identified three ‘knowledge-constitutive interests’:

i. technical - concerned with acquiring knowledge to gain control over natural objects. This is empirical and instrumental knowledge which enables individuals to explain scientific phenomena and is basically the form of knowledge discussed so far, and the major concern of science education.

ii. practical - concerned with understanding and clarifying the conditions of
meaningful communication and dialogue. This hermeneutic or interpretive aspect of knowledge has been implied in the above discussion about communication.

iii. emancipatory - concerned with knowledge, gained through reflection, of the objective framework in which communication and social action occur. This was the dimension of most interest to Habermas and was the basis for his advocacy of discourse as a means of gaining such knowledge.

Polanyi (1962) has also been influential in terms of his epistemological work. He held a view of 'personal knowledge', which cannot, he claimed, be termed either subjective or objective (p300). This is discussed further in Chapter 6. He also identified three categories of tacit knowledge. The first might be seen as totally ineffable and an example is the way we ride a bicycle. The act does nothing to add to our knowledge of bicycle riding. A second kind is illustrated by reading a book during which we articulate one aspect of our work at the same time as using a related tacit component. We read for meaning without attending to the process of translating symbols. Another example he cites concerns a craftsman's use of tools; the tool is an extension of the body and to Polanyi, 'in-dwelling' is involved. The final achievement in terms of learning to use a tool is to be at one with its use. Conscious learning begins where this tacit knowledge ends. His third type of tactic knowledge is when the other two kinds have "fallen apart". This means each can be used to explore or regulate the other in a useful manner. Solomon (1992a) discusses this and points out that if articulation "runs ahead, as when we speculate out loud, then tacit knowledge may be used to check it. 'That doesn't feel right', we say.". She goes on to compare tacit knowledge with general knowledge:

Tact knowledge acquired from action is strongly situational, and 'taken for granted', much as general knowledge. But it is different from general knowledge because it is almost exclusively personal and cannot be reinforced or added to by social converse until it has been verbalised.

1992a, p92

Solomon's writing stresses knowledge in two domains: 'life-world' and 'abstract academic' and
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the relationship between these and the difficulties learners have moving between the two domains, in and out of school.

In summary, for the purposes of this research, knowledge is viewed as tentative and not absolute. Knowing involves an individual in actively constructing or generating ideas which have or can be verified or tested out against experience and the views of others. Knowledge is, therefore, ideas which are held by an individual in an ordered way which allows them to be used for decision-making about future actions. Understanding involves the selection and use of knowledge in a variety of contexts to meet a variety of demands.

The treatment of knowledge outlined introduces the view accepted by constructivist theorists who regard children as the active constructors of their own unique understanding of the world. This active construction of ideas, as has been noted, results from the process of making sense of experiences. From a very early age, it is asserted by constructivists, children begin to build up a cognitive structure or conceptual model of the world around them. This conceptual model can be likened to a dynamic network of inter-related ideas, or concepts, that a learner links together in a unique manner. Some of these ideas will be well-tested and supported by evidence. Others will be more like conjectures or tentative hypotheses being tested. Some experiences the learner has will prove compatible with their existing ideas and be explained within the existing conceptual model. Others will challenge or contradict existing ideas and will not be explainable within the existing conceptual model. These experiences lead to cognitive conflict (Wood, 1988, p43) and will require the learner to 'rethink' or restructure the model they hold of the world. Consequently, by the time children reach school age constructivists recognise that they have already developed a complex set of ideas, or concepts, organised in a structured way as constructs or conceptual frameworks, which will have an influence on future learning. These existing ideas will inevitably include many which do not match 'accepted' scientific thinking. However, since they have been constructed and tested, if perhaps naively, by the learner and found adequate and workable they may be held firmly and be resistant to change unless the learner is offered convincing evidence or reasons
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This view of knowledge is explicit in the National Curriculum Non-statutory Guidance.

In their early experiences of the world, pupils develop ideas which enable them to make sense of things that happen around them. They bring these informal ideas into the classroom and the aim of science education is to give pupils more explanatory power so that their ideas can become more useful concepts. Viewed from this perspective, it is important that we should take pupils's initial ideas seriously so as to ensure any change or development of these ideas ... becomes 'owned' by the pupil.


2.3 The contribution of Piaget

It is not my intention to detail Piaget's work on child development since this is extensively documented and discussed elsewhere (Ginsburg and Opper, 1969; Light et al., 1991; Piaget, 1929, 1930, 1967; Wood, 1988). However, it is important to recognise that although, as discussed later, some aspects of his work have been subsequently criticised, his extensive experimental work with children led him to articulate a theory of cognitive development which has been influential on later psychologists and educationalists who have contributed to the literature on constructivism. Piaget attempted to identify the logical structures that underpin cognitive development and in doing so rejected the associationist and psychometric traditions which had dominated psychology in the previous period (Light et al., 1991).

Piaget (who began his work as a biologist before turning to psychology) basically proposed that children's knowledge is constructed through interaction with their environment (Driver, 1983, p51). In doing this he established the premise that the child is the active constructor of his/her own knowledge and understanding. He also recognised the crucial part 'doing' plays in the development of a child's cognitive structures. For him, activity changed the 'knower-known' relationship (Sinclair, 1989, p56). His background in Biology led him to regard children as becoming better 'adapted' to their environment, or in his term engaging in a process of equilibration, that involves the assimilation of experience (when the individual finds a 'fit' with
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their existing cognitive framework, or action-scheme, in Piaget's term) and the accommodation of knowledge structures to that experience, when experience does not 'fit' with existing ideas and they need changing or replacing.

Through these processes of disequilibrium and subsequent equilibration new intellectual structures are developed which incorporate the preceding structures and consequently development is through an invariant sequence of hierarchically ordered stages.


Piaget suggested that children pass through stages of development from egocentric to more objective thought (from pre-operational to formal thinking) and, through his experimental work, detailed the characteristics of these stages. He claimed that a child's thinking results from a sensori-motor period, which begins at birth and involves the child in acting, initially on reflex, then in a search for patterns in reactions and later in goal-directed ways. These early interactions with the environment and the learned co-ordination between actions and their sensory consequences provide the basis on which a child's cognitive structures develop.

When some actions are rejected on the basis of mental action alone, as a result of imagining outcomes, the child has begun to internalize mental action (Wood, 1988). The pre-operational period, from about 18 months to 7 years, is, according to Piaget, characterised by egocentrism and is a stage in which children's perceptions dominate their thinking. The concrete operations period from approximately 7 to 11 years is when a child begins to think more logically and becomes decentred, they can coordinate, compensate, reverse and appreciate the nature of invariance. Into adolescence the child reaches the formal operations period which is characterised by full logical thinking and the capacity to think in abstract ways.

Piaget saw children's thinking as qualitatively different to that of adults,

The young child is not only less knowledgeable but will view her entire world quite differently depending on the limitations of the mental structures governing thinking at any one point in time.

Piaget, 1962 quoted in Light et al., 1991, p19

Piaget's theory postulated that progress through these stages was natural and resulted purely
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from maturation and not from education. It was a theory of cognitive development, rather than a theory of learning (where learning is seen as involving instruction, for example, in terms of what goes on in school or indeed informally at home). This implied that children could not learn or be taught how to operate at a particular stage until they had passed through earlier ones and informed much of the educational thinking of the 1960s and 70s. It led to many teachers accepting the notion of 'readiness' and consequently not providing children with experiences which did not match their perceived Piagetian developmental stage. For example, Piaget suggested children could not think hypothetically at the concrete operations stage and this had implications for how teachers approached primary science. He regarded formal logic as the highest level of intellectual development. His emphasis on the importance of action was readily adopted by many primary teachers and the importance of children problem-solving which he also advocated was adopted by curriculum developers and projects as discussed in Chapter 3 (eg Nuffield Mathematics Project and Science 5 -13).

Piaget's theory regarded action as the foundation for developing knowledge and therefore placed less importance on the significance of children's language in the process of learning. To him language was a child's symbolic means of representing the world, it did not create the structure for thinking, it simply facilitated its emergence. His approach was endogenous and focused on the individual child and did not consider in any detail the child as a learner in a social context.

To summarise, in somewhat simplistic terms, Piaget's theory leads to, "an image of the child as a solitary thinker, struggling to construct a personal understanding of the .. world" (Light et al., 1991, p x).

The role of language and social context were addressed by others who shared with Piaget the premise that thinking is an active and constructive process. The Russian psychologist, Vygotsky, researching in the 1920s and 30s, considered the place of instruction and the significance of the learner in a social context (Vygotsky, 1962). He described intelligence itself
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through the capacity to learn through instruction (Wood, 1988, p9). His work informed a school of thinking known as social constructivism, which emphasises cognitive development within a social context rather than emphasising the individualistic perspective of Piaget and his followers.

2.4 The contribution of Vygotsky.

Vygotsky adopted a perspective that was based on a desire to link a theory of learning to the cultural and social context in which it occurs. He, like Piaget, recognised the importance of activity as the basis for cognitive development, but his emphasis on the role of instruction and the relationship between the learner and her/his peers or adults leads to another view of readiness based not only on what a learner knows but on her/his capacity to learn with others' support.

His work leads to a very different relationship between cognitive development and learning. To explain the development of a child's cognitive structures Vygotsky recognised that we need to look not only at the individual but at the external world in which the child exists. For him a child's thinking results from social interactions and in that sense development results from learning, which in turn allows further learning to occur. There is an iterative relationship between them and they are inextricably linked. Development is not separate or transcendent to learning but results from it:

Any function in the child's cultural development appears twice, on two planes. First it appears on the social plane, and then on the psychological plane. First it appears between people as an intermental category and then within the child as an intramental category. This is equally true with regard to voluntary attention, logical memory, the formation of concepts, and the development of volition.

Vygotsky, 1978, p163

This process of internalization is the basis of Vygotsky's view of cognitive development and in that it involves a notion of reconstruction his views are close, in this respect, to those of
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Piaget.

Vygotsky's view of the initial stages of cognitive development, unlike Piaget's placed the child's social context centre stage:

> From the very first days of the child's development his activities acquire a meaning of their own in a system of social behaviour and, being directed towards a definite purpose, are refracted through the prism of the child's environment. The path from object to child and from child to object passes through another person. This complex human structure is the product of a developmental process deeply rooted in the links between the individual and social history.

p30

He introduced a key notion of *Zones of Proximal Development* (ZPDs) which describe the difference between the learner's "actual developmental level, determined by independent problem-solving and the level of potential development as determined by problem solving under adult guidance or in collaboration with more capable peers" (p86). Subsequently, problem solving has been understood by neo-Vygotskians to mean performance in other domains of competence (Light et al., 1991, p45; Wertsch, 1985a and b). In other words the child's potential for learning is evident and realised when they receive instruction or support from more 'mature' members of their culture. Piagetian theorists would see such 'learning' before the child was 'ready' as the learning of procedures, rather than the development of understanding (Wood, 1988, p24). Vygotsky offers a view of learning that deals with the educability of an individual. This is an outcome that Piaget never set out to provide. Vygotsky also places greater emphasis on language not, in Piaget's terms, as personal and egocentric, but as social and communicative in origin and intent (op cit, p27). Language is regarded as a tool for thought rather than a medium for representing it (Britton, 1989). Even egocentric utterances were seen to serve an intellectual purpose (Vygotsky, 1962, p17). To Vygotsky, word meanings 'evolve' during childhood and he recognised a child's meaning may be very different to that held by adults. He accepted, along with Piaget, the development of 'spontaneous concepts' which are arrived at as a result of experience, but crucially added to
Piaget's view, non-spontaneous concepts which are “taken over from other people (notably teachers) - taken over as problems needing solution, or as 'empty categories' so to speak which need embodiment in .. experience and (to) ground themselves in (the learner's) knowledge base” (Britton, 1989, p210). The distinction between spontaneous and scientific concepts is central to Vygotsky's analysis (Panofsky et al., 1988, p 251). Vygotsky stated that with scientific concepts, 'the relationship to an object is mediated from the start by some other concept ... the very notion of scientific concept implies a certain position in relation to other concepts ie a place within a system of concepts' (1962, p93). The learning of such concepts is linked to the word meanings learners have developed through everyday experiences. In this sense he saw everyday concepts standing 'between the conceptual system and the world of objects' (p180). He recognised that learners may have an understanding of everyday, spontaneous, concepts but be unable to define those concepts in logical terms and in contrast be able to define certain scientific concepts, about which they have received formal instruction, without having a sense of their concrete realisation. Spontaneous and non-spontaneous concepts may have very different origins but cannot be separated, according to Vygotsky, in the thinking of the child. According to Panofsky et al., "In the ideal case, the scientific concepts will eventually acquire concrete meanings for the child, and the spontaneous concepts in time will become rational and accessible to his or her conscious and volitional verbal strategies" (p252). Another significant factor in children's conceptual development was, according to Vygotsky, their ability to read and write, which facilitated reflection in a way not possible through oral language.

Vygotsky's view therefore lead us to an image of a child, "being initiated into shared cultural understandings through close relationships with parents and teachers as well as siblings and peers” (Light et al., 1991, x).

Vygotsky's work focused on children's thinking but it has been claimed that identical processes can be seen operating in the learning of adults (Light et al., 1991, p40) as I intend to illustrate with evidence collected during this enquiry. Before finishing this brief treatment of
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Vygotsky's contribution it should be noted that he died at the age of 38 and left his ideas in an incomplete and 'sketchy' form (Ingleby, 1986, p311) which allowed various interpretations. This is one of the reasons why his influence can be traced in many of the diverse treatments of social constructivism discussed below.

2.5 Developments resulting from the work of Piaget and Vygotsky

The role of language in learning has been researched and discussed extensively since Piaget and Vygotsky carried out their research, and Chomsky's theoretical view that children acquire language naturally since they are born with the neurological prerequisites for learning language (Chomsky, 1957) was influential but much criticised in the light of evidence regarding the 'role of social relations in providing the foundations for language' (Ingleby, 1986). Evidence to support the view that language plays a crucial part in cognitive development is considerable (Barnes, 1976; Robinson, 1981; Tizard and Hughes, 1984; Wells, 1986).

Bruner's contribution to the debate about the nature of learning was grounded in information theory; he adopted Vygotsky's view of the significance of a learner's social experience (including culture, social interaction and instruction) but he also considered the influence of biology and evolution (Bruner, 1968, p2). The interaction of these two dimensions is explored by Wertsch (1985a). In some senses then Bruner bridges the gap between Piaget and Vygotsky although he dismisses Piaget's stages of development. In Bruner's own words,

My model of the child ... was very much in the tradition of the solo child mastering the world by representing it to himself (sic) in his own terms. In the intervening years I have come to increasingly recognise that most learning in most settings is a communal activity, a sharing of the culture. It is not just the child that must make his knowledge his own, but that he must make it his own in a community of those who share his sense of belonging to a culture. It is this that leads me to emphasise not only discovery and invention but the importance of negotiating and sharing - of a word of joint culture creating as an object of schooling and as an appropriate step en route to becoming a member of adult society ...
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Bruner, 1986, p127

This view, that recognises the individual and social perspectives on learning is one that is revisited in more detail below.

Subsequent researchers, in common with Vygotsky and Bruner, have questioned the validity of Piaget's stage theory. Some have questioned the approach he used (Wood, 1988, p44). The experimental basis of his work and of much developmental psychology led to the somewhat cynical view that it was, "the science of strange behaviour of children in strange situations with strange adults for the briefest periods of time" (Bronfenbrenner, 1977). Criticisms of Piaget's experiments centred around such issues as the sample he selected and the relevance of the context of tasks required of children and their interpretation of those tasks (Brown and Desforges, 1979; Donaldson, 1978; Isaacs, 1936).

Donaldson's work (1978) had particular significance since it represented one of the first major developmental research projects to explore the educational implications involved in developing a view of learning. Her research emphasised the importance of children's language and offered evidence of the extent to which children's thinking is context-bound. The way a problem is presented, the language used, the child's interpretation of the task and the relationship between child and adult all influence the child's success. She found children were far more competent thinkers than Piaget suggested when the thinking takes place in embedded contexts. She recognised, however, that disembedded, context-free thinking was required in schools.

Despite the evident weaknesses in aspects of Piaget's views, there have, as noted, been significant curriculum projects based on a Piagetian approach. *Science 5 - 13* is the obvious example that is familiar to many primary teachers (see Chapter 3) and within secondary science the work of Shayer and Adey (1981) has been influential. Their work became a common text used in initial teacher education and was, in the author's experience, regarded by curriculum
developers and advisory staff as a sound theoretical position upon which to develop a secondary science curriculum. Shayer and Adey claimed the Piagetian model offered, "a promise that no other learning theory could offer, and one that was allowed to guide, but not to direct, the course of our investigations" (1981). This involved them accepting the stage model. Their research, which involved tests with 11,000 school children, offered, they claimed, little evidence to challenge Piaget's views. Others have questioned the adoption of teaching approaches based on 'readiness' and matching tasks to children's Piagetian stages (Driver, 1983, p57). Ironically, later work by Shayer on Cognitive Acceleration provided evidence that teachers can help children develop abstract ideas before they are 'ready' in the Piagetian sense (Shayer and Beasley, 1987). The emphasis upon the individual evident in Shayer and Adey's work, and in the personal constructivist view below, has ensured that this school of thought, with its Piagetian origins, remains influential in science education, perhaps at the expense of recognition of the influence on learning of the social context.

Vygotsky's ideas have been adopted and developed by those who have been more interested in the social, rather than personal, factors in development and learning. The more 'extreme' position at the 'social' end of the continuum is taken by some who regard themselves as 'social constructivists'. This is a label used (Gergen, 1985; Ingleby, 1986) to describe a school of thinking which explicitly emphasises the social dimension. Ingleby (1986) provided a thorough discussion of the strands of psychology and sociology which, he claimed, had effectively established this new 'paradigm'. The influence of the critical movement of the 60s (including the work of Habermas) is evident in social constructivism. Although social constructivism encompasses quite diverse thinkers they have in common the way they deal with the individual/social 'dichotomy'. According to Ingleby this recognised, "first, human thought, perception and action must be approached in terms of meanings: secondly, the vehicles of 'meaning' are codes (especially language) whose nature is essentially intersubjective" (p305). Therefore "mind is an intrinsically social phenomenon". Many Western social constructivists were influenced by the work of Vygotsky (Bruner, 1968; Donaldson, 1978; Wertsch, 1985a). However, Ingleby (1986) found Vygotsky's treatment of
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the dualism of individual and society inadequate (p305). He claimed a major weakness in social constructivist thinking was the extent to which it failed to address the affective dimension of development, particularly in terms of motivation (p316). Despite this criticism, social constructivism, with its almost exclusive emphasis on the social rather than individual perspective of cognitive development and learning has had a significant influence on educational thinking during the recent period (Pollard, 1985; Pollard and Tann, 1987; Richards and Light, 1986). Within science education the influence of social constructivists has been less evident (Solomon, 1989, p127). However, Solomon's work (1987, 1988, 1989) provides examples of the social context for learning in science being given some attention in secondary science and Driver (1989, p84) has also drawn attention to this social context. Within the primary sector, there is evidence of social aspects of learning being prioritised (see Pollard, 1985), but not explicitly in the area of science.

To return to the more individualistic view, alternatives to Piaget's stage model, but still retaining a constructivist perspective, have been offered by others. Novak proposed, "a model of cognitive development that .. (is) .. dependent on the framework of specific concepts and integrations between these concepts acquired during the lifespan of the individual" (Novak, 1978, quoted in Driver, 1983, p58). This view is based on the work of Ausubel who proposed a 'theory of meaningful learning' (McClelland, 1983). He contrasted meaningful learning, which is non-arbitrary, non-verbatim and concerned with the substantive incorporation of new knowledge, with rote learning, which is arbitrary, verbatim and involves non-substantive incorporation of new knowledge. Meaningful learning requires a disposition of the learner to link new concepts to existing ones and it requires the learner to have an existing relevant cognitive structure to which new concepts can be related non-arbitrarily. Rote learning, according to Ausubel, characterises much of school-learning. Ausubel differed from Piaget in suggesting knowledge is structured around specific concepts not within logical structures which are independent of content. This led him to reject a teaching strategy based on readiness, implied by a Piagetian framework, and propose one that recognised the importance of the learner's existing ideas:
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The most important single factor influencing learning is what the learner already knows. Ascertain that and teach him accordingly."


This approach is one that has much in common with the constructivist approach to teaching science discussed below.

This section concludes with Harlen's (1985a) view of learning which she restated more recently (1992), and is based on a constructivist perspective. It summarises the view of the child as an individual learner which continues to influence teachers' current thinking about learning in science. It should be noted that Wynne Harlen is the most prolific and widely read theorist in primary science. She proposed her view of learning as a working hypothesis to help teachers understand children's development. In this sense it has added significance since it is the terms by which a complex and sophisticated view of learning has been communicated to primary teachers, although often this communication has been mediated through INSET tutors or advisory teachers. She identified four steps in the generation of ideas in science that involve connecting an experience with an existing idea; creating a possible explanation(s) (or hypothesis) based on it; using the explanation to make a prediction; testing the prediction (Harlen, 1985, p57). This process could lead to an existing idea being retained in much the same form as before (cf with Piaget's assimilation); the existing idea being modified to take account of the new experience or the existing idea being rejected totally and perhaps replaced with a new one as a result of evidence obtained (accommodation). This is offered as a process by which a child actively constructs new ideas although obviously it simplifies a complex, and sometimes almost instantaneous process of assimilation or accommodation.

Harlen's treatment also discusses the extent to which children use process skills such as observation, predicting and testing in the development of scientific ideas and establishes an inextricable link between the two which is explored further in Chapter 3. It fails, however, to recognise the significance of the social dimension of learning which has been highlighted in this chapter.
2.6 The relationship between individual and social constructivism

The two constructivist perspectives, focusing on the individual and social dimension of learning, have tended to be polarised in the writing of educationalists who seek to inform teachers' practice. The individualistic view has been the most common in the literature concerning science education, particularly at primary level. The next section considers the extent to which the two views of cognitive development and learning outlined so far, based on individualistic and social dimensions, can and have been synthesised. It is my premise, and that of others discussed below, that ideas that a learner constructs, particularly those concerning the natural world (physical and biological), are the result of their individual cognitive activity and the social context in which experience or instruction occurs. The individual has to deal with experiences in their own unique way to construct an understanding of that experience, but the nature of the experience, especially if it occurs in a social context, and the way an individual learns from it will depend upon the interactions between the learner and others. The personal and social dimensions of cognitive development and learning are inextricably and dynamically linked and it is therefore preferable to avoid emphasising either to the detriment of the other, in terms of decisions concerning teaching.

Sinclair (1989) recognised that, as well as the psychological reasons for considering social interaction as essential for knowledge acquisition, there is an 'epistemological necessity' for knowledge to be constructed in a social context, since this is the way in which an individual can 'judge the quality of the knowledge' they have acquired (p56). It has been noted earlier in this chapter that an individual can have no way of matching their conceptual framework to reality (von Glasersfeld, 1989) and therefore checking ideas against those of others becomes a necessary means of assessing the probability that one's existing ideas are acceptable, in terms of conventional or shared understanding of everyday experiences. This has similarities to Habermas' view of emancipatory knowledge being obtained through discourse, discussed in a previous section. Sinclair also noted a third reason for accepting the importance of the
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social as an essential factor in knowledge acquisition in terms of the accumulation of knowledge within a society and the way this "intervenes in the individual processes of the construction of knowledge". If not, he claimed, every generation would start rediscovering from the knowledge base of cave-dwellers. There is implied in this view another way of looking at knowledge which recognises 'personal knowledge' as that which is unique to each individual and based upon their own modes of cognition, experiences and personality; everyday knowledge which is the shared, communicable basis for making sense of the world based in both individual and collective experiences and discipline-based knowledge which is also shared, but more universal and having agreed central concepts, structures and procedures (Broadhead and Squires, 1989). Whilst identifying the significance of shared or socially constructed knowledge this position recognises that "ultimately personal knowledge, each individual's versions of public knowledge, whether common sense/everyday or discipline-based, is mediated through individual perception and cognition" (p9). This view is similar to Solomon's (1992a) discussed above. As discussed below, there are often similarities between the discipline knowledge of a previous generation (e.g. Aristotle's views on motion) and the alternative, intuitive ideas of a later generation (that there is always a force acting in the direction of movement of a moving object).

The two perspectives of personal and social constructivism, often over-simplified as the nature (genetically-influenced) and nurture (environmentally-influenced) views of development, are not as polarised in the writings of Piaget and Vygotsky as is sometimes suggested (Wood, 1988). Both see nature and nurture as 'inseparable supports for individual development' and 'both theorists chose to emphasise one or the other aspects for further elaboration' (Rogoff, 1990, p71). For example, Furth (1974) provides clear evidence that Piaget recognises the importance of 'nurture' and this is explicit in some of his later work (Piaget and Garcia, 1983) where it is recognised that, particularly, as children get older "their direct experience with objects becomes more and more subordinated to the system of meanings the societal milieu confers on the objects" (Sinclair, 1989, p57). Vygotsky, as already noted, recognised the need for the learner to internalise through a process of...
cognitive reconstruction. The zones of proximal development are, according to Cole (1981) and Rogoff (1990), where culture (or the social dimension) and cognition (the individual dimension) meet. Rogoff extended this by describing a process of 'guided participation' (p68) in which the role of the learner as an active participant in their own socialisation is emphasised. She claimed learners do not passively receive support from adults and more capable peers, they actively 'seek, structure and even demand' it. The term 'guided reinvention' is used in a similar way by Fischer and Bullock (1984, p112) who credit Vygotsky with anticipating this perspective, which "expressly excludes the extreme positions found in some versions of modern social learning and cognitive-stage theories" (Tharpe and Gallimore, 1991, p44). Others have considered the role of the adult and child during instruction and the metaphor of 'scaffolding' has been used (Edwards and Mercer, 1987; Wood, Bruner and Ross, 1976). The term is explained by Mercer and Edwards as "the cognitive climbing frame - built by children with their Vygotskyan teacher - which structures activity more systematically than the discovery sand-pit of the Piagetian classroom" (p167).

My enquiry has, as established above, been based upon a position between the extremes of social and personal constructivism or more accurately one that recognises the inextricable links between the individual and social perspectives. This view is also evident in the work of Brazelton (1982), Bruner (1968), Papousek and Bornstein (1985) and Scaffer (1984) and Wartofsky (1984). The latter summed up the position succinctly,

The child is an agent in its own and the world's construction, but one whose agency develops in the context of an ineluctably social and historical praxis, which includes both the constraints and potentialities of nature and the actions of other agents. Nurture, in short is both given and taken; and so is Nature.

West and Pines (1985) offer a metaphor that is also helpful in viewing the way in which an individual gains (scientific) knowledge. They begin with Vygotsky's sources of knowledge; the spontaneous, or intuitive knowledge gained from interaction with the world and influenced by a learner's language and culture and formal knowledge gained through instruction. Genuine
conceptual learning is an integration of knowledge from both sources and they describe this integration through the metaphor of two vines. One, representing the learner's intuitive knowledge, is upward-growing (emphasising the growth of the learner), the other vine, represents knowledge resulting from formal instruction, is downward-growing (emphasising imposition from above). Genuine conceptual learning occurs when both vines intertwine and neither can be identified as the source of new knowledge (p3). They use the metaphor to consider a variety of ways in which a learner might deal with learning. A conflict situation arises when both vines are well-established but the learner recognises a conflict between existing ideas and that being offered which leads to reconstructed ideas and new understanding. A congruent situation is where both vines are again well-established and the learner's existing ideas are not in conflict with ideas being offered. In this situation school knowledge reinforces existing knowledge, perhaps encouraging wider application and therefore extending understanding. A symbolic knowledge situation results when the upward-growing vine is inadequate and the learner's existing conceptual structures are not relevant and therefore cannot accommodate the new ideas being offered. In this situation, meaningful learning is not possible and only rote learning occurs (using Ausubel's terms). A final scenario involves uninstructed learning where intuitive ideas dominate and little formal instruction is offered. In this context cultural influences can be strong and the learners ideas be informed by culturally-dependent understandings (see Hewson, 1985). The implications of these situations for dealing with formal instruction are dealt with in a later section in this chapter discussing teaching strategies appropriate to a constructivist view of learning. It should be noted that West and Pines' work focuses upon the source of knowledge and has superficial similarities to the view of Solomon. She, however, is making claims that the two domains of knowledge she discusses, 'life-world' and 'abstract-academic' are "differently received, stored and valued" (1992a, p96).

The view of learning and cognitive development adopted through this work therefore recognises the construction of knowledge and understanding as an active process involving the individual operating within a social context which has a significant influence on that
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process. Ideas are not simply constructed as a result of an individual's actions on the world but jointly constructed through interactions with others, who may already hold similar, or different, ideas, within a cultural context. This cultural context may involve particular ways of doing and thinking related to formal and informal teaching which are themselves significant factors in the process of cognitive construction. This conclusion may appear fairly obvious, but in the context of science education, where there has been a tendency to accept more polarised positions, it is significant to establish the significance of both personal and social views within constructivist thinking.

There are parallels in this position and the one outlined in Chapter 1, Section 1.9, related to Popper's view of the individual scientist and Kuhn's view of science as socially constructed.

Before considering the implications of this view for teaching it is appropriate to discuss the nature of the existing ideas children or adult learners are likely to bring to new learning. It has already been established in this chapter that the development of new knowledge will be dependent upon ideas that learners already hold. It is therefore relevant to consider the nature of those ideas.

2.7 The nature of children's alternative ideas

The next section of this chapter discusses the nature of children's existing ideas, or preconceptions, in the area of science, that is, those that they bring to a new learning experience. If children are constructing their own unique mental picture of the world around them it is inevitable that they will develop alternative views of the world which do not match accepted scientific thinking. These are described in the following as alternative ideas or concepts, organised into alternative frameworks.

Piaget was one of the first to recognise that children's ideas could be based on experience but still be illogical and strange in adult terms (Harlen, 1985a, p62). The reason for these
alternative ideas can be explained in several ways. Returning to Harlen's (1985a) view of learning, it may be that a child inappropriately 'tests' their explanatory 'hypothesis' or collects evidence inaccurately. Perhaps the informal experiences children have and the influence of adult and peer talk can also cause them to form intuitive and naive ideas. Children are often offered ideas from adults and other children which do not match accepted scientific ideas. For example, ideas such as 'cold is substantive and can travel' might be accommodated by a child being told, "Close the door or you'll let the cold in!". Harlen calls these 'ready-made' ideas (p63) which children may well integrate into their cognitive model if they find them acceptable, particularly given the 'status' of such ideas if they are offered by someone the child is likely to perceive as a more knowledgeable member of society. Vygotsky termed these, 'non-spontaneous'. It is unlikely that young children will have encountered evidence to cause them to question the statements such as the one cited. However, Harlen argues that these ideas and similarly, perhaps, those ideas deliberately presented to them in school, may be considered as 'free-floating' and not linked into their network of ideas as firmly as those generated through the process of hypothesising and testing, outlined above. They become more firmly tied into the web of ideas when tried out as a hypothesis and found to be working. For example, when trying to explain why they feel cold when they open a refrigerator door the idea of cold being something that is substantive and travels is supported by the child's sensory experience. The idea may therefore become more firmly established. Later formal experiences in the classroom designed to establish a more acceptable scientific concept about heat may not be successful in causing children to restructure their alternative idea, as research cited later indicates. Free-floating ideas, such as those introduced in school are regarded as Harlen as 'learned' only in so far as they are rote-memorised. Unless the learner tests them it is likely that they will be forgotten.

The nature of these alternative ideas or alternative frameworks (Driver and Easley, 1978) provided the basis for a revised interest in constructivism in science education in the 1970s and a mass of research into pupils' existing ideas (Carmichael et al., 1990; Driver and Easley, 1978; Osborne and Freyberg, 1985). The research has covered many areas of scientific
content with a particular focus of the physical sciences (eg. dynamics, gravity, electricity, heat, light, energy) although the natural sciences have also been researched (eg. plant nutrition and concept of living/animal). It is interesting to note that the literature on alternative frameworks in other areas of the primary curriculum (Willig, 1990) is not as extensive and possibly due to the well-developed and structured body of knowledge of which the science curriculum is comprised. The only other curriculum area with an extensive literature related to constructivism is mathematics (eg. Cobb et al., 1992; Davis et al., 1990). Solomon (1992a) identified the emergence of relativist philosophies of science (Kuhn, 1970) and the acceptance of multiple understandings of natural phenomena together with new interpretist approaches to educational research as reasons for the 'explosion of research' into children's ideas in science.

An example of this research, which has particular relevance to a later section of the thesis in which I discuss similar findings from my own enquiry, is provided by Watts (1983a), who investigated children's alternative frameworks of the concept of force. He interviewed individuals, aged 11 to 18, using a method called, Interview-about-Instances approach (Gilbert, Watts and Osborne, 1985). He used a series of line drawings to elicit the children's existing ideas about such situations as the forces acting on a golf ball at different points in its flight. His analysis of the taped interviews led to him identify a set of alternative frameworks which he labelled:

i. Affective forces (forces are obligations to complete an action against some resistance);

ii. Configuration forces (objects restrained in a position have a force);

iii. Designated forces (forces are designated to those objects that are causing or will cause events to occur);
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iv. Encounter forces (when two or more forces come together they can be combined to change the movement of an object);

v. Impact forces (moving objects are a force, which is manifest when the object collides with some other body);

vi. Motive forces (if a body is moving there is a force acting upon it in the direction of the movement. If the body is not moving there is no force acting upon it);

vii Operative forces (Force is an action. The amount of force is proportional to the amount of activity taking place).

Each of these is illustrated with examples of children's explanations and related to similar findings by other researchers. Along with others, his intended aim was to provide teachers with a repertoire of common frameworks to inform likely ideas their pupils may hold and appropriate teaching decisions. However, for some (Solomon, 1992a) the question remained were these children's descriptions, explanations or misunderstandings?

Gilbert (1986) refers to this revised interest in constructivism as 'personal constructivism' to distinguish it from its Piagetian roots (Gilbert, 1986, p281). The differences identified by Gilbert between Piagetian and personal constructivists are important. He noted that Piagetians see learning as independent of content and context, they adhere to stages of development with their implied notion of predestination and see progress in terms of passing through hierarchical stages. Personal constructivists, by contrast, regard learning as content and context specific, localised and developing without preordained directionality and largely independent of age. Progress is seen in terms of 'developing one's conception of a phenomena' (Gilbert, 1986, p281).

Ros Driver has made a major and varied contribution to the literature on constructivism within
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science education (Driver and Easley, 1978; Driver 1981, 1983; Driver and Erickson, 1983; Driver, Guesne and Tiberghien, 1985; Driver and Bell, 1986; Driver and Oldham, 1986; Driver, 1989). She played a key role as Director of the *Children's Learning in Science Project* (CLIS, 1984-91) which produced a wealth of material about pupils' alternative ideas and appropriate teaching strategies and materials. She also played a significant part in the construction of the National Curriculum for Science as a member of the working group invited to produce the original proposals (DES, 1988c).

Early in her work based upon small-scale enquiries, she used the term 'alternative frameworks' to describe the 'beliefs or expectations (learners) hold about the way natural phenomena occur' which differ from the currently accepted scientists' view and from teachers' intended outcomes of learning. (Driver, 1981, p94). She recognised the role of everyday language in fostering alternative ideas that children subsequently apply to the words in their specialist context. She also noted the 'creative and imaginary' element involved in the development of children's ideas. Her perspective led her to be critical of inductivist approaches to science in schools because of the extent to which all observations are, she claimed, theory-laden and informed by the current ideas pupils' hold. She concluded:

> Because any theory is not related in a deductive and hence unique way to observations, there can be multiple explanations of events. Pupils can and do bring alternative frameworks to explain observations which are in keeping with their experience and in this respect are not 'wrong'. However, we may recognise them as partial and limited in scope.

Driver, 1981, p96

She avoided the use of the term 'misconception' used by others (Carey, 1989; Gilbert and Watts, 1983; Helm, 1980; Linke and Venz, 1979) since, she claimed, children's existing ideas are coherent and often have a logic of their own, which works for the learner. Novak and Gowin also hold a similar view although they use the term - describing a misconception as an unaccepted (but not necessarily wrong) interpretation of a concept, illustrated in a statement in which the concept is embedded. The expressed meaning is not, they argued, a
misconception to the person who holds it, but a functional meaning (Novak and Gowin, 1984, p20).

Carey recognised that learning involved relating new information to an existing mental schema but, in the case of science, that often means that learners do not have a 'schema' available to form the basis of understanding (1989, p105). This, she suggested, had important implications since although learners do not have the experts' mental schemata, they “bring some schemata for understanding the physical, biological and social worlds. This ensures some understanding” (p108). However, the inappropriateness of existing schemata may lead to the development of what she was prepared to label 'misconceptions'. The origins of these, based on inappropriate schemata, helped her to explain why they are so resistant to change. Her essay examined the nature of knowledge restructuring in the context of 'novice-expert' shifts. This required her to consider ways of describing differences between novices and experts. She identified three key means: documentation of misconceptions; analysis of perceived similarities amongst elements in the domain (for example how do novices and experts group physics problems); analysis of how problems are solved (p110). Consideration of the outcomes of these led her to recognise weak restructuring (where the novice and expert systems share concepts, such as force and energy, and restructuring involves changes in the relations between them) and strong restructuring (where conceptual change is necessary). Weak restructuring is effectively gradual, continuous and cumulative, which in many ways can be seen as similar to Kuhn's normal science (Kuhn, 1970). Strong restructuring, by contrast is drastic, non-continuous and was compared, by Carey, to historical changes in scientific theories based on Kuhn's paradigms. Carey cited strong restructuring as involving the following differences in successive conceptual systems: the domain of phenomena accounted for; the nature of explanations deemed acceptable; the individual concepts involved (Carey, 1989, p 111). The key question for science educators then becomes whether existing alternative frameworks require 'weak' or 'strong' restructuring. She claimed, the way researchers have characterised pupils existing 'alternative' ideas may suggest the learners' misconceptions are merely false beliefs requiring 'weak' restructuring.
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Carey doubted whether this 'characterises most changes in conceptual frameworks achieved by successful science education' (p114). She used the example of 'force is a quantity in a moving object in the direction of movement', which many have found commonly held amongst learners of all ages (Kruger, Palacio and Summers, 1988-91; Watts, 1983a) and the research of others (McCloskey, 1983; McDermott, 1984) to indicate 'hard' restructuring, comparable with the shift scientists made from Aristolian to Newtonian paradigms was involved. This view, emphasising the challenge learners face when restructuring their ideas in science, and comparing the changes required to paradigm shifts in science is held by others (Driver, 1989, p104).

Solomon (1992a) raised the issue of whether the persistence of children's naive ideas might arise from the 'theory-laden' nature of their own observations in the classroom (p31) She also notes that the language of a learner and the words they use serve to direct an individual towards a particular point of view or way of thinking (p33). Her interest in the social context of learning also led her to question, along with others, whether there might be "an insidious social reinforcement of children's notions" (p25); alerting teachers to a problematic aspect of working with learners' alternative ideas. This is a theme I return to in Chapter 11.

Some researchers have questioned the validity of labelling learners' existing ideas as 'alternative conceptual frameworks' (White, 1981) since their frameworks are inconsistent and confused. Carey, along with the other researchers whose work is drawn upon in this section, accepted the term and noted the similarities between learners' intuitive ideas and those of past scientists. She claimed, that only consistency of explanations within a particular domain was necessary (Carey, 1989, p116). There are differences, however, between children's ideas and those of scientists as well as differences in the processes used to generate them which will be addressed below.

For the purposes of this research, the term 'alternative frameworks' has been used, in preference to 'misconceptions', to describe those ideas which learners hold which do not
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match accepted scientific thinking. It is noted that others use alternative frameworks to describe 'accepted' scientific understanding in different cultural and historical contexts (Hewson, 1985). In this view, current scientific thinking within Western European culture would be regarded as 'alternative' frameworks. This is a tempting view of alternative frameworks since it emphasises the tentative and dynamic nature of scientific ideas. However, for clarity and consistency the term is confined in this thesis to individuals' ideas, as defined above.

Driver explored the characteristics of alternative frameworks and along with others found that they often had common features and were held by many children in different parts of the country and, indeed, different countries (Driver and Easley, 1978; Osborne and Freyberg, 1985, p13) as discussed below. Although she noted Piaget's contribution to our knowledge of children's ideas, she suggests we should examine the causal nature of these ideas rather than their logical structures (Driver, 1981, p99). In her work in the early eighties, she set the scene for much future research by setting aims related to examining the structure of thought in the learner, rather than the structure of disciplines, whilst appreciating that this required a focus on scientific content and not just the process of thought. Significantly her early work, unlike much of that cited about children's ideas in science, also drew attention to the implications of her view and findings to classroom practice.

Gilbert, Osborne and Frencham (1982) took up this theme and made claims for children's alternative frameworks that went further than Driver's. They used the term 'children's science' to give the children's ideas greater status as coherent and theoretical explanations. They noted patterns in the existing ideas elicited from children related to the child's use of everyday language; the self-centred and human viewpoint assumed; the non-existence of non-observables; the endowing of objects with characteristics of animals and the endowing of objects with certain amounts of physical quantity (p 626). Osborne, Bell and Gilbert (1983) compared the nature of children's science with that of scientists, drawing upon these features and noting scientists' ideas are more abstract; generalistic and use specialist language, but still
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implying children's ideas were worthy of the label 'science'. Others have subsequently been critical of these attempts to make claims for children's alternative ideas as 'science'. Solomon (1992a) summarises these and stresses the dynamic, complex, multifaceted, highly situational and context dependent nature of children's ideas identified by researchers (p27). Drawing upon research from the early eighties she describes pupils who "slipped cheerfully from one alternative framework to another in the course of questioning in an interview, or over longer periods of time" (p24). She also notes the differences between processes used by scientists and those used by children.

Gilbert, Osborne and Frencham (1982) went on to consider the consequences for teaching of 'children's science' and identified possible outcomes of teaching, which can be compared to those discussed by West and Pines (1985), based upon their vine metaphor discussed above:

i. the learner's present view is not disturbed;
ii. the adoption of two different perspectives, one for school use and one for everyday life;
iii. a reinforced outcome - the school experience is misinterpreted and strengthens the learner's existing idea;
iv. a mixed outcome - new ideas accepted but integrated with existing ones and they co-exist;
v. a unified outcome - leading to a view more closely matched accepted scientific thinking.

There was considerable evidence (eg. Osborne, 1981) and it has been extensively added to since (see Carmichael et al., 1990), to convince Osborne et al. (1983) that children's viewpoints were largely uninfluenced or influenced in unanticipated ways by teaching (p4). This led them to consider the pedagogical implications and suggest that learners must be supported in discovering that their present conceptions are unsatisfactory and be offered
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new ideas which are 'intelligible, plausible and fruitful' (p5). They recognised the need for teachers to understand the nature of learners' existing ideas but suggested a research approach was necessary to obtain this information rather than the adoption of appropriate teaching strategies, which can provide teachers with the necessary insights into existing ideas. Whilst accepting the valuable insights teachers can gain from research into learners' existing ideas, and such research has been drawn upon extensively in the present thesis, the pedagogical implications of the need to elicit children's existing ideas and use them for the basis of teaching decisions are the focus for the next stage of the discussion. However, before that it is appropriate to review some aspects of the nature of learning discussed so far.

2.8 Summary of a constructivist's view of learning

The purpose for adopting a view of the nature of learning, in the context of this thesis, is to use that understanding to develop a pedagogical approach that is likely to be effective in enabling learners to come to a better understanding of the world. In that context, it is appropriate to list some aspects of a constructivist view of learning that have informed my approach, drawing upon the influences of the literature cited:

i. An individual's knowledge and understanding is most appropriately viewed as tentative;

ii. learners construct their own unique knowledge and understanding of the world through interaction with natural phenomena and through social interaction with peers and teachers;

iii. children's ideas are dynamic and likely to change and indeed to have already changed in significant ways during the child's preschool years;

iv. by the time children reach school age they have already developed ideas about
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the natural world that are organised into cognitive structures or frameworks;

v. children will attempt to explain new experiences in terms of their existing ideas;

vi. children's language is the means by which they can clarify, articulate, share and verify their existing ideas;

vii. existing ideas usually make sense to children in terms of their own logic and are likely to be firmly held. They are likely to be resistant to change and will not be changed unless children recognise the ideas are inconsistent or inadequate and find convincing evidence or reasons for changing them;

viii. new or modified ideas are the result of experience and existing ideas that were held before the particular experience;

ix. as children gain more experience their ideas and the links between them become more complex and more useful in explaining new phenomena;

x. children's ideas, though based on experience, will not necessarily match accepted scientific ideas about the world;

xi. children's naive ideas often show common features, particularly within one culture;

xii. Children find talking and thinking about their own ideas, and those of others, interesting;

xii. the construction of knowledge does not always lead to belief and learners can reject ideas that they have constructed. However, once new concepts become
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successfully integrated into a learner's conceptual structures they become useful if they provide increased explanatory power. In this situation a learner is likely to acquire an emotional attachment and this leads to belief.

This view of learning in children has significantly influenced my approach to working with adults. There is evidence that adults hold alternative ideas about the world around them which are in many ways very similar to those held by children. The Primary School Teachers and Science Project (PSTS), based at the University of Oxford and Westminster College, has researched primary teachers' existing ideas in a variety of areas (PSTS, 1988-91) This reinforced findings from other research (Peters, 1982) that adults' views of the world have been uninfluenced by formal science education and therefore they have retained intuitive and common sense ideas to provide 'working' explanations for everyday purposes. Although there may be differences in the nature and process of restructuring required the evidence of alternative frameworks in adult learners provided the basis for my adoption of a constructivist view of adult learning. Adults, like children, approach new learning experiences with ideas about the world already established. In some senses these existing frameworks in adults may be much more firmly established than those in children since they have proved 'viable' for a longer time. Children, it might also be suggested, are more used to changing their ideas as a result of new experience or teaching than adults and therefore adults may require more support during restructuring. Like children, adults are engaged in an active process of constructing new ideas based on their existing ideas and new experiences. Adult learners construct their own unique understanding of the world within a social context and therefore the implications of this context need to be addressed in proposing teaching strategies aimed at enabling adults to develop ideas which more closely match conventional scientific thinking, than their existing ideas. The importance of language, in terms of confusion resulting from everyday use of scientific terms is no less significant in adult learners than with children although it may be easier for adults to appreciate the significance of these differences in terms of their more sophisticated knowledge about language. However, adults may also be more capable of using technical vocabulary more effectively to disguise or hide misunderstandings.
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Solomon makes the following point about learning in science which has important implications for adult learners who come to learning situations with meanings for many of the words they will meet in new contexts:

"Every time a student of physics learns in a new field they need to accept that, like a child opening a Russian doll, they are looking into a new reality where concepts with familiar names will not exactly match older ones they already have in mind."

1992a, p viii.

Adult learners already work with abstractions and are more capable than children at dealing with abstract models. This provides a fundamental difference to young learners and opens new approaches to learning not available to children. For example, Kolb (1984), provided a model for experiential learning in adults with phases of concrete experience, reflective observation, abstract conceptualisation and active experimentation. This useful model, which I have explored in INSET contexts (Ritchie, 1990c) also introduces different preferred learning styles which relate to the cycle. Such a model has limited potential for young learners who lack abstract thinking skills. In the context of work with adults, however, considerable similarities exist between Kolb's model and the constructivist approach discussed later in this chapter.

There is an affective dimension to learning, which has significance for adult learners that is different to that for children (Solomon, 1992a, p96). Learning outcomes depend upon a learner's attitudes and goals. The experience of making sense of the world is an important source of emotional satisfaction (Head and Sutton, 1985, p92) and perceived lack of understanding can lead to feelings of anxiety and inadequacy. Kruger et al. (1990c) provide evidence of this in the context of primary science. Clough and Driver (1986) discuss the extent to which physical phenomena are neither "particularly pleasant nor unpleasant and so are not particularly emotionally charged" and as most people "can live happily without them" there is little reason for spontaneous theorising and a lack of motivation for learning. This may be a factor for primary teachers but the need to know in the context of the National Curriculum
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acts against these factors.

However, despite the differences, in the light of the tentative parallels between adult and children's learning, discussed above, a working hypothesis was adopted that a teaching strategy for improving teachers' knowledge and understanding of science, and perhaps of their own teaching, could be based on a constructivist view of learning.

2.9 A teaching approach to support a constructivist view of learning in science

The approach to teaching being evaluated in this project is based on one developed by the author, in collaboration with others, during the Assessment in Primary Science Project, funded through the National Primary Centre (SW) (PIPE, 1990). It was grounded in the work of the Children's Learning in Science Project (Needham, 1987; Scott, 1987), and influenced by Harlen (1985a; 1992). This section begins with an outline of the model adopted and a discussion of its origins. The term 'constructivist approach' has been used to describe a teaching approach that is based upon a constructivist view of learning. It is, in other senses, an approach developed through a constructive process as one which best meets the purposes outlined above. This aspect, dealing with my construction of understanding of appropriate teaching strategies is dealt with in a later section of this chapter. Equally significantly it involves teachers in a constructive process as they facilitate children’s learning. A constructivist view therefore links, in a dynamic way, teaching and learning.

A teaching strategy, based on the view of learning offered above, needs to enable learners to recognise and reflect upon their existing ideas; realise that other people may hold different ideas which are worthy of consideration; test out their own and others' ideas to see if evidence can be found to support them; apply new ideas in a variety of different situations. The approach should encourage active learning in recognition of the learner's active construction of knowledge. The learner should also be given the opportunity to take responsibility for their
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own learning in order to maximise their commitment to it. The approach adopted involves a sequence of phases which are illustrated in Figure 2.1.

Figure 2:1 A Constructivist Approach
based on work with the Assessment in Primary Science Project
National Primary Centre (SW)

ORIENTATION
Arousing learners' interest and curiosity

ELICITATION / STRUCTURING
Helping learners to find out and clarify what they think

INTERVENTION / RESTRUCTURING
Encouraging learners to test their ideas, to extend, develop and replace them

REVIEW
Helping learners recognise the significance of new learning

APPLICATION
Encouraging learners to use their ideas: to integrate them into their 'everyday' thinking

Orientation is the phase when the learner's interest is aroused and it sets the scene for what is to come and is particularly important when an area of study is new to a learner or they cannot draw upon everyday experiences. Elicitation is the phase that enables the learner and the teacher to become aware of existing ideas that the learner holds. In this sense the learner begins to structure and clarify their existing ideas as they articulate and share them (Ollerenshaw and Ritchie, 1993, Chapter 3). Both of these phases usually involve the learner in exploratory activities during which questions may be raised which will lead to more systematic scientific investigations. Learners and their teachers identify the starting point for future learning. This is vital for all concerned, particularly to ensure there is not a mismatch
between what the learner thinks and what the teacher thinks the learner thinks. The **Intervention/restructuring** phase is intended to raise learners' awareness of alternative ideas; to encourage them to test the validity of their own and others' ideas. It will often lead to investigative practical work, but discussion and 'thought' experiments play a vital part. The teacher's role is crucial in terms of supporting learners in testing, developing and extending their ideas. The teacher may, appropriately, be introducing more conventional or scientifically accepted ideas alongside the learner's as ones worth considering and testing. A **review** phase helps learners recognise the significance of what they have found out and become aware of how their ideas have changed as a result of what they have done. **Application** is the stage when the learner has to relate what they have learned to his/her everyday lives. It encourages the reinforcement of reconstructed ideas in familiar and novel situations.

This sequence is very similar to that proposed by Scott (1987) but places greater emphasis on the place of review prior to application. The process as described appears linear. However, in a teaching context it is inevitable that phases overlap, for example elicitation is happening throughout. The model offers an indication of important 'staging posts' to be visited during work with learners. A cyclic process is involved with feedback at each stage. The stages involved in this process have been discussed in more detail by the author elsewhere (Ollerenshaw and Ritchie, 1993).

The role of the teacher when adopting a constructivist approach to teaching such as the one outlined is one, as noted above, which can appropriately be seen as a constructive activity. The teacher is attempting to construct a model of the learner's ideas and operations. As von Glasersfeld noted,

> inevitably, (this) model will be constructed, not out of the child's conceptual elements, but out of the conceptual elements that are the teacher's own. It is this context that the epistemological principle of fit rather than match, is of crucial importance. Just as cognitive organisms can never compare their conceptual organisations of experience with the structure of an independent objective reality, so the teacher can never compare the model he or she has constructed of the child's conceptualisations with what actually goes on in the child's head.

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The teacher has to generate working hypotheses about the best way of moving learners from their existing ideas, or the teacher's construction of those existing ideas, to those which more closely match accepted scientific ideas. In order to do this it is necessary for the teacher to also have an analytical model of the scientists' conceptualisations in order to provide appropriate guidance. However, like children, teachers will have actively constructed their own unique understanding of the physical world. This will not necessarily match accepted scientific ideas. Gilbert, Osborne and Fensham (1982) distinguish different different forms of scientific knowledge. The accepted, or conventional view is called *scientists' science*, a sub-set of that is selected by curriculum planners to constitute *curricular science*. Teachers ideas, which may be similar, but not necessarily the same as this, is called *teachers' science*. This interacts, in the classroom, with *children's science*, perhaps through the mediation of *curricular science* (where books or other resources are used) to produce *students' science*. Each of these forms of scientific knowledge is different and, as discussed later in this thesis, teachers need to be aware of these differences. There is also a question of whether children's or teachers' existing ideas warrant the label 'science' and this question is addressed in more detail later in the thesis. The teacher is therefore engaged in an active process of constructing understanding which varies at different phases of the approach: during elicitation, constructing an understanding of the learner's existing ideas; during intervention, relating the learner's existing ideas to the teacher's understanding of accepted scientific ideas in order to make formative decisions about the most appropriate intervention; during review, refining and modifying her/his understanding of the learner's changed understanding; during application, selecting appropriate contexts and activities for the learner to use new or modified ideas.

Scott describes the teacher's role as a 'diagnostician' and 'prescriber of activities' (Scott, 1987, p16). The latter label could be criticised as placing too much emphasis on the teachers' activities and devaluing the learners' own efforts to organise their own investigations based on questions they themselves have raised. The focus of a teacher's attention during learning necessarily involves the individual at some stages of the process and this has implications in
The origins and influences on the constructivist approach outlined above are now discussed. It is impossible to reduce the complexity of teaching approaches in real situations to simplified models without losing much in the process. However, in order to isolate key aspects of teaching approaches such an analysis can be useful. Osborne and Freyberg (1985) offered a helpful review of teaching models advocated to reflect a concern for the cognitive development of learners. They contrasted these approaches with what they called conventional approaches to science teaching which tended to involve telling, confirming and practising (p102). Such 'transmissionist' (Watts, 1984) approaches are based on a very different view of knowledge and the nature of cognitive development to that proposed in this chapter. They treat the learner as 'an empty vessel, to be filled with objective scientific facts about the world'. Teaching strategies implied by such a view include didactic teaching through which the teacher transmits to the learner a specific body of knowledge, perhaps including some demonstrations or practical activity to reinforce the ideas presented. This approach has been criticised extensively (Qualter et al., 1990; Wellington, 1989), although it is still apparent in some teachers' current practice in my own (and my 12 and 14 year old daughters') experience.

Osborne and Freyberg's analysis was based on a constructivist view of learning. They reported that Renner (1982) advocated phases of experience, interpretation and elaboration. The teacher helps the learner, at the interpretation stage, by introducing terms to help them make sense of experiences which the teacher has provided. Elaboration involves meshing new understanding with existing knowledge through further activities. This approach places no emphasis on finding out what existing ideas the learner holds. Karplus (1977) offered a model which began with relatively unstructured exploration during which questions are raised. This leads to an explanatory phase when the teacher introduces and explains a concept which is expected to lead to learning. A final, application phase is similar to the application phase discussed above. In many respects the first and last phases of Karplus' approach are reflected
in the one adopted. His exploratory phase includes aspects of orientation and to some extent the need for the learner to structure their existing ideas more clearly before they can change them. However, he does not emphasise the elicitation of existing ideas by the teacher and offered little help to the teacher in terms of enabling the learners to construct new ideas, relying on the teacher’s ‘correct’ ideas being ‘transmitted’ to the learner as a result of the explanation offered. Nussbaum and Novick (1982) explicitly offered a model that recognised the importance of existing ideas. The phases in their model were exposing alternative frameworks; creating cognitive conflict and encouraging cognitive accommodation. Their first step had much in common with the elicitation phase discussed above. They highlighted the difficulties of changing learners’ existing ideas as others have done (Ausubel, 1968) and recognised the need for learners to make their existing ideas explicit as a step towards becoming aware of their own preconceptions. To them, the identification of conflict through activities provided by the teacher should be sufficient to, “induce students to recognise that their existing ideas require modification” (Osborne and Freyberg, 1985, p104).

Accommodation results, according to Nussbaum and Novick, when learners search for solutions to the exposed contradictions in their existing conceptual frameworks. Erickson (1979) described similar stages as experiential manoeuvres, anomaly manoeuvres and restructuring manoeuvres. The first involves familiarisation with a range of related experiences to expose existing ideas (orientation and elicitation); the second required the teacher to introduce activities leading to unexpected outcomes to challenge those existing ideas (intervention), which leads to the need for restructuring.

Barnes (1976) also made a significant contribution to the development of teaching strategies which recognise the importance of the learner becoming actively involved in their own learning. He proposed a sequence which involved a focussing stage (to get the learner to clarify their thinking about an area of knowledge); an exploratory stage (involving discussion and practical activity to extend and challenge individuals' ideas); a reorganising stage, when the teacher refocuses learners' attention through as preparation for the public stage during which learners articulate their present understandings to stimulate further discussion. Barnes
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reinforced throughout his treatment the vital part language plays in learning (see Ollerenshaw and Ritchie, 1993, Chapter 3 for a fuller treatment of this).

Rowell and Dawson (1977) advocated eliciting learners' existing ideas, 'retaining them' whilst the teacher offers a more scientifically accepted possibility (if necessary), which is linked to existing ideas, and provides the basis for comparison. In this approach the learner's ideas are valued alongside more conventional ideas and the learner is consequently, according to its advocates, less 'threatened'. Solomon (1983b) has suggested this may lead to learners retaining two sets of ideas, their own intuitive ones for everyday use and more acceptable scientific ideas for school use.

Osborne and Freyberg's own model is based on the premise that "the teacher needs to understand the scientist's views, the children's views and his or her own views in relation to the topic being studied" (1985, p105). This view corresponds closely with mine and is particularly significant in the case of primary teachers who own ideas may be somewhat different from the scientist's view. They proposed a model of teaching which they described as 'generative' and based upon Wittrock's (1974, 1977) view of learning. It involved the following phases:

i. **Preliminary** - teacher ascertains learners' ideas, clarifies these, seeks scientific views and historical views.

ii. **Focus** - teacher provides learners with motivating experiences, asks questions, interprets responses and elucidates learners' views. The learner is structuring their ideas.

iii. **Challenge** - teacher facilitates an exchange of views, presents evidence for the scientist's view and accepts the tentative nature of learners' reactions, contrives problems that can be solved using accepted scientific view. Learners are testing
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the validity of ideas and comparing scientists' views to their own.

iv. Application - teacher assists learners in clarifying new views, helps in solving problems. Learners are solving practical problems using new ideas.

The influence of this model on the one outlined at the beginning of this section is evident. One difference concerns the extent to which learning is seen as the reconsideration and modification of the learners' existing alternative viewpoints, in the first model, rather than focusing upon the generation of new concepts.

There are distinct differences between the constructivist approach being discussed and other approaches which are associated with primary teaching and learning. For example, a constructivist approach is not a form of 'discovery learning' which was adopted by many primary teachers during the sixties and seventies to respond to the perceived needs of the Piagetian learner (Ollerenshaw and Ritchie, 1993, p7). Discovery learning is underpinned by the belief that children/learners should find out things for themselves. Its origins go back far beyond Piaget and 'heuristic' methods can be traced back to at least Rousseau (see Chapter 3). The intellectual 'dishonesty' of assuming children can discover key ideas in science and the pedagogical limitations of discovery learning have been well documented (Driver et al., 1985, p3; Harlen, 1992, p45; Wellington, 1989) and attempts to modify it into guided-discovery have generally been unsuccessful (Wellington, 1989). Another common strategy, used in science education, is enquiry learning, which again is different to a constructivist approach. Most enquiry learning (Harlen, 1992, p47) is seen to involve problem solving as its key feature. Learners are expected to gain new understandings through their attempts to solve teachers' or their own problems (Fisher, 1987; SCSST, 1985). At primary level, this has led to more technological activity than science (Harlen, 192, p47; Johnsey, 1986). The key difference between these two approaches and a constructivist approach is that the latter focuses on learners' existing ideas and processes and uses these as the basis for further
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development. The teacher plays a more proactive, and 'constructive' role when adopting a constructivist approach. Whilst the child is actively constructing her/his understanding of phenomena the teacher is actively constructing an understanding of the child's learning and making decisions about how this can best be supported.

This section has described the key features of a constructivist teaching approach which has been used during this enquiry as a model that is appropriate for work with child and adult learners. It has been used by me in running sessions for adults and been advocated as the approach the teachers involved could use themselves when working with children. There are, of course, disadvantages in focusing teaching upon any one strategy however, it has been offered as a flexible framework, rather than as a specific technique. It is a framework which can accommodate different teaching styles, techniques and preferred modes of classroom organisation. Consequently, the approach adopted is based upon the constructivist model outlined in this section that provides the flexibility to address individual students' needs with regard to preferred learning styles.

The next section will discuss the extent to which my own learning during the research can be seen as 'constructive'.

2.10 The construction of professional knowledge

The view of knowledge as personally constructed and the significance of learner's existing ideas to new knowledge has been discussed above in the context of scientific knowledge related to natural phenomena. This section considers the relevance of that view to the professional knowledge practitioners develop through initial and inservice training and as a result of their professional activity. There are close links between this and the discussion of practitioner-based research in Chapter 6.

It is evident that any professional, at any point in her/his professional life holds personal
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‘theories’ about her/his practice (Johnston, 1988, p194). These theories may be articulated or implicit in the action taken. These existing ideas about the nature of pedagogy, the curriculum or learning are going to influence any changes that occur to a practitioner’s professional knowledge resulting from self-initiated or externally-supported change. New insights and understanding of practice will be the result of existing understanding and new experiences. The development of any new understanding into a practitioner’s practice will result from a process of active construction on the part of the practitioner. In this sense the practitioner developing professional knowledge and understanding can be seen to be learning in a way that parallels the learning of scientific knowledge discussed above. This would therefore seem to provide a way of looking at the learning of students and teachers during initial teacher education and inservice activities. It also provides a way of analysing my own learning during this enquiry. The relevance of the phases of orientation, elicitation/structuring, intervention/restructuring and application in terms of my learning are therefore worth consideration. If my own learning parallels those with whom I am working these phases should be identifiable. I will therefore consider later in this thesis the extent to which I orientated my thinking to the enquiry, the extent to which my own existing ideas were structured and clarified during the exploratory phase and what evidence I can find of restructuring of my professional understanding and application of that restructured understanding in new contexts.

The literature on teacher knowledge is considerable and Calderhead (1987, 1988) discusses the diverse views of researchers about how this knowledge can be conceptualised. He discusses the relationship between theory and practice and the extent to which they are sometimes seen as separate entities in teacher education (1988, p9). The college course offering theory which is later put into practice in school. He argues this is a false dichotomy and this is a theme I will address in some depth in Chapters 6 and 11. Fosnot (1988) adopts an explicit constructivist view to looking at the development of teachers’ professional knowledge in an American context. She provides an example of an approach to developing teachers’ professional knowledge underpinned by a constructivist epistemology and although she is not working with students in the area of science there are similarities between her work and
my own in terms of engaging teachers in activities as learners and encouraging them to understand their own learning as well as that of pupils. Calderhead (1988, p51) also addresses the issue of metacognition in terms of teachers developing professional knowledge and this signals another key area of my own enquiry for later discussion. Schon (1983) provides a sound basis for much of the subsequent work on professional knowledge. His view of reflective practice introduced a concept of "knowledge-in-action" to describe that which is embedded in the practice of a professional and is tacit, not requiring a conscious process in order to use (cf. Polanyi's first kind of tacit knowledge). Schon also discussed 'reflection-in-action' when a practitioner steps back from his activity to gain insights into what is happening and 'reflection-in-practice' which is a conscious reflection after the episode about what happened. In this way a 'reflective practitioner' can develop professional knowledge. Although not explicitly stated in Schon's work, there is an implicit assumption that each individual practitioner is constructing a unique understanding of their own practice, which is inevitably tentative and dynamic. Further reflective activity will lead to changes to the knowledge.

Action research, as will be discussed in more detail in Chapter 6, is an approach to practitioner-centred research which has as an aim, alongside improving practice, the development of practitioners' knowledge about that practice. In that discussion the significance of Habermas' view of knowledge in terms of its practical and emancipatory domains is explored further. However at this stage the intention is to indicate my view that there are important similarities between the constructivist view of knowledge as it has been introduced in terms of learning science; the development of professional knowledge and action research.

A common epistemological position can be used for these three areas based upon the tentative and dynamic nature of the knowledge involved. All recognise the place of action in the development of knowledge: for the child using scientific skills and processes in dealing with materials and phenomena in the classroom; for the practitioner in engaging in their professional role and for the action researcher in taking considered and premeditated action.
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to improve their practice. All three areas can be seen to involve conflict, disturbance or surprise as significant to knowledge development. For a child evidence or experiences that do not fit with existing conceptual frameworks may lead to restructuring; for the practitioner something going wrong or the unexpected occurring lead to reflection and reconsideration of existing personal theories about practice; for the action researcher the identification of dilemmas or the recognition of values denied in action are the stimulus for changes and subsequent development of understanding of that practice.

This enquiry is intended to help me understand the nature of my own professional knowledge and the way it develops and in that sense it involves metacognition. This section has been an attempt, at early stage of the thesis to indicate common features of the view of learning that informs my approach to science education with children and adults, the nature of the development of my own professional knowledge about my practice and action research as an approach to improving my practice and my knowledge of it. In all three areas I intend to show the extent to which a constructivist view of learning, discussed in this chapter is applicable.
Chapter 3 - Science in the primary school

3.1 Introduction

Teaching science to young children has a long history. Aspects of science have been taught in some primary schools (or their equivalent) throughout the last century and before. However, it has only recently become an established element of the curriculum of all primary schools. In the past it has been taught by those teachers with a particular interest or enthusiasm for science or by a limited number who had been influenced by curriculum projects or other national and local initiatives. Until the recent imposition of a National Curriculum, science had remained an optional element of primary schools' curriculum, despite the considerable effort made by various parties to convince teachers of its importance and relevance to young children.

This chapter traces the history of science teaching in primary schools in order to enable the reader to contextualise the present work. This is treated as a chronology of significant events, projects and documents. The nature of this area of the curriculum is discussed and some of the key issues identified. The extent to which science has been evident in primary schools and the pedagogical issues that have arisen as teachers have introduced science into their classrooms are explored. The nature and influence of some key curriculum projects in science are outlined. This includes a treatment of the debate concerning the balance between process skills and knowledge and understanding, in terms of children's learning in science and process and content, in terms of the science curriculum, which has particular significance to the present study. The place of science within the primary curriculum has now been established as a result of it being identified as a core subject within the National Curriculum. The nature of primary science, as defined by the National Curriculum Orders and Non-Statutory Guidance is discussed. The relationship between science and technology is briefly discussed towards the end of the chapter. Although these two subjects have been seen, by some, as one area of experience that is not a view I hold, nor does it reflect the National Curriculum treatment of the two subjects. Throughout this chapter the focus is upon science, even where initiatives have attempted to address both 'science and technology'.

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3.2 The place of science in the primary curriculum

In the context of the National Curriculum, in which science is a core subject for all children from the age of 5 to 16, primary teachers no longer have to make a professional decision about whether or not to include science in the curriculum they offer children. However, until the announcement of this by the Secretary of State for Education in 1987 (DES, 1987a) it had been necessary for advocates of science in the primary schools to try to convince teachers that science was appropriate for young children and should therefore be included as a curriculum element.

It is indeed possible to find advocates of science education long before the beginning of the present century as the following indicates:

Teach your scholar to observe the phenomena of nature; you will soon rouse his curiosity. Put problems before him and let him solve them for himself ... Let him not be taught science, let him discover it.

Rousseau, 1763 quoted in Blenkin and Kelly, 1987, p15

Sentiments that were not widely adopted by teachers of the period but which re-emerged in later official reports and projects in the twentieth century.

3.3 Primary science in the nineteenth century

During the nineteenth century, the Church exerted an influence on the curriculum of many schools and consequently science was not seen as relevant (especially for working class children). The publication of Darwin's *Origin of the Species* (1859) and the reaction of the Church to his ideas ensured that science did not gain wide acceptance as a curriculum element of schools. The only aspect of science one would have observed in the schools at that time would have been nature study and object study lessons, both of which would probably have involved emphasis on religious rather than scientific aspects of the work. In 1862 a revised code was published, defining the curriculum of elementary schools and
restricting it to the so called 3Rs (reading, writing and arithmetic).

There were some attempts during the period, described by Gordon and Lawton (1980), to encourage some physical science in the classroom. An example of this was Reverend Richard Dawes approach to the 'study of common objects' (op. cit.). In 1853, the Board of Trade, prompted by a growing awareness of the threat to Britain's role as the leading industrial nation, provided funding for courses in science for elementary teachers. Few teachers took up the offer and by 1859 the grants had been restricted to secondary teachers.

By the time of the Paris Exhibition, in 1867, the further decline of Britain's industrial role led to a revision of elementary schools' curriculum and science as added to the list of subjects that could earn a grant in standard IV to VI.

Education had become available to all 5 to 10 year old children by the 1880s but the curriculum offered varied from one area to the next. Some areas, in response to local needs or employer demands, included science. Indeed Cox and Taylor (1989, p4) refer to what might be regarded as the first advisory teacher for science; a peripatetic science instructor who took his apparatus around the elementary schools of Birmingham in a handcart.

3.4 Developments in the early part of the twentieth century

The twentieth century saw the publication of a handbook for elementary teachers (1905) which included a section on teaching the natural sciences. Physical sciences were noted as appropriate for older pupils. This emphasis on natural sciences, or more narrowly nature study, influenced the teaching of young children for the next sixty years.

Educationalists such as H.E. Armstrong had been encouraging a systematic approach to such work, although he was later to note of much work in elementary schools that:

Nature too seldom comes into the work and too often study is the last thing thought of.
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Armstrong, 1913 quoted in Black, 1980

The establishment of separate secondary schools by the nineteen thirties led to an even clearer division of the teaching of science and the physical sciences became firmly rooted in the secondary, rather than primary curriculum. This division subsequently led to pressure being applied to primary teachers from their secondary colleagues not to teach physical sciences (DES, 1967, p244 para.673; Redman, 1968, p17).

Consequently, prior to the establishment of primary schools, as opposed to elementary schools, by the 1944 Education Act science, other than nature study, had not been very evident within the curriculum of young children. The curriculum was regarded as content (Blenkin and Kelly, 1987, p66), a view which was grounded in a rationalist epistemology (p13) and was to be dominant in terms of curriculum development for the next twenty years.

However, before exploring developments after the Education Act it should be noted that there was endorsement at a national level for active approaches to learning, similar to the approach advocated by Rousseau, which were to become an accepted feature of primary science work. The Hadow Report, published in 1931 stated:

The curriculum of the primary school should be thought of in terms of activity and experience rather than knowledge to be acquired and facts to be stored.

Consultative Committee of the Board of Education, 1931

This report laid the foundations for primary education over the next thirty years and the Plowden Report, published in 1967, noted the significance and impact of its predecessor on primary practice (DES, 1967, p1).

3.5 Post-war developments

The forties, fifties and sixties saw a steady growth in the number of teachers introducing more practical science into their classrooms although this continued to emphasise biological work
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through 'nature' activities. Jean Conran (1983) provides an illuminating personal view of primary science in this period in which she describes the influence of her initial training at the Froebel Institute in the late 1940s and the variety of activities she was providing children as a result of her own interests and enthusiasms:

"We saw the world as an interesting place to discover and explore rather than a series of problems to be identified and solved. Children interacting actively with reality were bound to develop some enquiry skills but in those days we were unaware of the coming shift in emphasis towards children behaving scientifically and much was left to intuition and chance."

Conran, 1983, p19

She cites the influence of broadcasts that she was actively involved in producing on her contemporaries and charts the gradual shift to a broader view of science covering the physical as well as biological areas.

This was encouraged amongst other factors by the response in Britain to the successful launch of Sputnik by the USSR (in 1957) and another national reappraisal of Britain's role amongst the industrialised nations. There was a growing awareness of the need for greater scientific and technological literacy. Another significant event of 1957 was instigated by the Ministry of Education which instructed HMI to consider the teaching of science in primary schools. The discussions with teachers that resulted informed a Handbook published in 1959 (Ministry of Education, 1959) which offered official endorsement for the teaching of physical science in the primary phase. A report published in 1961 reinforced this (DES, 1961). It provided evidence that science was gaining acceptance as an element of the primary curriculum within the ministry.

Educationalists were making their own contributions to the debate about the place of science within the primary school and an example of this is a paper written by Nathan Isaacs (1962). In this he described science as gaining knowledge through adopting certain approaches which have much in common with the way children learn naturally. He stated that, "when our children enter the primary school the basic learning drives are as a rule still vigorously active" (Isaacs,
He therefore concluded, "we do not have to bring science, as here understood, into the primary school; our first decision has only to be not to shut it out". He defended this view by drawing upon the work of Piaget, discussed in Chapter 2. Isaacs recognised the implications of a rigid application of Piaget's stage model and suggested:

"...his (Piaget's) more negative conclusions regarding the primary school age-range need only be kept in mind as partial ceilings applying under present circumstances and in certain limited directions."

This was a critical interpretation that was only later to become more generally accepted as was discussed in the previous chapter. His arguments for science in primary schools related children’s natural curiosity and desire to learn about the world to somewhat simplistic views about the processes of science. This view was repeated frequently in the literature written over the next 25 years and in the rationale of primary science guidelines produced by LEAs in the seventies and eighties (Harlen, 1985a, p196). Avon Local Education Authority’s original Primary Science Guidelines (County of Avon, 1981, p1) provided a clear example of this.

The Association for Science Education (ASE), through its Primary Schools Science Committee, produced a policy statement in 1963 which made its commitment to science in the primary phase explicit. The Association had been in existence for many years, having held its first conference in 1901, but had not previously paid much attention to primary science. It was to provide various forms of support for primary teachers over the next thirty years as the primary dimension of its activities gradually gained a higher priority.

However, despite the best endeavours of individual advocates and national bodies the influence of these initiatives was limited. Nature study continued to be taught but there is little evidence that is was approached 'scientifically' (Conran, 1983) and even less evidence is available that physical science was being taught in primary schools, although an HMI report of 1963 (DES, 1963) identifies some examples.
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3.6 The Plowden Report

When the *Plowden Report* was published in 1967 (DES, 1967) it included, amongst its support for child-centred teaching methods and progressivism, positive statements about the nature and place of science in primary schools (p240) summarising its treatment of the subject matter as "learning by discovery" (para. 669). Surprisingly the Report also seems to overestimate the extent of physical science work in primary schools at the time:

> Although we welcome the extension of primary school science to include the physical sciences, we regret any tendency to underestimate the importance of the opportunities of natural history.

DES, 1967, p242

The Plowden philosophy was very much in line with Isaacs and we find in paragraph 673:

> If children leave their primary schools with their natural curiosity not only unimpaired but sharpened, with experience of first-hand discovery in several different fields, with some idea of what questions to ask and how to find answers, they will be well equipped to proceed with a scientific education.

p244

The *Plowden Report*’s emphasis on child-centred, active learning was to influence much of the subsequent curriculum development in primary science. It provided a justification for children engaging in practical activities and learning experientially. It provided a rationale for group work and redefined the role of the teacher as a facilitator of children’s discovery as opposed to a transmitter of knowledge. However, as noted later in this chapter, although Plowden’s philosophy was espoused by curriculum developers, educationalists and many teachers the extent to which the progressive movement which it encouraged actually influenced teachers ‘theories in action’ (Eason, 1985, p6), ie their classroom practice, was not as extensive as the politician’s advocating a ‘return to basics’ in the eighties and nineties suggested.
3.7 The Nuffield Junior Science Project

The sixties were a significant period for primary science because of several curriculum development projects.

The Nuffield Junior Science Project ran from January 1964 to December 1966 and resulted from the HMI paper of 1961. It was a project that attracted substantial funding of £75,000. It adopted a research approach and involved groups of teachers in various parts of the country. The project team underpinned their work with an explicit process approach which regarded the way the children tackled scientific work as more important than the content covered or the knowledge and understanding that might be involved:

At this level we are concerned more with the development of an enquiring mind than with the learning of facts.

Nuffield Junior Science, 1967a

The project's philosophy was summed up in this way:

Children's practical problem solving is essentially a scientific way of working, so the task of the school is not one of teaching science to children, but rather of utilising the children's own scientific way of working as a potent educational tool. Science is ... essentially a practical investigation of the environment. It makes use of some of the child's most outstanding characteristics, his (sic) natural curiosity and his love of asking questions.

The similarity with Isaacs' (1962) philosophy is evident. It was an attempt by the curriculum development team to, "make a clean break from the type of science typified by the 'object lesson'" (Harlen, 1985a, p10). No longer was science in primary schools to involve children in being told about things; it was to involve them in activities and finding things out for themselves. This project and the subsequent Science 5 - 13 initiative were firmly based on the premise that although children engaging in scientific activities would be developing basic concepts these were essentially a "by-product" of the processes. It was to be some time before a balance was to be achieved between processes and knowledge and understanding and their link was articulated. The emphasis, at this time, was on the processes children used.
However, the project director describes the ongoing debate between teachers and project workers over the content/process question as, "fierce and filled with emotion" (Westnedge, 1983, p142). It would be wrong to assume the project did not consider the importance of content. Their resolution of the issue was to suggest that, "choice of subject matter (it seemed to us at the time) will be taken care of through a carefully-planned range of starting points for study" (p143). The materials produced were in the form of case studies and guides for teachers (Nuffield Junior Science, 1967). In this way the team avoided adopting a content or objectives-led curriculum and preempted, in some respects, a process model of the curriculum as described by Blenkin and Kelly (1987, p94). In this context, 'process' is taken to concern the process of education, rather than the narrower view of process used to describe the way children engage in the process of science.

An interesting feature of the project was its demand that areas working with the team establish teachers' centres to support the staff involved. Although these were not the first teachers' centres established, the success of such centres in this project ensured that they became a common aspect of teacher support. These centres, as noted later, contributed to the establishment of geographical pockets of primary science experience and enthusiasm.

The project team ran inservice courses for the teachers involved and these involved teachers being asked to work scientifically at their own level:

By the time the second of the inservice courses was held ... the thinking of the team about the nature of primary science courses had moved on considerably. From presenting the teachers with specific problems to solve we moved through a phase of giving them problems arising out of children's questions and ultimately to asking them to observe the environment and define their own problems.

Wastnedge, 1983, p142

The project team's final approach was similar in some ways to that being adopted on the DES courses being considered in this research. However, their initial approach of tutor-provided questions or problems remained the norm for much inservice work over the next twenty years.
as my own experience of inservice as a student in 1982 and later as a provider indicated.

Wastnedge, a member of the project team, reflecting on the achievements of the project, considered it had been a significant forum for discussions about the nature of primary science. He also cited the project’s contribution to inservice:

The Nuffield Project also helped to set a pattern for inservice education. In particular it recognised that most teachers, because of the way they had been taught, or because they dropped the subject at an early stage, or both lacked understanding of many scientific ideas, were often unskilled in practical work and had no experience at all of using processes such as experimental design.

These concerns reappeared on the agenda of educationalists and government over twenty years later when it was clear that little progress had been made in alleviating the problem. Wastnedge considered, however, that any primary teacher could teach science well given the appropriate support and he claimed the project demonstrated this was possible. He also noted that whilst the project was successful with the teachers with whom it had direct contact it had less impact on teachers who simply received the written outcomes. In many cases he claimed the important sections, such as the teachers’ guides were not read. Even if they read the material carefully he recognised, “translating what has been read into action is an unsurmountable obstacle unless continuing practical help is available”.

3.8 The Oxford Primary Science Project

During the same period a less well-funded project was adopting a very different approach to primary science. The Oxford Primary Science Project, although basing its approach on children’s practical activities, planned the work around concept areas: four broad themes of energy, structure, change and life. The project was again set up as a research project and began by finding out what concepts were already being taught to primary children by asking a number of primary teachers. The questionnaire used highlighted another problem, not initially anticipated by the team:
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Teachers were asked ... which scientific concepts they thought the children might have formed as a result of their science lessons and the answers suggested that the term 'scientific concept' meant little to them.

Redman, 1968, p18

The team then approached scientists in education and industry in an attempt to elicit their ideas about the key scientific concepts that might be taught. This was something that some of the scientists found difficult (p19). From this exercise the team identified four key concepts that were to become the project's four themes. The themes were explored with the project teachers through inservice activities as part of the pilot phase. This involved a week-end course on one theme when the science was presented to them at an adult level. This was followed by some tentative suggestions about how the same concepts could be introduced in their classrooms through a variety of different content areas. The ideas were tentative because the teachers were regarded as the experts in the classroom (p21). The teachers were then asked to implement activities with their classes and maintain notes of the children's responses. Indeed the project was explicit about asking the teachers to explore, "techniques of objective assessment of concept formation". The school-based phase also involved support in the classroom from project team members where requested or appropriate.

The teachers were introduced to a new theme each term. The project team explored different methods of presenting the science to the teachers and as a result of responding to requests from teachers not directly involved for courses built up considerable experience of inservice aimed at improving the teachers own scientific knowledge and understanding. The team made it clear to potential recruits to the project that, "knowledge of science was to be regarded as neither an essential condition or handicap as far as the teachers were concerned" (p22). The researchers reported however that they were, "assuming unwittingly a knowledge of science which the teachers did not possess". As scientists the team were having difficulties in communicating ideas to non-scientists. They also discovered, as a later team from Oxford would, that, "misconceptions (sic) (amongst teachers) were common".

An analysis of the teachers' evidence by the project team allowed them to identify concepts
which teachers found it hard to teach eg equilibrium and disorder (p23). Interestingly, they also highlighted the importance of pupil discussion in developing scientific ideas and found it, "highly favoured by teachers".

The project has been cited by many subsequently as one which focused on knowledge and understanding through specific content. Despite this, the team recognised the importance of relevance and practical activity: "work arising out of particular concepts should only be done where it is relevant to the things the children wanted to do" (p25).

However, this curriculum project can be categorised as 'curriculum as content' (Blenkin and Kelly, 1987, p66) since it claimed a primacy for particular knowledge. It assumed a rationalist epistemology (Peters, 1959, 1966) in that it identified areas of knowledge (with so-called expert help) which should be imposed upon learners. The project team regarded some knowledge as more important than other and their approach implied that knowledge was objective, absolute and unchanging.

3.9 Science 5 - 13

In the year the Plowden Report was published (1967), another and perhaps the most significant of the sixties curriculum projects began. The Science 5 - 13 project was jointly sponsored by the Schools Council, the Nuffield Foundation and the Scottish Education Department. It was intended to consolidate and extend the work of the earlier Nuffield Junior Science Project discussed above. The philosophy was again explicitly child-centred and the emphasis was on the processes of science rather than the concepts or content. Like its predecessor, the Nuffield Project, it adopted an inductive view of science seeing knowledge as coming from observations and evidence; consideration of the particular leading to hypotheses or statements about the general. Its major development upon the earlier Nuffield Project was to set clear learning objectives which were linked with Piagetian stages, which were assumed to be an accurate description of child development. It was the first major curriculum project to be underpinned by an explicit theory of learning. The relationship
between the theory of learning adopted and an objectives approach is detailed in the project's introductory book, *With Objectives in Mind* (Ennever and Harlen, 1972). Numerous objectives were listed for Piaget's three developmental stages (pre-operational, concrete operational and formal operational) based on eight broad aims: observing, exploring and ordering observations; developing basic concepts and logical thinking; posing questions and devising experiments or investigations to answer them; acquiring knowledge and learning skills; communicating; appreciating patterns and relationships; interpreting findings critically; developing interests, attitudes and aesthetic awareness (p21).

The team produced a series of units for teachers based on content areas such as *Time*, *Metals* and *Minibeasts*. The materials were trialed in twelve LEAs and received an enthusiastic reception from those teachers who used them. Another innovative feature of this project was the inclusion of an evaluator as part of the team. Consequently the project's evaluation was formative (see Harlen, 1975) in that the evaluator informed the direction of the project's development.

The project can be seen as having two linked strands, one related to the objectives approach which encouraged teachers to be more analytical in terms of their pedagogy (considering why they were providing particular activities for children) and the other related to the guidance offered teachers of a more pragmatic and practical nature (how the experiences could be provided). Both of these were subsequently developed by later initiatives.

The significance of *Science 5 - 13* has been discussed by various commentators including team members (Harlen, 1985a; Parker-Jelly, 1983) and a group charged with evaluating the take-up of the outcomes in schools (Steadman et al., 1978).

The project aimed in the words of its director, Len Ennever, to, "help teachers help children learn science" (Parker-Jelly, 1983, p148) and in that context its significance to class teachers should be seen as paramount. There was evidence collected at the time by Harlen (1975) that there was an impact on the practice of teachers directly involved in the project. However,
retrospectively there is less positive evidence of the project's influence on practice. Although well over a million copies of units were sold and were still being sold into the nineties, when Steadman researched the take up in schools he found 70% of schools never used the materials (Steadman et al., 1978). This figure was supported by a smaller survey conducted by Parker-Jelly in one LEA (Parker-Jelly, 1983, p150). HMI, in their survey of 1978 (see below) stated that the, "materials produced by curriculum development projects have had little impact in the majority of schools" (DES, 1978, para. 5.82). However, Parker-Jelly claimed the influence has been developing slowly and although later data was not collected she suggested a greater impact than the figures suggest (Parker-Jelly, 1983, p150). My own observations as an advisory teacher in 1985-88 (when I visited nearly 90 Avon schools) confirmed that Science 5 - 13 units were evident on many staffroom shelves but were rarely used.

Parker-Jelly noted the significance of the project on other groups. The approach of the project with its emphasis on objectives meant it gained the interest of many academics (Blenkin and Kelly, 1987; Lawton et al., 1978; Stenhouse, 1975). Some of these were critical of the approach (Blenkin and Kelly, 1987, p81; Stenhouse, 1975, p70) but their interest led to Science 5 - 13 gaining significance through curriculum courses in initial teacher education establishments as well as in method courses which often embraced its child-centred approach and practical guidance. Consequently many primary teachers met the project during their initial training. The project materials were also used extensively on inservice courses, particularly those provided by colleges or teacher centre wardens and advisory staff in the original pilot LEAs. My own experience of science inservice as a teacher in 1982 confirms this since the year-long course drew on the project's philosophy and materials.

The influence of the project can also be identified in ASE publications (eg ASE, 1974) and the work of the Assessment of Performance Unit (APU) (eg APU, 1981). As already noted the two key aspects of the project, its objectives-based pedagogy and its pragmatic support for teachers were both influential on subsequent projects. The objectives model was taken further by Harlen in Match and Mismatch (Harlen, 1977a and b; Harlen, 1992). This was a
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project based at Reading University which resulted in materials to be used on inservice; *Raising Questions* (which considers ways of assessing children's level of development in science) and *Finding Answers* (which details the kind of development teachers can expect to find). The *Learning Through Science Project* which is discussed below provided further guidance for teachers and support material for use with pupils (Richards et al., 1980, 1982, 1985) as did another project based at Chelsea College called *Teaching Primary Science* (Diamond, 1978).

Parker-Jelly (1983) noted how some agencies, such as LEAs, used the project, "for its pragmatic guidance and ignore, or considerably underplay, the objectives thrust" (p151). Some did this through the production of their own guidelines, resource material and pupil materials or the provision of equipment. This approach implies that the pedagogy that underpinned the project and was so fundamental to the team's approach was not valued by those responsible for facilitating the implementation of science in primary schools. There was an assumption by some LEA advisory staff and others that 'hints and tips' for teachers was enough to encourage more science into primary classrooms.

Another interesting point about the project team's approach, related to the relationship between process/knowledge and understanding, was identified by Parker-Jelly:

At first efforts were directed towards the framework of concepts deemed desirable .... and recollection of this period in the project's life is one of intense mental activity associated with attempts to produce a hierarchical/network map of the concepts involved in various science topics appropriate to children in the 5-13 age range.

The team evaluator had experience of the previous Oxford team's work. Despite this, the difficulty involved in the attempt to deal with concepts related to science caused the team to turn to the objectives model focusing on processes and linked to Piaget's stages.
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Only two of the aims identified related to knowledge and understanding and the objectives related to these included statements, such as the following at Stage 1, "awareness of properties which materials can have" (p63). This is very similar to statements of attainment in the National Curriculum relating to Attainment Target 6, level 1, "be able to describe familiar and unfamiliar objects in terms of simple properties" (DES, 1989a, p14). Many of the objectives can be identified in the National Curriculum statements of attainment. However, the balance of the Science 5 - 13 objectives was heavily weighted towards process objectives and as noted before the concepts developed were almost regarded as incidental to the benefits gained through working in a scientific way.

Parker-Jelly’s reflections conclude with some questions about how the project might have achieved greater significance: noting the success a greater emphasis on teachers’ pragmatic concerns might have had; questioning whether the objectives’ framework was the most suitable and asking how dissemination might have been made more effective (p155).

The criticisms directed at an objectives approach have been based on its implication that the curriculum can be regarded as product (Blenkin and Kelly, 1987, p72). Such approaches, which were originally developed in the USA to bring the efficiency of industry into education, assume human behaviours can be defined in such a way as to make them measurable. They assume a positivist view human behaviour (see Chapter 6, Section 6.3) can be explained in the same way phenomena in the natural world. Arguments for an objectives approach include the view that education is a rational activity which has a purpose that can be defined; that it enables teaching to be evaluated and enables teachers to become accountable. Blenkin and Kelly's criticisms also focus on the concern that the learner may be viewed as passive; that learning is not a linear activity; that the definition of objectives leads to categories that are unrealistic in practice and untenable in theory; that it can restrict the freedom of learners and teachers (p72). They also note, citing Science 5 - 13 as evidence, that teachers do not use objectives in the way curriculum planners suggest. In fact, they also raise doubts about the extent to which the project identifies objectives:
Although prespecification of objectives played a major part in the evolution of the Science 5 - 13 Project, these objectives on examination prove to be rather more loosely framed than at first sight they appear to be and in practice they have been used to support an approach to the teaching of science in the primary school that is Enquiry-based.

Blenkin and Kelly, 1987, p86

In conclusion, Blenkin and Kelly recognise the validity of objectives, as short term goals or intended learning outcomes, in certain contexts such as vocational training or narrowly defined skills within education but reject the model as an appropriate one for defining the primary curriculum or aspects of it.

Science 5 - 13 was therefore based on a suspect model of the curriculum, although one which is in part the basis of the National Curriculum. It espoused a child-centred approach which in some respects was contradictory to its objectives dimension. This contradiction and the evident difficulty primary teachers had in working with objectives may have contributed to the limited impact the project had on primary practice.

3.10 The Dalton Committee

During the early life of Science 5 - 13, the Dainton Committee on Science and Technology in Higher Education reported:

Since most young children show an interest in scientific concepts, a failure to foster and nourish early interests and curiosity may well be responsible for the apparently growing reluctance to follow .. science.

Dainton, 1968 quoted in Cox and Taylor, 1989, p7

The scientific literacy of the population at large was becoming a higher priority for politicians and industrialists in the sixties who recognised the implications of this for living in and contributing economically to a society that was increasingly technological.
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3.11 The seventies

The post-Plowden era of the seventies included increasing pressure on primary teachers to include science in their teaching although the influences of the sixties curriculum projects remained minimal. An interesting aspect of developments in this period was the extent to which curriculum development in science occurred in specific geographical areas, often centred around teachers centres that were involved in Nuffield Junior Science or Science 5 - 13 Projects. Areas such as Bristol, Oxford, Liverpool and Sheffield established reputations as areas where innovative primary science practice was evident. Local initiatives ensured the initial experiences and enthusiasm generated by the early projects continued throughout the period, often supported by the efforts of individuals such as teacher centre wardens, advisers and advisory teachers.

Teachers were however facing conflicting pressures during this period. The then Prime Minister, James Callaghan made his famous Ruskin speech in 1976. This and the publication of the first Black Papers (see Musgrove, 1987) who were calling for a return to basics provided comfort to the primary teacher who was reluctant to broaden the curriculum they provided.

In reality the progressive education of the post-Plowden period seems to have been a myth and major projects into primary teaching (eg Galton et al., 1980) and small-scale enquiries (Barker-Lunn, 1984) found "the vast majority of junior teachers ... firmly in control of their classrooms".

3.12 Primary Education In England: an HMI survey

The extent to which primary teachers were implementing science in their classrooms was investigated by HMI who reported on their findings in 1978 (DES, 1978). This report indicated how little progress had resulted from the curriculum projects of the previous period:

Few primary schools visited in the course of the survey had effective programmes for the teaching of science. There was a lack of appropriate
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equipment; insufficient attention was given to ensuring proper coverage of key scientific notions; the teaching of processes and skills such as observing, the formulating of hypotheses, experimenting and recording was often superficial. The work in observational and experimental science was less well matched to children's capabilities than work in any other area of the curriculum.

DES, 1978, paragraph 5.66

The evidence was clear; primary schools were not prioritising science and were not providing children with a satisfactory science education. Headteachers' statements provided for HMI indicated only a small minority, "recognised the important contribution which science could make to children's intellectual development" (para. 5.69). Nature tables and work in the natural sciences were most common and about 66% of schools visited had nature or 'interest' tables (para. 5.70) although limited use were made of these opportunities for investigational work. Textbooks and workcards were evident in 20% of classes (para. 5.74) and the same proportion made use of television broadcasts for teaching science (para. 5.73).

The report discussed the content covered in more detail noting that, "studies relating to man-made artefacts and mechanical actions are comparatively rare" (para. 5.81). The physical sciences had not become commonplace in primary classrooms.

HMI were clear about the reasons for the disappointing progress of science teaching:

The most severe obstacle to the improvement of science in the primary school is that many existing teachers lack a working knowledge of elementary science appropriate to children of this age. This results in some teachers being so short of confidence in their own abilities that they make no attempt to include science in the curriculum. In other cases teachers make this attempt, but the work that results is superficial since the teachers themselves may be unsure where a particular investigation or topic in science should lead.

para. 5.83

They recognised that, "making good the lack of science expertise among existing teachers is a complex matter" and also offered the suggestion that those teachers with expertise should be deployed as "class and specialist teachers" (para. 5.84). This provided the impetus for science coordinators to be appointed in primary schools. The report also identified the need
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for inservice training for existing teachers and appropriate initial training for new teachers.

This report is of considerable significance to the present study since it was the first national report to highlight the need for improving primary teachers' background knowledge and understanding of science. A senior figure amongst HMI at this time, Norman Thomas, commented on this report a couple of years later:

"The difficulty that primary teachers have had in taking on and adapting the various primary science projects of the last two decades suggests that teachers in general are not convinced of the worth of this kind of work, or that they find it extremely difficult to organise, or that they feel too unsure themselves to undertake it."

Thomas, 1980, p10

At that time, there was obviously still a need to convince teachers of the worth of this area of the curriculum for children, although, as evidence in this chapter indicates, many had tried.

3.13 The debate about content in the science curriculum

As discussed above the question of whether content mattered in primary science and the relationship between content and process aspects of the curriculum had been considered by the major curriculum development projects in science during the sixties and seventies. A contribution to this debate had been made by Wynne Harlen who had been actively involved in several projects (Oxford Primary Science, Science 5 - 13, Match and Mismatch). In 1978 she published a statement of her position, Does content matter? (Harlen, 1978), which was to be influential over the next decade.

In this paper she explored the emphasis of previous curriculum projects and reviewed their common features in terms of encouraging concrete experiences which involve children in seeing and doing in order that they develop their own ideas rather than memorise those of others.

She considered the issue of how the content of children's scientific work could be selected
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and identified the following as points against a common content:

i. children should be raising their own questions and seeking answers to these;
ii. the scientific ideas that it might be appropriate for children to have change;
iii. a common content may not take account of local and regional variations;
iv. a common content makes integration of the curriculum difficult;
v. children are better motivated when working on content that interests them.

(p617)

These points are based on a number of premises about the nature of science for young children that had been assumed by those advocating its place within the curriculum and Harlen recognised that the teaching approach implied by these premises is very difficult for teachers. She accepted the weakness of some of the points, for example noting that some children are, apparently, never interested in the content regardless of its relevance. She also recognised the problems of a lack of common content in terms of continuity.

The evidence for her second point exists in the changes that can be seen in recent exam syllabuses (at age 16) compared to those for the same aged children during the earlier part of the century (Uzzell, 1986). The other points are less easily supported by evidence and all of these can be accommodated within a common curriculum as has become evident in the literature documenting how the National Curriculum might be implemented in primary schools (Coulby and Ward, 1990).

Harlen then considered the points in favour of a common content:

i. there is a body of knowledge that it is beneficial for all to know;
ii. common content allows progression to be addressed in providing children with experiences;
iii. some content is better than other for developing scientific processes;
iv. adults can select more appropriate knowledge for children than that which they chose for themselves;
v. it encourages teachers to provide a balanced curriculum.

(p618)
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She considered the objections to these points, particularly concerning the "implied arrogance" of the case for common content. She identified some of the inherent problems that might arise, for example the likelihood that it would lead to all children doing the same things. She then revealed her resolution of the dilemma by exploring whether there is a middle way and concluded:

What seems to be required are content guidelines that are firm enough to ensure that children encounter the range of ideas and facts which are relevant to understanding their environment, yet are loose enough to enable teachers to use a variety of routes to arrive at them.

She clarified her view of how content should be viewed by defining it as, "a set of ideas, generalisations and facts". She suggested that what was needed was content objectives which could be treated in the same way as process and attitude objectives. The paper concluded with a listing of such content objects, for two age ranges (9/10 and 11/12) under headings: about ourselves and other living things; about the physical surroundings; about forces, movement and energy; basic concepts. The statements listed included examples such as 'to make anything move (or change the way of moving it) there has to be something pushing, pulling or twisting it' (p621). This can be compared to a National Curriculum statement of attainment linked to Attainment Target 10 at level 2 (an average 7 year old), 'understand that pushes and pulls can start things moving, speed up, swerve or stop' (DES, 1989a). Similar comparison can be made with most of her statements. Harlen regarded her list as the "core of generalisations that (children) should acquire" as they were investigating problems and developing skills. In other words, she identified the inextricable links between process and content and attempted to resolve the dilemma posed by asking whether one or the other should be the priority in primary science. This view is one we see reflected in the subsequent National Curriculum and exemplified in the two profile components (Exploration of Science and Knowledge and Understanding) which were given approximately equal weighting at the primary stage (DES, 1989a; NCC, 1989).
There are, however, some weaknesses in the treatment which deserve consideration. She did not address the criticisms that had been made of objectives (Stenhouse, 1975) that are discussed earlier in this chapter. Her notion of content guidelines was perhaps a more useful concept and in fact her so-called objectives are no more specific than those developed during the Science 5-13 Project which Blenkin and Kelly (1987) subsequently noted were much more loosely described than objectives (p86). Her definition of content also raised some problems since she did not distinguish between content, as the experiences children might be offered, from the knowledge and understanding they might develop as a result of those experiences. Her production of content guidelines implied that progression in terms of scientific knowledge and understanding can be easily defined. This was a task which those who developed the Science NC found difficult and the results of their endeavours led to considerable criticisms (Ritchie, 1990a).

Fundamentally, however, the major problem about her approach was its attempt to combine different approaches to the curriculum (based on content, objectives and educational process) which others regard as incompatible (Blenkin and Kelly, 1987, p85).

Harlen's paper also failed to address who should have control of the curriculum and hence produce the content guidelines she advocated, although the assumption seems to be that such guidelines should be produced by educationalists. There is no treatment of the political or social context in which a science curriculum is defined. These issues were addressed by others at a later date (eg. Hodson and Prophet, 1986; West, 1986) before political decisions resolved the question and control of the curriculum became centralised through the National Curriculum.

3.14 The National response

The conservative government that was elected in 1979 soon indicated its intentions for educational reform and the place of science was on the verge of being firmly established as a governmental priority. The DES produced a discussion paper called A View of the Curriculum
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(DES, 1979a), and it was followed, after consultation, by A Framework for the Curriculum (DES, 1979b) in which it was clearly stated that, "the Secretaries of State consider that science should form part of the experience of every pupil (in the primary school)". The paper also referred to the role of the science specialists in terms of giving guidance to other colleagues. It indicated however, although Harien's ideas about content guideline were being discussed amongst many involved in primary science, that the emphasis at primary level should be on the processes of science.

This increased pressure from central government led to a more explicit response from LEAs than had resulted from other initiatives and it was at this time that many LEAs, particularly those with areas that had been piloting Nuffield Junior Science and Science 5 - 13 materials, began to take primary science more seriously, providing courses at teachers centres and producing LEA guidance, resources (eg. Science Horizons (produced by West Sussex LEA), 1982) and policy statements (eg County of Avon, 1981). Many of these focused teachers' attention on the skills and processes of science (rather than offering anything approaching Harien's content objectives). Raper and Stringer (1987) review these various developments and illustrate what Day describes as, "a picture of immense energy and richness of response" (Day, 1988, p 167).

1982 saw the publication of a DES consultative paper, Science in Schools (DES, 1982) which proposed that science education should be regarded as a continuum from 5 to 16. By 1983, a change of emphasis was becoming more evident in HMI's view of primary science and their discussion paper, Science in Primary Schools (DES, 1983) stated, "it is impossible to develop a mode of thought without some basic content about which to think" (p2). This paper gave considerable attention to the content and offered key themes: living things and their interaction with the environment; materials and their characteristics; energy and its interaction with materials, forces and their effects. They emphasised systematic enquiry (p3) but recognised the links between process and content, adopting a similar stance to Harien but avoiding the task of stating content objectives. The paper provided further evidence of HMI's concerns about teachers' own knowledge:
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Very few teachers in their own science education were given the experience of designing or carrying out their own experiments and this probably accounts for the difficulty so many of them have with this aspect of the work. It seems wholly unreasonable, not to say unrealistic, to expect all primary teachers, or even most, to be able to meet this kind of demand and any insistence on it is unlikely to result in good science.

That insistence, of course, occurred six years later with the implementation of the National Curriculum.

During this period other significant publications and initiatives included the development of the pragmatic dimension of the Science 5-13 project through the Schools Council funded Learning Through Science Project. This project produced numerous publications alongside pupil materials: Formulating a School Policy (1980); Science Resources for Primary and Middle Schools (1982); Science for Children with Learning Difficulties (1985); Guide and Index (1985). The significance of this project was discussed by its director, Roy Richards (1983) and he made it clear that “the emphasis of our pupil material and teachers’ guides is on developing the processes of science” (p165). The pupil materials were generally well-received and the author’s observations during 1985-88 indicated it was more common in primary schools and more likely to be seen in use than any other material available at that time. The demand for pupil material had come from teachers who, as noted earlier, had found it difficult to implement the objectives approach adopted by the Science 5-13 team. There was a significant move by the Learning Through Science Team away from an objectives approach and this development was considered more acceptable by some of the critics of Science 5-13 (Blenkin and Kelly, 1987, p119).

In 1983, international recognition of the importance of primary science was evident through the publication of a justification for science in the primary curriculum from UNESCO (UNESCO, 1983). This document reflected the arguments for primary science which have been outlined above.
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The APU surveyed 10 and 11 year olds during 1980/81 and its reports (APU, 1981; 1983) provide evidence that children were generally performing well on generic skills used in various curriculum areas but performed less well on more specific science skills such as the recognition of pattern in observations, the explanation of events using basic scientific concepts, the use of controls in practical investigations and the critical examination of practical procedures (Harlen 1983, p83). The APU produced further reports for teachers and included an assessment framework in which it has defined operationally scientific skills and processes (APU, 1984b).

The ASE was adding to its contribution to the support for primary science and updated two useful guides for primary heads and coordinators (ASE, 1981a and b).

By 1984, the APU found science activities in the curriculum of 90% of primary schools and over half had a member of staff responsible for science (APU, 1984a, 1985). However, others were suggesting primary science had reached a “quality plateau” (Day, 1988, p167). This was a view supported by research looking at classroom practice (Galton et al., 1980; Bennett et al., 1984). Day’s explanation was based on the complexity of the task teachers were being asked to perform in implementing science that reflected the elements of practice required such as using the children’s own questions and lines of enquiry. This is discussed further in Chapter 4.

3.15 Science 5 - 16: a Statement of Policy

In 1985, the government made its commitment to science for all explicit in one of its first policy statements (DES, 1985a) in which it states, “science should have a place in the education of all pupils of compulsory school age whether or not they are likely to go on to follow a career in science or technology” (p1). The policy statement was a result of the comments received about the earlier consultative paper (DES, 1984c). It was an attempt to get, “broad agreement on the objectives and content of the school curriculum (Day, 1988, p164). The fact that science was one of the first statements published was another indication of the priority it had in government thinking. There is a clear indication of the forthcoming National Curriculum
proposals in that the Government's "intention of publishing broadly agreed curricular objectives" (DES, 1985a, p1) was made explicit. The document dealt with science in both primary and secondary phases and was the first attempt to deal with issues related to continuity for 5 to 16. The message to primary teachers was unequivocal; "the objective should be that all class teachers, without exception, should include at least some science in their teaching". Its view on the nature of primary science has much in common with earlier thinking and it stated, "much of the science work should arise from children's spontaneous interests and from their natural curiosity". It also reiterated HMI's view that science at this stage should develop scientific ways of working, but also ensure children, "gain a progressively deeper understanding of some of the central concepts of science" (p9). It required teachers to "be clear about which scientific concepts are to be used or developed". The place of content is "emphatically declared" (Day, 1988, p165) and the four areas from HMI's earlier paper (DES, 1983) were listed: living things; materials; energy and forces. Again the issue of how individual teachers or whole schools were to construct programmes of study which delivered specific scientific concepts but also arose from children's interests was avoided.

In the document the DES listed principles for planning a science curriculum which were: breadth; balance; relevance; differentiation; equal opportunities; continuity; progression; links across the curriculum; teaching methods and approaches; assessment. The government had produced a statement about science in primary schools which was to lead to the subject becoming a core one in the National Curriculum. It was a statement that was generally well received by the profession (ASE, 1986; Ritchie, 1990a, p72) and provided a sound basis for advisers, advisory teachers and others working with primary teachers to offer as evidence of why they should be providing science experiences for children before progressing to how they might do it. It did not however, recognise or address the criticisms that had been levelled at its view of the curriculum that attempted, as Harlen had done before (Harlen, 1978), to define a curriculum in terms of content and objectives (Blenkin and Kelly, 1987, p85; Stenhouse, 1980).

The policy restated the earlier HMI view concerning the greatest obstacle to science in primary...
schools being lack of background knowledge amongst teachers. It proposed the following:

- courses and materials which offer or consolidate a foundation of scientific knowledge which will give teachers the confidence necessary to teach science;
- course which enable teachers themselves to practice scientific skills and method; and
- continuous support within and outside school over a long period.

DES, 1985a, p8

In the same year Harlen published a book outlining her current thinking about teaching and learning in primary science (Harlen, 1985a). This provided a comprehensive case for, "the interconnectedness of children's ideas with their ways of gathering and processing information" (p55). She also expanded on her views with regard to the question of content and the criteria that should be used in its selection (p75). The text provided guidance for teachers covering most of the principles identified by HMI (see above).

3.16 Support for primary teachers

The DES made grants available to LEAs to support inservice training for primary science coordinators (DES, 1984a) and science was one of the designated areas to receive Education Support Grants (ESG) (1984b). This first initiative led to courses, mainly provided by higher education institutions, which are discussed in Chapter 5. The ESG funding was generally used by LEAs to employ primary science advisory teachers whose job was to support classroom teachers by working alongside them in the classroom. This development was evaluated by *Initiative in Primary Science: an Evaluation* (IPSE) which not only evaluated the work of advisory teachers but also supported their work by offering national coordination and dissemination of good practice. Their findings are published by the ASE (IPSE, 1988a, b and c). The impact of advisory teachers was evaluated by Harland (1990) who concluded, "the research produced convincing and varied evidence to substantiate the view that advisory teachers are an extremely valuable and potentially very effective vehicle for delivering school-based INSET" (p50). The nature of support offered by advisory teachers and the breadth of
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initiatives in which they became involved is discussed by the author and others elsewhere (ASE, 1990; Ritchie, 1987, 1991c). By 1986, over 90 LEAs had science advisory teachers and many primary teachers were benefiting from having a more confident colleague working alongside them. However, by 1991 less funds were available and many LEAs reduced their advisory teacher teams considerably. For example, Avon was an extreme case and had a team of six primary advisory teachers from 1985 to 1988. By 1991, only one was in post. The reductions resulted from a number of factors. In many LEAs the posts had never been made substantive since a commitment could not be made to continue funding when the DES reduced its contribution. Some LEAs suffered from charge-capping and were required to make educational cuts and advisory teachers were early casualties. Generally however, the reductions did not result from a dissatisfaction within the LEAs about the value of advisory teachers.

Prior to the Secretary of State's announcement in 1987 that science was to be a core subject in the National Curriculum, many primary teachers had been offered support for science in one form or another. Most primary schools had a coordinator for science, some of whom had been on long courses at institutions of higher education (funded by DES grants), and a written science policy: most teachers were including some science in their teaching (APU, 1985), some of whom had been supported by advisory teachers or attended courses: a wealth of curriculum materials were available to support the less confident teacher: there was an increasing amount of research into how children learn science. However, it was still a surprise to many primary teachers that science was identified as a core subject (Ritchie, 1990a, p68). Teachers' response to this and a discussion of the implications for their teaching is discussed in Chapter 4.

When HMI published their inspection findings in 1989 (DES, 1989b) they provided a much more positive picture of science in primary schools than their previous major report (DES, 1978) and they reported, "the teaching of science in primary schools has increased markedly over the last ten years and most schools have increased and improved their resources for science teaching" (p5). In 300 inspections between 1982 and 1986 only one school did not
include science in the curriculum provided. They recognised the significance of the ESG initiative and stated this "has led to a slow but steady improvement in teaching competence and in the confidence of teachers to provide more physical science". They expressed reservations about the impact of coordinators on colleagues' practice, identifying the lack of time to work alongside them as a key factor; they criticised some aspects of topic work as poorly planned and ineffective; and were not impressed by assessment practice and the matching of activities to children's abilities.

The report provides a broad picture of primary science teaching in the eighties and through case studies offers teachers a valuable insight into the nature of the best practice they observed. They illustrate the development of scientific skills, ideas and attitudes in an holistic way and provide specific examples of the principles that had been listed in Science 5 - 16 (see above). The report stresses that there is no single way of organising science teaching but did find better progression in the work when it was taught separately.

Again it was noted that teachers need, "to improve their own knowledge of science in relation to what children should know" (p25).

3.17 A National Curriculum

Under the Education Act of 1944 responsibility for the curriculum was in the hands of the LEAs who had limited powers and so although in some areas LEA policies for primary science existed they could not be 'enforced' and in real terms control of the curriculum was with teachers and schools. LEAs were, in many cases, actively encouraging primary teachers to teach science, but as we have seen the success of this was limited, certainly prior to 1985. Consequently, until the National Curriculum for science was introduced in 1989, primary teachers had been able to choose whether or not to teach science. If they decided to include it in the curriculum they offered children the choice of content was dictated by their own preferences or that of the staff with whom they worked, if a whole school policy existed. The 1988 Education Reform Act (DES, 1988a) allowed the Secretary of State to prescribe the
curriculum and returned to the situation that existed from 1902 to 1944. The teaching of science became a statutory obligation for schools. The nature of the science curriculum, consisting of both process and content was prescribed (through the two Profile Components established for reporting purposes, and the balance between them) and the knowledge, understanding and skills children should be taught described as statutory Programmes of Study for each Key Stage. Attainment Targets (ATs) provided objectives against which children's learning was to be assessed were also statutory. Each Attainment Target included statements of attainment at ten levels.

The story of the development of science within the National Curriculum is a complicated one and related by the author elsewhere (Ritchie, 1990a). That treatment also includes a discussion of the relationship between science and technology in the context of the National Curriculum (p75). However, this section will discuss Science within the National Curriculum at the time the research data was collected (1989-91).

It is significant to note that the National Curriculum is subject-based and the identification of science as a separate subject implied for some primary teachers an immediate rejection of a more integrated approach at the primary level, although much of the non-statutory guidance subsequently provided supports teachers' attempts to integrate subjects (e.g. NCC, 1989, C8). A subject-based curriculum in the primary school has been extensively criticised (Blenkin and Kelly, 1987, p130).

The National Curriculum is based on a view of the curriculum, discussed earlier, that is focused on both content and product (objectives). It is not dissimilar to the model advocated by Harlen in 1978 (Harlen, 1978) and builds explicitly upon that approach outlined in Science 5 - 16 (DES, 1985a).

The National Curriculum for Science (DES, 1989a) included two Profile Components (PCs), Exploration of Science (PC1) and Knowledge and Understanding of Science (PC2). This separation is again significant in that, in my experience and that of others, it led to some
primary teachers assuming the two aspects could be taught separately (Harlen, 1992, p58),
despite the approach encouraged by the non-statutory guidance available (see below). Within
PC1 there was a single attainment target (AT) called *Exploration of Science* (AT1). This
included the statements of attainment related to the skills and processes involved in science.
Statements of attainment can be regarded as objectives of learning (Harlen, 1992, p55) and
as was noted above, were defined at ten levels. This treatment of objectives implied to some
teachers a view of learning that involved a linear progression. This reflects a criticism of
objectives discussed earlier (see Blenkin and Kelly, 1987, p81). The attempt to map learning
at ten levels, especially without a firm research base to work from was inevitably difficult and
one of the key figures in the group that produced them admitted that they "may not be all that
accurate" (Harlen, 1992, p59). This did not help primary teachers who attempted to make their
assessments of children match the levels. The other profile component included 16 ATs
although only 13 applied at Key Stages 1 and 2. These attainment targets were content
based:

AT 2  The variety of life
AT 3  Processes of life
AT 4  Genetics and evolution
AT 5  Human influences on the Earth
AT 6  Types and uses of materials
AT 9  Earth and atmosphere
AT 10  Forces
AT 11  Electricity and magnetism
AT 12  Scientific aspects of information technology
AT 13  Energy
AT 14  Sound and music
AT 15  Using light and electromagnetic radiation
AT 16  The Earth in space.

The two PCs were equally weighted, in terms of assessment, at Key Stage 1 and weighted
45.55% at Key Stage 2. However, the imbalance in the number of attainment targets in each profile component led to primary teachers, again based on my experience, considering Profile Component 2 more important and requiring greater emphasis in terms of teaching. Therefore, although in some respects the National Curriculum in Science was an attempt to balance processes of science with knowledge and understanding of science in terms of curriculum content, children’s learning and aims for teaching, this was not necessarily reflected in the way teachers interpreted and implemented it.

The attainment targets and the statements of attainment provided the means by which the curriculum was to be assessed and provided teachers with the objectives that defined the curriculum in terms of outcomes or product. These objectives however, did not cover all of the content which was also a statutory requirement. The content was separately described by Programmes of Study (PoS) which were defined for each key stage. The positioning of these in the final document which reached schools was significant since they were collected together at the end of the document and after the attainment targets. This had the result that the attainment targets and consequently the assessment aspect of the curriculum was assumed by many teachers to be the more important and therefore the part of the document to use when planning work. Others, often advisory teachers and trainers, wishing to avoid an assessment-led curriculum encouraged teachers to use the PoS as their tool for planning (Ritchie, 1990a, p82). The Non-Statutory Guidance produced by the National Curriculum Council (NCC, 1989) was helpful in this respect.

HMI claimed that the resulting curriculum was, “built upon a consensus about science 5 to 16 which has grown over a number of years” (DES, 1989b, p22). This consensus is debatable as the reaction to the original report (Ritchie, 1990a, p77) indicated.

It is important to recognise what the National Curriculum did not prescribe, nor has at the time of writing. There was no attempt to include statements of attainment related to attitudes. This is common to all subjects and resulted from a decision of the Task Group on Assessment and Testing (DES, 1988a) that “the assessment of attitudes should not form part of the prescribed
part of the national assessment system" (para. 30). Attitudes have always been an important strand of primary science work (eg County of Avon, 1981, p2; Ennever and Harlen, 1972, p8) and the Non-Statutory Guidance discussed below included a list (NCC, 1989, A8) which was almost identical to the one produced by Avon eight years before. The working group that produced the original proposals (DES, 1987b) had included some of these attitudes in the attainment targets they proposed covering communication and science in action. These were rejected by the Secretary of State and did not appear in the final document.

The National Curriculum did not require teachers to spend specific amounts of time on particular subjects or programmes of study; it did not specify the teaching methods or classroom organisation that should be used; it did not provide a detailed syllabus indicating specific experiences that children should be offered; it did not require particular materials or resources to be used (DES, Circular 5/89). For example, teachers could decide what particular materials and artefacts to use to ensure children "experience natural and manufactured forces which push, pull and make things move" as required by the Key Stage 1 Programme of Study (DES, 1989a, p66) and whether they organised the activity as individual, group or class work.

This freedom, together with the specific nature of attainment targets and general nature of the programme of study led, as was noted as a concern above, to some teachers using the statements of attainment as the basis of their planning (DES, 1991a) rather than the Programmes of Study which were intended to be the starting point (NCC, 1989a, C6). This led to an assessment-led curriculum in some schools with teachers planning activities to deliver specific statements of attainment. This was successfully avoided by others (Ritchie, 1990b, p177).

The statutory requirements (DES, 1989a) were supported by Non-Statutory Guidance (NSG) which was produced by the National Curriculum Council (NCC, 1989). This provided guidance for teachers attempting to implement the curriculum and offered suggestions about approaches and methods. It drew from the earlier report (DES, 1987) produced by the original working group convened by the Secretary of State and included a clear exposition of the

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contribution science can make to the curriculum (NCC, 1989, A4). The nature of learning in science was explicitly based on a constructivist view:

In their early experiences of the world, pupils develop ideas which enable them to make sense of what happens around them. They bring these informal ideas into the classroom and the aim of science education is to give pupils more explanatory power so that their ideas can become useful concepts. Viewed from this perspective, it is important that we should take children's initial ideas seriously so as to ensure any change or development of these ideas ... becomes 'owned' by the pupil.

NCC, 1989, A7

It also recognised the inextricable links between processes and knowledge and resolved for teachers any doubts they might have about the appropriate balance between processes and knowledge and understanding in terms of children's learning:

For the pupil learning science, as for the scientist, the way understanding develops depends both on existing ideas and on the processes by which those ideas are used and tested in new situations.

ibid.

The National Curriculum provided a framework in which primary teachers had to plan and implement their work. However, the framework allowed teachers to make certain decisions for themselves about how they would teach and what experiences they would provide for children. It made many demands on primary teachers and school staffs, discussed by the author elsewhere (Ritchie, 1990b, p170) including: the need to find more time to spend on science; planning for science at a whole school and class level to provide coverage of programmes of study and progression through attainment targets and ensuring continuity between classes and schools; giving greater attention to developing children's knowledge and understanding and ensuring this develops alongside and linked to the development of process skills; assessing and recording children's scientific achievements; providing the necessary resources; making appropriate use of information technology; providing equality of opportunity and access to the curriculum for all children.
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3.18 Implementing the National Curriculum

HMI reported on the implementation of science in Key Stages 1 and 3 in 1991 (DES, 1991a). This covered the first year of the National Curriculum's implementation and involved visits to over 200 primary schools. Overall standards during the summer term were satisfactory or better in 75% of classes (p9). They found 8 to 10% of curriculum time being given to science in Key Stage 1 classes. Planning of science had improved and they identified improved confidence, although not where physical science and earth science topics were involved, amongst key stage 1 teachers. Assessment was proving problematic and teachers were, "investing a disproportionate amount of time and energy" in it. Crucially, the quality of work in 20% of primary classes was, "adversely affected by a lack of suitably qualified staff".

Most Key Stage 1 teachers had had some INSET on science in the National Curriculum, usually of a couple of days with an advisory teacher. By the end of the year the teachers, "were beginning to identify their own training needs... for example ... improving their own scientific knowledge" (p31).

3.19 Conclusions

There has been considerable shift in the primary curriculum during this century and over the last 10 years this has seen science established as an element of the primary curriculum and more recently identified as a core subject in the National Curriculum.

The emphasis has moved from an approach to science in the sixties and seventies which emphasised the scientific processes and skills involved, in the curriculum, to a recognition of the importance of content and knowledge and understanding which culminated in a National Curriculum which saw these as inextricably linked in terms of the curriculum provided. Reflection on the curriculum projects of the last thirty years indicates that all the teams were aware of the need to consider the relationship between science process and concepts in primary science and the difference between the approaches adopted reflects a different
balance between the two aspects, not an outright rejection by any project of one or the other. The debate that has been discussed in terms of primary science has an interesting parallel with that which has engaged those concerned with secondary science where the shift has been from a content driven curriculum towards a more process-focused curriculum (see Wellington, 1989).

Linked with this debate about process skills and content and concepts that constitute the primary science curriculum has been a growing awareness amongst some primary teachers of the nature of learning in science. Here the shift has been from encouraging children to use scientific skills and processes, regardless of the concepts involved, because the approach fitted well with the pedagogy of child-centred discovery learning, to a recognition that children develop scientific knowledge and understanding as a result of engaging in the processes of science. By using such processes children can also become aware of the tentative nature of their own, and scientists', current ideas.

The content of primary science has shifted from an emphasis on nature study and the biological sciences to a more balanced curriculum that includes the physical and earth sciences. This shift has been encouraged throughout the century by numerous initiatives and resources but only the statutory requirement to teach a balanced science curriculum has led to all teachers including physical science content in the curriculum they provide children. There has been a related issue for primary teachers concerning the relationship between science and technology. During the seventies and eighties the two areas were seen as indistinguishable by many primary teachers and this was encouraged by various initiatives (Frost and Turner, 1987, p14; SCSST, 1985). This led to the then Secretary of State for Education asking the original Science Working Group (DES, 1987b) to produce proposals for science and technology at Key Stages 1 and 2. It was only later that it was decided to separate science from technology (see Ritchie, 1990a). From that point the two areas of the curriculum were more firmly established as distinctly different, although having important links. This chapter has focused throughout upon science in the primary curriculum.
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The above shifts (to a balance between content and processes in the curriculum; to a broader and balanced content) have made considerable demands on teachers' own scientific knowledge and understanding. This has been identified as problematic and an obstacle to the implementation of science in primary schools for many years. It is interesting that the Oxford Primary Science Project and the Nuffield Junior Science Project identified and attempted to address this concern over twenty years ago. Both projects provided inservice education for teachers aimed at improving the teachers' use of scientific processes and knowledge and understanding. The first focusing on knowledge and understanding and the latter on processes.

Consequently the concern which led to the DES funding for the course that is the focus of data collection for this research is not a new one and there have been previous attempts to address it.

The choice of content has shifted from being at the discretion of individual teachers and schools to being nationally prescribed. This has resulted from political decisions which indicates the extent to which science education needs to be viewed in its social and political context. This perspective has not been evident in the literature on primary science prior to the establishment of the National Curriculum although this aspect has been more widely discussed in terms of secondary science (Millar, 1989; West, 1986).

Linked to this curriculum shift has been a pedagogical shift. The initiatives of the sixties and seventies were strongly influenced by a Piagetian view of children's learning which led to child-centred, discovery methods (Harlen, 1992, p45) which involved children finding things out for themselves. In the eighties, teachers were encouraged to use problem solving (SCSST, 1985) or enquiry approaches. These started from a problem which children are expected to solve, which were either completely open-ended or more structured to allow the teacher some control over the development of the task. More recent initiatives were underpinned by a view of learning which recognises the importance of children's previous learning and involves a notion of cognitive 'readiness', as discussed in Chapter 2. The
importance of the social context of learning was recognised and discussion and talk were given greater emphasis. Teachers were also becoming more aware of the significance of children's 'alternative frameworks' and the extent to which these need to be elicited and challenged.

All of these approaches to primary science advocated since the sixties have in common the importance of practical first-hand experiences for children. They all involve recognition of the need to make work relevant to the learner. There has also been a general consensus that in the primary school science was best taught by classteachers as part of an integrated topic rather than a separate subject. The more recent suggestions for specialist teachers of science in the primary school (DES, 1992a) were not evident in the late eighties and the issue will be revisited in a later chapter. All the advocated approaches to primary science make considerable demands upon teachers in terms of professional knowledge and skills, including classroom management and subject knowledge and understanding.

In particular, the recent requirement for teachers to assess children's learning in science highlighted the importance of these different areas of competence. Teachers needed to understand the nature of assessment and how it might be implemented in the classroom. The Standard Assessment Tasks (SATs) first implemented in 1991 required teachers to organise the class in groups and also to manage the class in such a way as to allow work with individuals. They also needed a sound understanding of the ideas and skills they were assessing. For example, assessing children's understanding of the factors that affect floating and sinking required teachers to understand those factors themselves.

The implementation of primary science has been significantly affected by teachers' perceptions of the subject and their confidence and capabilities to make it happen in the classroom. This is the theme of the next chapter.
4.1 Introduction

This chapter considers some of the teacher-related factors which have affected the teaching of science in primary schools. These are: teachers' attitudes to the teaching of science; teachers' confidence to teach science; teachers' scientific knowledge base for teaching science; teachers' scientific process skills; teachers' understanding of the nature of science; teachers' professional knowledge base and professional skills in planning, implementing and evaluating classroom work. These key factors are linked and although they are discussed in separate sections of the chapter there is appropriately some overlap.

The chapter will also consider other potential barriers to effective teaching of science such as resourcing (class-size, equipment, storage space), curriculum overload, lack of time, pressure from parents/governors and other agencies.

4.2 Teachers' attitudes to the teaching of science

A key question related to primary teachers' attitudes towards science is whether they are convinced of the value of science education for young children and its place in the primary curriculum. The previous chapter outlined the history of primary science and provided evidence that for much of this century science, particularly in terms of a balanced science curriculum, has not been recognised by the majority of primary teachers as an essential element of the primary curriculum. However, during the last decade, prior to the introduction of the National Curriculum and the inclusion of science as a core subject, primary teachers have been generally more positive about the importance of science teaching and were evidently becoming convinced of its role within the primary curriculum. The reasons for this, discussed in Chapter 2, include changing government policy and additional financing of science education. In a study of primary teachers' views, elicited just before the introduction of the National Curriculum, there was evidence that the vast majority of teachers thought science should be part of the primary curriculum (Cox and Taylor, 1989, p26). Teachers' own attitudes to science and its place in the curriculum tend to be influenced by their own science
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Figure 4.1: The vicious circle of primary science
based on Raper and Stringer, 1987, p42
Although, it could be argued that, the National Curriculum and changes in the requirements of initial teacher education are likely to 'break the vicious circle' there are still large numbers of primary teachers who were certainly affected by the implications of this model. Teacher attitudes to science in the primary curriculum have changed over the last few years but the success of primary science teaching requires positive attitudes to the subject from all teachers. This is not yet the case.

4.3 Teachers' confidence to teach science

Teachers confidence to teach science will be influenced by a number of factors, including their attitudes towards the subject and upon their perception of the adequacy of their own knowledge base. The evidence in this section draws the Leverhulme Primary Project, directed by Professor Wragg, at Exeter University. It involved a major survey of over 900 primary teachers in the spring of 1989, just before the National Curriculum was introduced. It found that only a third felt confident of their ability to teach science (Wragg et al., 1989a) and widespread anxiety was reported among the remainder in terms of their perception of their lack of scientific knowledge. This compared with 81% who felt confident to teach English and 67% who felt confident to teach mathematics (the other two core subjects of the National Curriculum). Music and Design Technology (sic) were the only subjects primary teachers felt less confident to teach (26% and 14% respectively). When asked about the inservice support they felt they needed, 7% identified the need for "substantial" inservice support in science and over a third wanted an input in science. The survey was clear evidence of "the anxiety that teachers felt about science" (p6). The pattern was the same for Key Stage 1 and 2 teachers although junior teachers were a little more confident about science. There were some gender differences and men generally expressed more feelings of confidence in science than women. Teachers with five years experience or less felt much less competent than their more experienced colleagues in all subjects except science and music. 31% of the less experienced group stated they lacked confidence to teach science compared to 37% of the more experienced group. This, the authors claimed, may reflect the increased time given to
science during initial training in recent years. This is discussed further in Chapter 5. Teachers were asked to rate their competence to deal with specific statements of attainment. Their perceived competence was not only related to the level of the statement since, for example, 76% felt competent to teach a level 5 statement related to the water cycle but only 18% were confident when it came to a level 5 statement about designing simple circuits with microelectronics kits. There was, according to the authors of the report, "a good deal more perceived confidence in certain aspects of this subject (science) than in others" (p7). The research indicated that in 1989, despite quite a marked increase in inservice provision during the previous four years, the majority of primary teachers surveyed did not feel competent in terms of their existing knowledge in science. This survey did not, of course, reflect the extent to which teachers' perceptions of their own knowledge base does not necessarily take account of areas of scientific knowledge they do not know that they do not know about. Nor does it take account of the extent to which the knowledge they have and which leads them to feel confident may be unacceptable in terms of conventional scientific understanding. These issues are addressed by Carre and Carter (1990) who were involved in the Leverhulme Primary Project.

The same team conducted a follow-up survey in the summer of 1991 (Wragg et al., 1991). The same schools were approached and new schools added. The same questions were asked, together with additional questions about the assessment of seven year-olds. Although the return was just under half the number of the first survey the authors claim the two samples were close enough in kind to allow comparison (p10). The results indicated that teachers' confidence to teach science had increased considerably. Science now rated as the third subject in the rank order of competence, behind English and Maths. Over 40% of teachers claimed, in the later survey, to feel competent with their existing knowledge to teach science. The detailed analysis of teachers' rating of individual statements remained similar to the first survey and confirmed teachers perceived confidence with the natural science content ('look after living things' rated 74% in 1989 and 77% in 1991) but more limited confidence with the physical sciences ('understand forces' rated 45% in 1989 and 48% in 1991; 'using power sources rated 36% and 31% and 'use of microelectronics' rated 17% in
This apparent increase in confidence should be regarded with caution according to some commentators (Cox and Taylor, 1989, p70; Kruger et al., 1990e) because of the points raised above about teachers not knowing what they do not know. By the time of this second survey there was evidence (see below) that many primary teachers were still unaware of gaps in their understanding, even in areas such as living things (Lenton and McNeil, 1991).

The Primary School Teachers and Science (PSTS) project (Kruger et al., 1990e), discussed in more detail in the next section, found very mixed reactions amongst primary teachers in terms of their confidence. Some who were forced to face the gaps in their knowledge as a result of interviews with researchers expressed fear and apprehension such as 'I feel I know nothing - totally inadequate ... and in that I feel inadequate to do it (teach science) I would rather walk away from it'.

Smith and Peacock (1992) report the findings of a small-scale enquiry carried out by a teacher, on their DES-funded 20 day science course into the confidence of his colleagues in different areas of science. The order of areas of least confidence to most was, Forces, Energy, Investigating, Electricity, Materials, Earth and Atmosphere, Life and Living. This again reflects perceived teacher confidence in the biological sciences compared to the physical sciences.

Cox and Taylor's earlier study, prior to the National Curriculum, had asked a sample of primary teachers to rate their confidence from 1 to 4 (4 being the lowest) and the mean was 2.51, almost exactly half way between confident and not always confident (Cox and Taylor, 1989, p35). In another pre-National Curriculum survey, Barnes and Shinn-Taylor (1988) surveyed 50 staff in five primary schools in the north-east of England, between 1986 and 1987, to elicit their competence in teaching across the curriculum. Science, together with music, were identified as subjects causing the teachers serious concerns. Over half of the respondents rated their competence in science low and only 20% considered their competence high. This survey found national policies had created "feelings of 'vulnerability' in many teachers" (p291). A large majority of this sample stated that "their own backgrounds had not been 'science-orientated'" and the researchers suggested that a great deal of assistance would be
necessary to improve the teachers' own confidence.

The overall conclusion from these studies is that many teachers lacked confidence to teach science prior to the introduction of the National Curriculum and, despite a variety of initiatives to support teachers, a significant proportion of primary teachers still lack confidence to teach science and implement the National Curriculum.

4.4 Teachers' scientific knowledge base for teaching science

Although evidence has been available, since at least the 1960s, that primary teachers' lack of scientific knowledge is one of the factors affecting the teaching of science in primary schools it is only the last few years that this has been explored by researchers.

The Oxford Science Project, discussed in Chapter 3 (Section 3.8), was one of the first to identify the concern (Redman, 1968). The team found 'misconceptions' were common amongst the primary teachers involved in the project. Because this initiative was small-scale, there is no evidence that it had an influence on national policy since no steps were taken at a national level to address the problem. However, the Oxford team did build support into their ongoing work with teachers. The emphasis of the major primary science initiatives (such as Science 5-13) were, as discussed in Chapter 3, focused upon the processes of science and enquiry approaches. Teachers' scientific knowledge base was therefore not regarded by most policy makers or curriculum developers as a significant issue. No attempt was made, for example, to ensure new entrants to the profession had a science qualification, although qualifications at GCE/GCSE level in mathematics and English have been an entry requirement for many years. However, evidence suggests that many primary teachers do have a science qualification gained from studying science up to the age of 16. This is usually in the biological sciences (DES, 1991b, p5). The Primary Teacher Survey (DES, 1987c) found 28% of teachers had no desirable science qualifications and only 40% of science coordinators had science 'A' Level or above. 28% of schools had no staff with science qualifications above 'O' Level. Beyond the age of 16, few primary teachers have studied chemistry or physics. This is
confirmed by numerous studies into primary science teaching (Barnes and Shinn-Taylor, 1988; Cox and Taylor, 1989). An older survey, thus covering teachers with 10 years experience, found only 8% had followed a 'science' course as a first degree or main subject level in training (APU, 1984a). A more recent, but smaller-scale survey, indicated this figure had not increased by the end of the decade (Bell, 1990).

It was suggested in 1989 at the Association for Science Education Annual Meeting, by the Executive Secretary of the International Council of Associations for Science Education, that this country would have to wait 30 years before the average primary teacher will be able to teach with an adequate background of scientific knowledge and understanding (Kruger et al., 1989).

Another Leverhulme sponsored research project at Exeter, *The Development of Teaching Competence*, and directed by Neville Bennett, examined the knowledge base of PGCE primary students at the beginning and end of their year-long course. The DES and CATE make the assumption that graduate students on a PGCE course already have an adequate knowledge base for teaching. Bennett's study aimed to ascertain students' knowledge and attitudes at entry and assess the extent to which these changed during a PGCE course. They assessed subject matter up to level 6 of the National Curriculum and found, amongst intending early years teachers, a success rate of only 50% in science; even those taking a specialist primary science course only achieved 60% success (Bennett and Carre, 1991). Only a half could show the wiring necessary to light a bulb. Success in biology-based questions was slightly better. The study showed the students held many alternative ideas similar to those elicited from children. A comparison with a national sample of able 11 year olds showed the children out-performing the students in two areas (related to the melting of ice and sound being caused by vibrations). Assessments at the end of the course indicated no significant increase in knowledge although considerable increases in curriculum and pedagogical knowledge were evident. The project team were also looking for evidence that subject knowledge had a positive effect upon teaching competence and found evidence that 'subject knowledge is a vital ingredient in high quality teaching and pupil learning'.
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The HMI survey reported in the late seventies (DES, 1978) and quoted in Chapter 3 (page 102) was one of the first occasions when the issue of primary teachers' scientific knowledge was raised as a priority at a national level. This concern was not, unfortunately, accompanied by any funds to improve the situation until the funding for DES 20-day science courses was announced in 1989 (DES, 1989c). In the intervening years other commentators added weight to the case such as Kerr and Engel (1980) who suggested that ignoring the low level of science training of many primary teachers "is simply escapist". Whittaker (1983) stated that "too little attention has been paid to helping teachers identify their own level of understanding in science". HMI returned to the theme in their reports (DES 1983, 1985a) and Her Majesty's Senior Chief Inspector for Schools reported in 1989 that 'weaknesses in (science) work often stem from teachers' lack of scientific knowledge rather than from difficulties over methods of teaching science' (DES, 1989b, para.10). That report went on to claim that "primary education is critically short of teachers with expertise in science, technology and mathematics" (para.35). It was, however, the demands that the National Curriculum, particularly in terms of assessment (DES, 1988b) which required the government of the day to find a way of dealing with the problem.

The reasons why primary teachers need a firmer scientific knowledge base are not simply related to their skills in assessing children's science. In the past, there has been a view that primary teachers only need to 'keep one step ahead of the children' or can even learn alongside the children (Kruger and Summers, 1988, p264). This fails to recognise the need for primary teachers to "give children experience to guide them along a line of conceptual development". This cannot be achieved without the teacher having some idea of what is at the end. This need is essential for any teacher adopting the constructivist approach outlined in Chapter 2, since a key feature of the approach concerns the teacher's ability to relate the children's existing ideas to accepted scientific ideas in order to make formative decisions about how those existing ideas might be challenged and modified.
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The nature of the subject knowledge needed has been debated recently amongst teacher educators (Bell, 1991; Carter, 1991; Qualter and Schilling, 1991) and has been raised in terms of the National Curriculum levels teachers need in order to teach to a lower level. Others have questioned whether a GCSE pass in science would be adequate. As Smith and Peacock (1992) note, "there is no shortage of evidence that pupils, and their teachers, who have studied to GCSE or beyond may still cling to alternative conceptions which could hinder their teaching" (p57). They go on to state that:

"... it cannot be assumed that teachers simply require a slightly higher level of knowledge across the subject. Different elements of their teaching will need different degrees of understanding of underlying concepts. The mathematical demands of some aspects at a higher level may be quite unhelpful to the teacher. In some topics width of knowledge and awareness of many different representations and explanations are likely to be crucial for teaching rather than a sophisticated scientific language.

This suggests a need to know more about the nature of teachers' existing knowledge and understanding and its implications for their teaching of the National Curriculum.

4.4.1 The Primary School Teachers and Science (PSTS) Project

The first major project to research primary teachers scientific knowledge and understanding was again funded by the Leverhulme Trust and based at the University of Oxford and Westminster College. The project started in 1987 and the team has subsequently researched teachers' understanding in a number of areas of science (including forces, energy and materials in the first phase). The rationale for the project is based upon the changing emphasis in science teaching towards knowledge and understanding (discussed in Chapter 3) brought about by the National Curriculum proposals (Kruger and Summers, 1988). Prior to this study there was little evidence (Lawrenz, 1986; Smith, 1987; Whittaker, 1983) to inform judgments about the nature of support primary teachers might need. An intention of the PSTS project was to develop materials to help primary teachers, based upon their research findings. During the period 1987-88 the team, led by Colin Kruger, Mike Summers and David
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Palacio, carried out a small-scale enquiry using in-depth interview techniques as a preliminary to the second phase when a much larger sample was used to map out the prevalence of particular views and alternative ideas. This was the evidence used to inform decisions about the support material.

Kruger and Summers claim a constructivist view of learning underpins their work (1988, p261) and this is evidenced by the focus of their research being the elicitation of teachers' existing ideas and the recognition of the significance of these ideas to future learning. The extent to which the approach adopted in the support materials is congruent with this view is discussed in Chapter 5.

The first phase of their work involved hour-long interviews with an opportunity sample of 20 teachers from three LEAs focusing upon materials, energy and forces. The choice of content and, in particular, the absence of biological science from the list was based upon evidence that the physical sciences pose more problems for primary teachers than the biological areas (Solomon and Palacio, 1988; Whittaker, 1983). It should be noted, however, that biological sciences were covered in a later phase (Pendlington, 1993). The researchers used 'interview-about-instances' (Osborne and Gilbert, 1980a) and 'interviews-about-events' (Osborne and Gilbert, 1980b). These were all based on everyday experiences, such as a ball in flight, and some of the materials used for these interviews have been used in the current research (see Case Studies 6 and 7). The findings of the exploratory phase have been extensively reported (Kruger, Palacio and Summers, 1990a, b, c and d; Kruger and Summers, 1989; Summers, 1990; 1991) and provide evidence of the range of common alternative ideas held by primary teachers. They clearly indicate that primary teachers knowledge base in science is not sound in the areas covered (Kruger and Summers, 1988, p263). Interestingly, although perhaps not surprising in the context of primary teachers having limited formal science teaching, the alternative ideas held by primary teachers showed features of those held by children and reported by others (Cosgrove and Osborne, 1981; Watts, 1983a and b) such as anthropomorphic and animistic views, 'depository' models of energy, motive forces and continuous rather than particulate view of the structure of materials. Teachers' ideas were
more varied and complex than children's, although in some cases the interviewees admitted that they simply did not know, having not thought about the particular phenomena until asked. Many teachers showed considerable uncertainty when questioned about their beliefs and were dissatisfied with the coherence of their answers. This contrasts with findings that young learners are not usually concerned with the need to have coherent and non-contradictory explanations (Osborne, Bell and Gilbert, 1983). Teachers showed a strong desire for better understanding. The interviews also provided evidence of teachers modifying their ideas in the light of questioning, showing the 'dynamic' nature of their understanding.

Kruger and Summers (1988) identified four types of primary teachers as a result of analysing responses to the interviews:

i. Teachers whose understanding of the concepts was necessarily based upon 'life-world' beliefs (Solomon, 1983b, 1992a). These were the group who had received little formal science education and were relying upon common-sense and intuitive explanations which were often vague and inconsistent.

ii. Teachers who had been exposed to formal models and theories during schooling but were unable to use them appropriately to offer explanations. They sometimes used the language of science but offered explanations that drew upon 'life-world' knowledge and half-remembered, incorrectly understood 'symbolic-world' knowledge from school. This group were often aware of inconsistent explanations, but usually resorted to half-understood scientific explanations or confessed that they could not offer a coherent explanation.

iii. A similar group to type (ii) but more likely to opt for a 'life-world' explanation. Their grasp of symbolic-knowledge was less firm and they provided evidence of the tenacity of their intuitive ideas and the resistance to change of those ideas. This mirrors similar findings related to children's ideas (Chapter 2, Section, 2.7).
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iv. Teachers who were able to give explanations that were almost congruent with accepted scientific understanding, in terms of the conventions of science. In the pilot stage, only one primary teacher fitted this type.

The first phase of the PSTS project therefore provided significant evidence to support the generally agreed proposition that primary teachers lack adequate knowledge and understanding in science. But more importantly it began to provide insights into the nature of primary teachers' 'conceptual difficulties' (Kruger and Summers, 1988, p263). Although, as discussed in Chapter 2, plenty of evidence has been collected related to children's alternative ideas, this project provided evidence of adults' ideas and in some areas (for example, the addition of forces) there were significant differences (op. cit., p264; Kruger et al., 1990a).

The second research phase of the project, or prevalence phase, was designed to extend the work to a larger sample of primary teachers using a survey questionnaire (Kruger et al., 1990a, p45). The same situations used in the interviews were illustrated together with a number of statements, that the smaller sample of teachers had made during the interview phase, with at least one scientifically acceptable statement. For each statement the teachers surveyed had to make one of four responses; true, false, don't understand or not sure. The forces questionnaire was administered in person to an opportunity sample of 159 teachers from three LEAs. The sample was predominantly female (80%) with teaching experience ranging from 1 to 40 years. This phase, which in total involved over 500 teachers, allowed the research team to evaluate the prevalence of various alternative ideas amongst teachers and generally the results confirmed the evidence elicited from the interviews. For example, 110 out of the 159 surveyed about forces affirmed that a moving car (without its engine running) has its own force, in the direction of movement, once it is moving. This 'impetus' notion (Cosgrove and Osborne, 1981; Fischbein et al., 1988; McCloskey, 1983) was evidenced amongst teachers involved in the current study. The results are documented in Working Papers 8-10 (Kruger et al., 1988-91). Reference to particular findings will be made later in relation to my research.
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As a result of this research the PSTS team went on to develop INSET materials designed to help primary teachers move towards more accepted scientific understanding, for example, in the area of forces to move towards the Newtonian paradigm. This material is discussed in Chapter 5, Section 5.7.

4.4.2 Children and Teachers Talking Science (CHATTS) Project.

Another project addressing primary teachers’ scientific knowledge base is the CHATTS project based at the University of London Institute of Education and coordinated by Katherine Hann, Tim Brosan and Jon Ogborn during 1990-92. It aimed to find out how primary teachers made sense of and used the science information available to them in the media. The team adopted an explicit constructivist view of adult learning (CHATTS, 1992, p4) claiming,

This stance, justifiable on psychological grounds, is also in the present case the only realistic one. Primary school teachers have no option but to interpret new scientific ideas in a framework of received common understandings, both because of their own backgrounds and because of their obligation to find ways of talking to young children about them.

The project involved small group discussions with primary teachers to help them understand some of the key scientific concepts behind issues that might be covered in scientific or cross-curricular topic work, such as global warming, genetic engineering and food safety. The approach was intended to help teachers clarify their understanding and not an attempt to systematically elicit and analyse the prevalence of particular ideas. Support materials were provided and the project team talked to primary children to collect examples of children’s ideas in the areas the teachers were tackling. During discussion sessions these ideas were discussed by the teachers who were asked to think about appropriate activities for developing the children’s understanding.

The project involved ‘assessment’ of primary teachers understanding of science but rejected the use of more traditional test items (CHATTS, 1992, p3) since, the team argued, drawing
upon the early work of Layton et al. (1986), such a methodology would be, "unlikely to allow members of the public (sic) to display their potential competence". They argued that more conventional approaches to assessing scientific knowledge and understanding would,

...in effect, only represent the public - questioned in a framework to which they are not a party - as 'incompetent scientists', having knowledge which, judged in that framework, can only appear as deficient or deformed. It also takes understanding of science out of any context of use.

They go on to criticise others, including the PSTS team, for adopting such a 'snapshot' approach. Although this criticism is valid in terms of 'topical' contexts and relevance, the PSTS team did ensure all of the elicitation activities they used were based upon everyday contexts to which the teachers could relate. The significant difference is that the CHATTS approach focused upon scientific topics that teachers found more interesting and had a greater motivation to understand since they had direct and immediate relevance to their everyday lives (for example compare CHATTS topic of 'Food Safety' with a PSTS elicitation activity on 'a large rock being moved'). The CHATTS methodology involved group discussions which reinforced the social construction of scientific knowledge whereas the PSTS team worked with individuals during the interview and prevalence phases. In summary, the CHATTS research tried to "avoid treating primary school teachers as merely incompetent in science, asking instead how their natural, actual professional discourse can engage in scientific thinking" (CHATTS, 1992, p4).

The main findings of CHATTS were:

i. Primary teachers can gain confidence and understanding by discussing science seen on TV and in print;
ii. Science is understood through constructing pictures, images and analogies;
iii. Common-sense thinking is a powerful and profound way of getting to grips with these 'pictures';
iv. People get an overall idea about how things work, which fits with other things
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they know;

v. They clarify what is not understood, giving a path to further understanding

The CHATTS approach has much in common with aspects of the model evaluated during this research and will be returned to in a later chapter. The project, like PSTS, found mixed levels of confidence amongst the teachers involved, that common alternative ideas were evident and that teachers generally had a desire to improve their scientific knowledge base.

Evidence is now available to inform INSET providers about the nature of primary teachers' scientific knowledge and understanding and this evidence has been used throughout the implementation phase of this research as will be discussed in the later review sections.

4.5 Teachers' scientific process skills

Linked to primary teachers' lack of scientific knowledge and understanding is their lack of experience of engaging in the processes of science and using scientific skills. The evidence above suggests that many primary teachers' own science education was not particularly extensive, broad and balanced or positively evaluated by them. Anecdotal evidence and that of others (Cox and Taylor, 1989; Crompton, 1991; Whittaker, 1983) would suggest few experienced primary teachers have themselves been offered a science curriculum that included a balance between content and process. My own anecdotal evidence indicates that few recollections of their own school science from teachers on INSET (or indeed, students on initial teacher education courses) have provided evidence of science processes being experienced. No doubt, the science education they received did include 'practical' elements but their memory of their school-days is usually exclusively of science as a body of (often difficult) knowledge to be learnt and remembered. This has implications for the teachers' competence to teach science in the way it is defined in the National Curriculum. It has already been claimed it is difficult, if not impossible, to teach and assess knowledge and understanding that teachers do not themselves have. Similarly, it can be claimed that supporting children in the appropriate use of scientific process skills is equally difficult if the
teachers have not, themselves, developed the use of those skills or do not recognise
science as involving the development of knowledge and understanding through the
application of appropriate process(es). It has been difficult to find evidence of previous
research in this area and the claim is therefore based on anecdotal evidence collected during
Inservice work and my role as an advisory teacher. The implications of this are addressed in the
teaching approach being adopted, where developing teachers' skills in the processes of
science are emphasises, alongside, and inextricably linked to the development of scientific
knowledge and understanding.

This factor, of teachers' scientific process skills is closely linked with the next to be
considered.

4.6 Teachers' understanding of the nature of science.

Although the discussion to date has concentrated on teachers' knowledge and
understanding of scientific concepts and processes there are related areas of understanding
about the nature of science. Cox and Taylor's study (1989) found primary teachers unsure
about the nature of science, and aware that their knowledge in this area is insecure, although
they were usually clearer about the part which science plays generally in society. The
researchers grouped responses in terms of statements regarded as 'hard' science (as
objective truth), 'soft' science (more tentative view of knowledge) and science as socially
constructed. No statements were rated high (using a scale 1 (strongly agree) to 4 (strongly
disagree)). The mean for 'hard' science was lowest indicating most teachers held a view of
science as objective truth whereas statements related to science as socially created received
the highest means (and were therefore least in line with the teachers' opinions).

The CHATTS approach, discussed above, provides one example of work with primary
teachers which is encouraging them to appreciate a different view of science and in those
discussions with teachers emphasis was placed upon the social construction of tentative
knowledge and the need to question the validity of scientists' claims. The view of science
which underpins this research, discussed in Chapter 1, is similar and the approach adopted has attempted to reinforce this view in teachers.

Teachers’ awareness of science as an activity that takes place and is influenced by the social context in which it occurs is key to this. The significance of the social context for school science has been well documented and the work of Joan Solomon is particularly influential (see for example, 1983a and b; 1987; 1988; 1989; 1992a & b). Her numerous studies have explored the significance of dialogue and group work upon learning in science. She has done less work on adult learners although her most recent work (Solomon, 1992a) is an in depth study of learning in the content area of energy for pupils and adult learners. She explores two domains of knowledge, ‘life-world’ and ‘abstract academic’ and the extent to which the first influences the second. She allies herself more closely with social constructivists than with those placing more emphasis of the individual construction of meaning and the significance of learners alternative frameworks:

If the meanings and notions in the social stock of knowledge need to be continually reinforced, then social consensus becomes of the highest importance. Consensus-building is a process which might completely by-pass cognitive structures. Agreement, and not preconscious cognitive development, would be the more valued commodity. Indeed, there would be little point in intellectual advancement if it made taking part in ordinary social converse, with its medley of context-bound and inconsistent meanings, almost impossible.

Solomon, 1992a, p75

The literature on adults’ views on the nature of science is also limited. In an study into the public understanding of science (Durant, Evans and Thomas, 1989) respondents were asked which method should be used to tackle a scientific question in two different contexts. In the first the context was medical - which of two medicines should be used for treating blood pressure. The second involved deciding which metal to use for a special purpose. The ‘processes’ were: ask for opinions; use own knowledge; do an experiment and no answer. The medical context resulted in 45% opting for an experiment whilst 30% suggested using their own knowledge. In the metal context the response was the opposite - only 30% for
experimentation and 45% for using own knowledge. The authors conclude that "medicine is the paradigm for science" in the public consciousness and scientific methods are seen by many to have limited fields of application. It is likely that some primary teachers share this restricted view of science.

Solomon reports another study, this time with 11-14 year olds, which revealed that about 50% of them believe scientists have no expectation about what the experimental result will be before they carry it out. The scientific process is reduced to 'a shot in the dark affair' (Solomon, 1992a, p86). In Durant’s survey similar results with adults revealed only 3% seeing science as theory building and hypothesis testing; 11% saw science as experimentation without reference to theory and 43% regarded it as fact-gathering. The rest of the sample admitted to not knowing. Solomon’s review of the literature (1992a) concludes that "scientific process is something of a closed book to both school child and general public" (p86). It is therefore likely that many primary teachers, with limited science education, also have a fairly limited view of the nature of science. This will influence their approach to teaching science.

The inclusion of AT 17 (the Nature of Science) in the original National Curriculum proposals (see Chapter 3) would, in the longer term, have ensured all new primary teachers had a greater awareness of this, and the original Non-Statutory Guidance had a section on AT17 which, although it did not apply to Key Stages 1 & 2, was available to primary teachers and that section was used on INSET (in my personal experience). Its removal from the later orders was not universally welcomed within the science education community (Boyle, 1992).

Frost and Turner (1987) discuss the implications that the ‘model of science’ teachers hold has upon the success of INSET. During the DES 35-day courses described the teachers invariably held a view of science knowledge as ‘true’ and that ‘scientific tests gave precise and quick answers’. Changing this view proved problematic.

Primary teachers’ views of the nature of science in primary schools were elicited by the PSTS team. In the interview phase of their study they asked teachers about the relative importance of the learning of content (facts and ideas) as opposed to the learning of processes. They
found 70% thought processes more important, 5% opted for content and 25% thought both equally important (Kruger et al., 1990c, p137). This indicates that even after the introduction of the National Curriculum Orders in which skills and knowledge and understanding were given equal weighting primary teachers still retained the 'process' view of science discussed in Chapter 3.

Lack of understanding of the nature of science are unlikely to affect primary teachers' perceived confidence to teach science, although it might be argued that having a more 'human' view of science, as socially-constructed provisional knowledge gained through the use of investigative processes, might improve their confidence. The importance of this is addressed later in terms of the view of science encouraged by the teaching approach evaluated through this research.

4.7 Teachers' professional knowledge base and professional skills

Teachers' competence to teach science is not solely dependent upon their subject knowledge base. There are other aspects of professional knowledge that must be taken into account, such as general pedagogical knowledge, curriculum knowledge and an understanding of learning in the subject area. Teachers require professional skills to plan, implement and evaluate classroom work. Linked to the implementation of classroom work are the skills needed to assess individual children and respond to their individual needs. These aspects of the primary teacher's role have been discussed in more detail by me elsewhere (Ritchie, 1990b, p169), but some aspects are outlined here to provide a full picture of the factors affecting the teaching of science.

Chapter 3 outlined a variety of initiatives, since the sixties, which have encouraged and supported primary teachers in adopting enquiry and active-learning approaches to science. However, the failure of these initiatives to have had a significant impact on teachers' approaches to classroom work (see page 100) suggests that the task of implementing practical science activities in primary classrooms is proving too difficult for many teachers, even
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if they are convinced of its value. My own anecdotal evidence and the experience of others
(Harlen, 1992; IPSE, 1988a, Raper and Stringer, 1987) indicates that questions and concerns
related to organisation of the classroom and the management of children, especially in terms
of group work, are the ones most frequently raised by teachers during Inservice activities.
Sound and practical guidance in these areas has been available for teachers (Harlen, 1985a &
b, Raper and Stringer, 1987, Jarvis, 1991), but making use of the suggestions is difficult,
even when supported by more confident colleagues, or advisory teachers, as an NFER
evaluation of primary science INSET found (Kinder and Harland, 1991).

The practical difficulties primary teachers face in implementing practical science activities have
been compounded by the contradictory pressures they have been put under over the last
twenty years. Although the curriculum developers, advisory staff and to some extent HMI
have been encouraging more active learning (be it 'discovery' learning; 'enquiry'; 'problem
solving' (Pocock, 1990) or 'constructive' learning (Harlen, 1992, p44)) there has been
pressure from politicians and right-wing educationalists to adopt more didactic, teacher-
centred rather than child-centred approaches. The Alexander Report (DES, 1992a) added to
this pressure by questioning primary teachers' 'taken-for-granted' values such as the
importance of child-centred approaches, group work and integrated cross-curriculum topic-
work. The swing towards 'process' approaches to science have also been challenged by
science educationalists who have argued that a more balanced approach to process and
content needs to be achieved (Wellington, 1989).

These pressures and contradictory advice may have discouraged some from making the
necessary professional commitment to changing their approach to teaching science. The
introduction of the National Curriculum has not changed this situation since, although it
ensures a common curriculum is covered, it does not tell teachers how they should teach and
therefore no consensus exists about the 'right' way to teach science, and teachers continue
to struggle to implement the National Curriculum within a context of contradictory advice and
pressures.
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Discovery learning, advocated by Plowden, and influential in much initial and inservice teacher education in the sixties and seventies has been much criticised in the context of science education (Brown, 1986, p121; Driver, 1983, p8; Qualter et al., 1990, p10; Wellington, 1989, p50) but still features in the strategies used by primary teachers in science (Harlen, 1992). Indeed, Kinder and Harland provide evidence that it was a 'message' teachers were still receiving from advisory teachers in the late eighties (Kinder and Harland, 1991, p157). Enquiry learning and problem solving approaches have similarly been criticised. The constructivist view is the new 'paradigm' in which most science educationalists are operating, although there is limited evidence, in the literature, that it is being used explicitly by primary teachers. However, it too has its critics (Solomon, 1992a). It is hardly surprising that primary teachers, trying to deliver the whole of the National Curriculum, are reluctant to make demanding changes to existing practice; a situation predicted accurately by Day (1988) (see page 109).

The result is that some teachers, who have been able to take on the 'process' approach to science, perhaps as a result of previous INSET, are reluctant to engage with the concepts (as evidenced in the Primary Science Teaching Action Research Project (STAR) (Russell et al., 1992, p76). Others have retained the teacher-centred approach (Cox and Taylor, 1989, p166) (previously observed by Bennett et al. (1984) and Barker-Lunn (1984)) that they are most comfortable using; others have adopted a more didactic approach than they would with other subjects because they are unfamiliar with the science area involved (Cronin-Jones, 1991). In that study several teachers reported that they were reluctant to embark on practical science because they did not know where to start; others described lessons as consisting of isolated, unrelated science ‘investigations’ and a few explained that lessons were dominated by worksheets.

The majority of primary science INSET prior to the National Curriculum, including DES-funded 35-day courses and advisory-teacher initiated support, focused upon ‘process’ science, and the implementation of practical classroom activities. This emphasis is reported by IPSE (1988a) and Kinder and Harland (1991). However, in some cases the results of these courses
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seem to have been to provide teachers with the vocabulary and insights to allow them to espouse theories about the nature of 'their' science teaching which is not matched by observation of 'theories-in-action' or what actually goes on in their classrooms (Cox and Taylor, 1989).

It should be noted that some educationalists recognise the enormous difficulties teachers face in implementing a science curriculum which comprises of both processes and knowledge and understanding. Claxton (1991) claims that what is being asked of teachers in terms of science is 'extremely difficult, if not impossible' and Peacock (1992) reports that this view of the curriculum is "out of step with several European countries whose economies are arguably more successful than ours, and in step with many African countries who after two decades or more of promoting process science are as yet not reaping any observable benefits" (p25).

On the other hand, many teachers have approached the implementation of the National Curriculum positively and have had the professional competence necessary to organise and manage the work in their classrooms effectively. Educational journals such as Child Education, Junior Education, Questions and Primary Science Review have all provided many examples of teachers making the National Curriculum work and delivering a science curriculum that reflects both processes and knowledge and understanding.

Another feature of the Leverhulme Primary Project at Exeter was the collection of detailed case studies showing how teachers were implementing the National Curriculum. Kennedy (1991) reports on a set of these concerning the teaching of electricity. Ten volunteer teachers were asked to teach four 'statements of attainment' from AT 11 and AT 12 in the 1989 Orders (DES, 1989a) to pupils between the ages of 7 and 11 in any way they chose. It should be noted, however, that many would cite such an assessment-led approach to teaching as inappropriate (DES, 1991a; Harlen, 1992). Despite this the research is of interest. All of the volunteers felt their background in science was weak, making them representative of the majority of teachers who took part in the larger survey. The data collected provides a valuable insight into primary teachers' approach to science, if unsupported in any way. The constraints
identified by the teachers prior to the work were: lack of equipment; inadequate books and work-cards and lack of teacher knowledge. None cited concern over teaching style or management. The first of these proved a major problem and the research team ended up providing ‘kits’ even though the LEA had previously provided resources and INSET in electricity for all its schools! Almost all of the teachers used books either to learn about electricity themselves, to plan a scheme of work or to use with the pupils. Many of the teachers spent a long time on their own using the equipment and books but found this unsupported self-directed study “time-consuming, inefficient in terms of learning outcomes and extremely frustrating and stressful” (p156). Other problems arose including major difficulties of interpreting some statements of attainment. It was also only when they started teaching that they became aware of the full extent of the shortcomings in their own knowledge. They found pupils’ questions very difficult to deal with. They had difficulties with appropriate use of language, lacking confidence to use words like “current” and “flow”. Encouragingly, although some claimed this was their 'first experience of teaching science', they all reported that the pupils had had fun and all but one reported that they (the teachers) had enjoyed the experience. There is evidence, however, that their attempts to teach were not successful in terms of adequately covering the areas intended. In these case studies classroom management did not cause too much concern and the teachers generally worked with groups - a strategy with which they were familiar. However, none of the teachers were able to get support from colleagues (particularly the science coordinator) that they needed.

It is obvious that 'good' science is not simply a question of organising practical work in the classroom. The nature of that practical experience is significant. For example, HMI found during visits to schools in 1989-90 that Key Stage 1 teachers gave a high priority to the development of observation and communication skills but placed much less emphasis on other scientific skills and processes (DES, 1991a). Newton (1992) reports a similar concern about the nature of the practical work indicating a lack of awareness amongst teachers of the differences between demonstrative or illustrative activities and investigative activities. The latter providing much more potential for developing process skills other than observation and communication. The demonstrative-type of activity was much more common in his (and my)
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experience.

Another common criterion for 'good' science is to make the work relevant to the learner (IPSE, 1988a, pA1; DES, 1985a). Newton's study of 50 teachers (1992) found relevance to be prioritised in much of the Key Stage 1 teachers' work but it was less common in Key Stage 2 activities (particularly in areas like energy and forces). Newton suggests this may be due to the teachers lack of scientific knowledge and ability to see appropriate links with everyday experiences. His study raised more general concerns about teachers' professional skills and knowledge,

There is evidence that science as a way of working and as defined by the National Curriculum, is not well-understood amongst some primary school teachers. This seems to be compounded by a lack of awareness of the functions of the practical activity.

Newton found very limited use of published schemes and resources for science work and this contrasts with the extensive use made of schemes in English and Mathematics. He advocated the use of published materials as one strategy that is under-used by teachers to support their scientific work.

Two projects based at the University of Liverpool, Science Teacher Action Research (STAR) (Cavendish et al., 1990; Russell and Harlen, 1990; Schilling et al., 1990) and Science Processes and Concept Exploration (SPACE, 1990-92) both involved developing primary teachers' professional competence and provide excellent case study material of the implications of this. The first focused upon teachers' competence to develop children's process skills and used collaborative action research as a means of facilitating this. The latter, as its title suggests, and as was discussed in the last chapter, addresses teachers' competence to develop children's scientific knowledge and understanding. The approach is explicitly constructivist and teachers were helped to develop skills to orientate children to science work, to use strategies to elicit existing ideas and then supported in designing
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practical activities to challenge those ideas through teacher intervention. The research team assessed changes in the children's conceptual development as a result of these interventions and found teachers having some success in getting children to restructure alternative ideas. The reports included a wealth of practical material about elicitation and intervention strategies which were drawn upon during the DES 20-day Course. They also provide primary teachers with the first extensive source of information about the common alternative ideas their children may hold.

The implementation of the National Curriculum has required primary teachers to develop a range of professional skills that many did not have prior to its implementation (Ritchie, 1990b). The Leverhulme study (Wragg et al., 1989a and b) discussed in an earlier section also asked teachers to rate their competence in the professional skills needed to implement the National Curriculum. Amongst the most difficult skills, according to the teachers surveyed, were diagnosis of learning difficulties (69%), assessment of children's work (57%). My own work, with the National Primary Centre (SW) Project on Constructive Teacher Assessment (Ollerenshaw et al., 1991) provides an example of support offered to teachers in this area.

Planning for individual children, for groups and for a whole class has become necessary to ensure Programmes of Study are covered. However, the National Curriculum has also required teachers to plan more collaboratively, to develop schemes of work and to plan on a whole-school basis to ensure continuity for learners. This has added to the burden upon teachers and required the development of other professionally-related skills. Linked to planning has been the issue of whether science should be taught as a separate subject or integrated into a topic. The latter has been the common view until recently (County of Avon, 1989; IPSE, 1988a; Kinder and Harland, 1991) but there is an increasing pressure upon primary teachers to teach science as a separate subject (DES, 1992a). This pressure becomes more evident after the data-collection phase of this research was completed and is only relevant in a retrospective way to the present study.

A recent book which I co-authored (Ollerenshaw and Ritchie, 1993) explores issues related to
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planning and implementing science in the classrooms and offers teachers a rationale for a constructivist approach. It draws upon case-studies of classroom work, some of which resulted from work linked to this research, to illustrate the practical implications of implementing such an approach. The reader is invited to refer to this text for further discussion of the professional skills required by a teacher. It is an attempt to support an approach to primary science which brings together science processes and knowledge and understanding.

4.8 Other factors affecting the teaching of science in primary schools

The successful implementation of primary science has been affected by other factors which are, in some respects, outside of the control of individual teachers. Resource implications have been cited as reasons for primary schools not implementing science with the enthusiasm anticipated by educationalists and curriculum developers (Carre and Carter, 1990). These are evident in terms of equipment and materials needed for science, although the basic requirements are not particularly demanding on school budgets (Ritchie, 1990b, p172; County of Avon, 1989) and there is evidence that the provision of resources will not, on its own, ensure the implementation of science (Kinder and Harland, 1991, p134). The constraints imposed by classroom size, lack of water, lack of storage space and suitable work-surfaces are all relevant and have, in my experience, been cited as reasons for the implementation of science not being as successful as hoped by the individual teacher involved. However, my own anecdotal evidence from teachers on inservice courses suggests that when motivated teachers do find ways of overcoming these problems.

If teachers are regarded as resources then the availability of time for collaborative work, particularly in terms of a coordinator working with a less-confident colleague, has been seen to be significant in terms of changing practice (Cavendish et al., 1990, p69; Ollerenshaw and Ritchie, 1993, Chapter 8). Again, however, creative use of time within schools can be used to free teachers to work collaboratively (Ollerenshaw and Ritchie, 1993, p202). Advisory teachers provided another means of providing support for teachers in their own classrooms.
which proved a successful way of changing practice (Harland, 1990; IPSE, 1988a), but changed funding arrangements over the last two years have led to a significant reduction in the numbers of advisory teachers in post (see Chapter 3, Section 3.16)

A more general issue related to resourcing is the issue of class-size (chosen by 45% of primary teachers in the Leverhulme Primary Project as a major constraint (Carre and Carter, 1990, p337)) . The difficulties cited in terms of organising science in the primary classroom are often referred to in terms of the size of the class - What do I do with the other 30? (Ollerenshaw and Ritchie, 1993, Chapter 2). A reduction in class-size would probably make the implementation of science more manageable, but in the present economic climate is not a realistic consideration worthy of more attention in this study. However, the issue of whether the use of a specialist science teacher would be preferable to the generalist class teacher will be considered later.

Pressures on teachers to ‘deliver’ an over-loaded curriculum can lead to subjects that teachers find more difficult, like science, being ‘squeezed out’. HMI reports indicate that few teachers are giving science the same proportion of time allocated the other core subjects of English and mathematics (DES, 1991a). This is hardly surprising given the emphasis traditionally placed on the 3Rs and the pressures from some politicians, parents and governors to ‘return to basics’ (DES, 1992a). However, the National Curriculum includes science as a core subject and there is an argument that it should be given the same emphasis as the others. Of even greater concern is anecdotal evidence from initial teacher education students returning from block school experiences with accounts of observing very little science in many classrooms during the four weeks they were in schools in November 1992.

4.9 Conclusions

Primary teachers have, in many cases and unsurprisingly, found the implementation of primary science, particularly in the context of the National Curriculum, difficult. The National Curriculum Orders provided primary teachers with a model of the curriculum which requires the processes
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and skills of science to be balanced with scientific knowledge and understanding in terms of pupils’ learning. Implementing a curriculum of this nature requires a different approach to classroom activities and teaching strategies to those which had been previously advocated by educationalists such as curriculum developers, Inservice trainers and advisory staff. The investment of time, energy and financial support which was made to support primary teachers in teaching science in a way which emphasised processes and skills has provided a context in which primary teachers are now aware of the importance of science and the significance of practical activities. However, the difficulties many found in adopting such approaches have inevitably affected their confidence for teaching National Curriculum science. The requirements of the National Curriculum make new and different demands upon teachers. The previous reassurance that primary teachers did not need to have a scientific knowledge base because ‘it wasn’t what you taught it was the way you taught it’ is no longer appropriate and primary teachers are well aware of this. Lack of confidence amongst primary teachers in the context of the National Curriculum relates to their concerns about their own knowledge base as well as their concerns about pedagogical issues; the nature of children’s learning and more pragmatic concerns about how to assess and record children’s progress in science.

There are therefore a variety of factors that need to be addressed by inservice and initial teacher education if the situation is to improve. The current research evaluates one approach that is intended to change teachers’ attitudes to science and to improve their confidence to teach science by helping them develop their scientific and professional knowledge, understanding and skills. This chapter provided evidence of why this continues to be necessary. The next will explore the ways in which initial teacher education and inservice teacher education have addressed teachers’ needs in terms of science in order to contextualise the work in which I engaged.
Chapter 5 - Initial and inservice education of primary teachers

5.1 Introduction

This chapter begins with a brief discussion of the relationship between initial teacher education and inservice education. The nature of science education within initial teacher education is then addressed. The next section considers the developments in primary science inservice education and the key features and issues evident. It should be noted that the term 'education' is preferred to 'training' when discussing both initial and inservice activities by the author, although official documents consistently refer to 'training'. 'Education' has a broader meaning, more consonant with the concept of 'professional development' than 'training' which implies the learning of 'skills' or a craft. The term 'training' will therefore only be used when referring to official documents, pronouncements and reports.

It is appropriate to see initial teacher education and inservice education as a continuum. This view was expressed by HMI some years ago,

The training of a teacher is a complex undertaking, and one that should be seen as a continuous process occupying the full span of professional life.... The teacher (on qualification) is only at the beginning of what should be a process of continual professional growth and renewal, with induction into the profession followed by a pattern of inservice training (INSET) across the years.

DES, 1985b, p2

The competencies achieved during the time students gain 'qualified teacher status' are the same competencies which need developing during teachers' later professional work. In a climate of constant change, such as that created by the Education Reform Act (DES, 1988a), it becomes even more likely that competencies appropriate in initial teacher education (ITE) will be equally appropriate in inservice education for teachers (INSET). For example, the implementation of the National Curriculum for Science meant that additional emphasis needed to be placed on ITE students' background knowledge and understanding and upon the assessment skills needed by teachers (DES, 1991b). The same priorities were necessary
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In INSET to address the needs of qualified teachers who also lack an adequate knowledge base, or who have limited experience of assessment. Consequently those involved in both initial teacher education and inservice education can develop strategies and materials that can be used in both contexts.

My research has involved work with ITE students and inservice teachers. The collection of data with BEd students occurred during the exploratory phase of the research. The main data-collection phase involved work with teachers on inservice courses. In both contexts I consider the aims and intentions to be similar enough to allow evidence and insights from one to inform decisions in another. The 'students' involved are similar in that:

i. they are adult learners, often of a similar age (25% of the BEd group are 'mature' students;

ii. many lack any qualifications in science;

iii. all lack adequate background knowledge and understanding in science and in most cases are aware of this;

iv. most lack an understanding of the nature of science;

v. many lack confidence to teach science;

vi. most have limited experience of teaching science.

The contexts for teaching the 'students' are similar in the following ways:

i. teaching is with groups of 12-18;

ii. teaching is in the same or very similar accommodation;

iii. the same resources are used;

iv. the work with the group is 'substantive' and on-going;

v. the gender mix is similar (predominantly women);

vi. the content covered is the same;

vii. the groups are 'mixed' ability and differentiation is necessary.
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There are differences which have to be taken into account:

i. ITE students have less experience of classroom work to draw upon;
ii. teachers can implement new ideas in their classrooms immediately, whereas ITE students must wait until their next block school experience;
iii. ITE students are usually more optimistic about the likely success of new approaches, having had less experience of unsuccessful 'innovation' than teachers;
iv. length of sessions (2 hours for BEd and whole-days for INSET) and time-scale of contact (over a term for BEd and a year for INSET).

These factors will be considered during later discussion of case study material. However, the next sections focus upon developments in science in both contexts.

5.2 Place of science in initial teacher education

This section concentrates upon BEd as opposed to PGCE courses. Both provide routes for primary teachers to enter the profession but the work carried out for this research was with BEd students and these students outnumber PGCE students approximately 15 to 1 in the college. Over the last four years the vast majority of my ITE teaching has been with BEd students.

Prior to 1979 the majority of primary teachers leaving non-university institutions completed a three-year certificate course for which there was no A-level requirement. Only a small minority remained for a fourth year and gained a Bachelor of Education (BEd) degree. However, in 1972 the government declared its intention for an all-graduate entry to teaching (DES, 1972)
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and over the following years there was a rapid expansion in the number of BEd courses. The final intake of sub-degree certificates occurred in 1979. In that year 88% of institutions offered a three-year BEd unclassified degree with the opportunity of a four-year honours degree for suitable students. By 1985, 70% of institutions had phased out the unclassified degree and were recruiting for the four-year honours degree only (DES, 1985b, p8).

The place of the 'curriculum' (as opposed to 'main subject') science in the certificate and early BEd degree courses was left to the discretion of the academic boards of the individual institutions since no national regulations existed covering science. In some courses it was a compulsory element but in the majority it was optional or non-existent. A survey carried out in 1981 of 655 teachers in Derbyshire found 257 had no curriculum science in their initial teacher education. Of those who had, 187 said it was adequate, 205 found it inadequate, complaining specifically that it was too content-orientated with a secondary bias and lacking relevance to primary education (Whittaker, 1983, p252). A report by HMI in 1985 (DES, 1985b) covered surveys of Initial Teacher Training Institutions in the period from January 1983 to January 1985. The report contained much positive comment about BEd courses generally, but the curriculum science provision was cause for concern. Although HMI found most institutions now provided science as part of a compulsory core the time allocation varied widely across institutions and in one instance was 12 hours in any year of the course (p150). The 'process' emphasis of the seventies and early eighties (discussed in Chapter 3) was becoming evident in courses, in contrast to the 'content' emphasis reported above, perhaps indicating a significant shift. However, HMI reported tutors were well qualified academically, but lacking appropriate primary experience. The standard of tuition observed was generally good but, "occasionally suffered from the inclusion of unwarranted aspects of secondary science". They were also critical of the lack of integration of the science courses with other curriculum components. The approach evident usually involved students trying out "simple practical activities so as to judge for themselves the efficacy of the aids or instructions". Accommodation was criticised since much of the work took place in general-purpose rooms or laboratories rather than "well-furnished primary bases which afforded realistic environments
to prepare students for the working conditions of a primary school" (p151).

Subject knowledge was also discussed;

For students who were not science specialists the time available, even in a four-year course, was seldom enough to overcome the inhibiting ignorance of subject matter. Though there was some good teaching during school practices, many students retained an understandable anxiety about their own knowledge and competence in science and this reduced their effectiveness in the classroom.

In 1984, during the period of this survey, a Council for the Accreditation of Teacher Education (CATE) was established by the Government to advice the Secretary of State on the approval of initial teacher training courses (DES, 1984d). This was the subject of DES Circular 3/84, the annex to which set out in detail the criteria to be observed by CATE when preparing recommendations. This specified that courses should involve at least the equivalent of two years' subject study. HMI's evidence was that in most institutions this was not the case (DES, 1985b, p25). They found about 10% of students doing subject studies in science, a percentage that has remained constant into the nineties (DES, 1991b). Circular 3/84 also specified minimum hours for curriculum maths and English, but made no specification about science. It also required all applicants to ITE to have a qualification in maths and English (GCSE or 'O' Level).

The concern about students' background knowledge in science was highlighted in HM Senior Chief Inspectors' Annual Report covering 1987-88 (1989b). A positive section about achievements in ITT includes, "the main exception remains science in which there are weaknesses in ITT primary courses and in the understanding and competence of the students" (para.33).

A later survey by HMI, covering the period March 1988 to June 1989, involved visits to 20 institutions, including Bath College of Higher Education (DES, 1989d). This report
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concluded that “the vast majority of BEd (and PGCE) courses were providing sound and in some aspects very good professional preparation for teaching in primary schools in the late 1980s” (p1). Concern was evident in this report about the lack of time available in some courses for science:

Over 50% of these 20 courses (accredited under DES Circular 3/84) had devoted fewer than 40 hours, some considerably fewer, to science alone. Thus, despite being well-designed with generally appropriate aims, content and broadly satisfactory staffing and resources, most were unable within the time given to prepare students adequately for science work in the primary school, mainly because of weaknesses in the scientific knowledge of the overwhelming majority of students.

DES, 1989d, p8

In the best examples HMI noted “good links between theory and practice were underpinned by illustrations from the tutors’ own teaching experience. The result was a confident, positive attitude in the students towards science, combined with an awareness of scientific skills and processes”. The teaching strategies used on the courses nearly all included practical investigative work which gave students insights into processes and skills. Courses were now staffed by tutors with more experience of the primary classroom.

During the period of this survey another DES Circular (24/89) added a requirement that all courses be revised to include at least 100 hours curriculum science. No requirement for a science qualification on entry was made.

Two HMI conferences were held in 1988 which provided evidence of how this change was anticipated by institutions. The first, The National Curriculum and Teacher Training, explored the general implications of the National Curriculum. Delegates were asked to provide papers indicating changes to courses already made or planned. Analysis of these responses showed that the vast majority specifically mention increased time for curriculum science courses, in the light of its status as a core subject. For some, such as BCHE, where the science course was already substantial (64 hours) the changes were not difficult to instigate.
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For others it was more difficult. One or two resisted changes to the science component at that time in order to await more details of the requirements. Raper (1992) discusses the changes at the University of Warwick which were not implemented until 1990.

The second conference, *Science in the National Curriculum: Teacher Training Implications* was specifically aimed at science tutors. 172 institutions were represented. Papers by participants for this conference indicate the nature of science courses provided at that time. The consensus, in terms of content and ‘espoused’ approach is evident. Analysis of these papers show that most courses still emphasised the processes of science in their aims and teaching strategies involved students in practical workshops using materials and equipment they would find in primary schools. Physical science topics were common including forces, electricity, energy. Themes such as Toys, On the Move, Water were commonly used to label sessions and most now encouraged students to see science as an integral part of the whole curriculum. Nearly all reading lists featured books by Harlen (1985a & 1985b) and drew upon the curriculum projects of the 70s and early 80s (*Science 5 - 13, Learning Through Science*).

In a few cases constructivist texts such as Driver (1983) began to feature, although no evidence was found in the papers of explicit references to a constructivist approach being used by tutors with students.

A briefing paper, produced by HMI for the conference (DES, 1988d) outlined, for tutors, the implications for their courses in relation to the National Curriculum for Science. It set out the following requirements for courses:

i. courses should portray a positive and responsible image of scientific activity both as a human enterprise per se and as a contribution to education;

ii. courses should provide opportunities for students to supplement or gain a personal understanding of all the main themes of the National Curriculum (ideally level 10, but realistically levels 5 or 6);

iii. courses should be designed to bring about understanding of the view of
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children’s learning in science as defined in “Science for Ages 5 to 16” (DES, 1988c);
iv. courses should enable students to gain an understanding, in outline, of the development of children’s grasp of scientific knowledge and process skills in the age range 5 to 11 and see this as part of a continuous development to age 16;
v. courses should reflect the pedagogic skills required by the approach of the National Curriculum for Science;
vi. students should be introduced to the structure of the National Curriculum;
vii. students should have opportunities to appreciate the purposes of assessment and be introduced to a range of assessment techniques;
viii. courses should begin from the strengths and weaknesses of individuals.

This set an agenda for ITE similar to that being addressed by schools covering continuity and progression in learning as well as assessment and differentiation.

HMI made an interesting point about the way in which “students’ understanding of certain scientific concepts and skills can be advanced through working with children, as well as through learning science at their own level” (p4). This offered a justification for the school-based element of the DES 20-day course model discussed later in the chapter. Another point made strongly in the paper is that the “methods used in teacher education constitute part of the message about teaching that students will receive” (p9). This again indicates a feature built into the DES 20-day course model. There was then an explicit reference to the significance of a constructivist view of learning in science for children and adults, “for students fully to understand the meaning of this kind of learning it is important for them to have experienced it for themselves” (p10). A strong case is made for addressing students’ own knowledge base (p18) and the need for courses to offer a broad and balanced content to cover all areas of science.

The extent to which institutions were able to cope with these demands was evidenced by a
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1991 report of HMI covering inspections of science courses during the period September 1989 to March 1991 (DES, 1991b). This covers the period during which I began to collect data from my own BEd sessions and is therefore of particular relevance for comparative purposes. HMI visited 22 institutions and overall found standards of teaching on courses to be generally sound, with tutors providing students with good teaching role models (p1). Many courses fell short of the time requirements set out in Circular 24/89. The time given to science still varied enormously from 200 hours in one institution to 12 hours in another (p2). Although most students were short of background knowledge in science, few courses attempted to compensate for this and there was a noted need to ensure subject knowledge was dealt with in a more systematic way. The limited time available was generally well used to give students the confidence to start teaching science and courses concentrated on preparing students for the practical tasks of planning and organising science. HMI noted greater attention being given to physical science topics, with earth science and astronomy beginning to appear. AT 1 (Exploration of Science) was given most attention, although meanings of terms like 'experiment' and 'hypothesis' were not well tackled and the links between AT1 and the knowledge and understanding attainment targets were insufficient. It is of significance that in HMI's own words, in only three cases did they consider they saw students "learning some science" (p4). They went on to amplify this by stating that in most activities "explanations were not rigorously sought or given" and "the underlying structure of science was passed over". By 1990 HMI found almost all tutors were appropriately qualified and had school teaching experience. The majority had a background in the biological sciences. HMI noted the number of recent appointments of classroom teachers and advisory teachers with extensive primary experience. Lack of early years experience was now a concern. Accommodation was often still inappropriate but resourcing was acceptable.

A significant publication became available in 1990 to support ITE tutors in science. A project called Science in Primary Teacher Education (SPRITE), funded by the University Grants Council (UGC), produced a set of workshop materials for teacher education (Harlen et al., 1990). The twenty two modules, produced by a team of writers with considerable expertise...
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in primary science, provided a valuable resource upon which tutors could draw for ITE and INSET purposes. This material was based upon Harlen’s views of the nature of science education and encouraged a mode of working that recognised the significance of the same approach being appropriate for adults and children:

The modules reflect in their mode of teaching that which is intended the teacher should provide for children. In some cases this also applies to the content, and the teachers should experience what their children should experience. However, the tasks are designed so that the content and processes of the science are presented at the teachers’ own level. That is, while adopting the approach and style of primary science, the activities present a mature challenge and are intriguing to adults.

Harlen et al., 1990, Introduction vi

The material also introduced tutors to strategies such as concept-mapping and the modules proved useful on the DES 20-day courses as evidenced in Section 5.7.

The conclusion to be drawn from this review is that science in initial teacher education has undergone considerable changes over the last 20 years, mirroring the changes in schools discussed in Chapter 3. Like teachers, ITE tutors have found it difficult to find an acceptable balance between processes and knowledge and understanding in their courses. Science process(es) was the focus of course development in the late seventies and for most of the eighties, and content then inevitably became a major concern for tutors in the context of the National Curriculum demands and the poor level of background science of many entrants to initial teacher education.

This concern has been discussed by tutors at BCHE over a number of years and the approach being evaluated is one result of these developments. As later discussion of case studies will indicate, the constructivist approach adopted is intended to address many of the concerns highlighted above. The BEd science course at BCHE has evolved since 1988, when I joined the college, from one which placed a very heavy emphasis upon skills and
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processes to one which is now designed to ensure broad and balanced coverage of National Curriculum content alongside the progressive development of students' scientific and professional skills (see Appendix 1, which provides an outline of the two year 'professional' element of the BEd course at BCHE).

The future for initial teacher education is somewhat uncertain at the time of writing with the move to more school-based training on the agenda of those in institutions and the DES. The implications for science education are considerable in terms of the need for the development of students' background knowledge and understanding of science. Can this be supported by primary teachers during school-based training if they themselves have an inadequate knowledge base?. Hart (1992) and others are concerned about this and it will be a theme I will revisit in the light of my own evidence.

5.3 Inservice education in science

In this section, inservice education is seen in its broadest sense as a term describing the professional development of teachers after they have taken up their first teaching appointment, post initial qualification. It encompasses far more than attendance at courses, although, traditionally the mode for inservice education has been 'courses' and consequently much of the section focuses upon this kind of provision. The relationship between professional development and inservice education (INSET) is one that needs clarifying. For the purposes of this treatment I regard the two as overlapping sets. INSET (which I am taking to be an activity involving someone other than the individual teacher) does not always lead to professional development, although the intention of providers is that professional development will result. The overlap is where this is successfully achieved. However, there are ways in which an individual can be involved in professional development, through, for example, individually motivated and implemented classroom enquiries, which are not INSET in the above terms since they do not involve an outside agent, even a colleague. Inservice courses have been provided for primary teachers in the area of science
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by curriculum development teams, LEA advisory staff, Higher Education tutors and others for many years. This section begins with a brief historical review of this provision before analysing key issues involved.

Some of the earliest inservice activity focused upon primary science was related to the key curriculum projects discussed in Chapter 3. Some of this early provision attempted to address concerns that were very similar to those addressed by current providers. For example, the *Oxford Primary Science Project* (Redman, 1968; Chapter 3, Section 3.8) provided courses to help teachers deal with key scientific ideas whilst also attempting to support the application of those ideas to classroom work. *Nuffield Junior Science* (Chapter 3, Section 3.7) and *Science 5 -13* (Chapter 3, Section 3.9) also had inservice dimensions, which focused upon 'enquiry' approaches to science, with less emphasis on the content involved. These were much more typical than the Oxford provision of the science INSET that was offered teachers during the seventies and eighties by LEAs. During the seventies, as primary science became a more common component of initial teacher education, Higher Education institutions began to offer primary science courses to teachers. Allsop (1983) discusses these early courses, indicating how the inservice provision mirrored the ITE provision, typically involving sessions of tutor input followed by practical activity of a type similar to that encouraged in the classroom with children. He goes on to discuss DES/Regional courses, underpinned by the *Science 5 -13* philosophy, and their failure to have an impact beyond the individual teacher involved. Dissemination to colleagues did not occur. This led him to explore whole-school initiatives (p248) during which he worked with the whole staff of schools. The support included work alongside teachers in their classrooms (anticipating the strategy later commonly used by advisory teachers). This developed to work with consortia of schools. His review of his college's approach to science inservice concludes with a section on accredited courses (including science at teachers' level up to 'O' level standard) which were targeted at individual teachers.

Whittaker (1983) provides another example, from the same period, of a college tutor working
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in schools as part of an inservice initiative. In her case the work was with children to overcome a common problem she (and I, in my experience) encountered of teachers saying, “It’s all very well, but it wouldn’t work with my children”. Her response was, “let’s see!” (p253). She also involved ITE students in these activities and provided one of the first examples of IT-INSET (Straker, 1987).

DES-funded long (35 day) courses for science coordinators (DES, 1984a) were offered during 1985. These were based in Higher Education institutions and developed in collaboration with LEAs. They provided the first substantive inservice for primary science which was funded nationally. The DES-specified aims were to develop coordinators’ skills for supporting science throughout the school. The focus of the courses was on the way science was organised and taught and not what was taught (Russell et al., 1992). Despite previous HMI comments about subject knowledge (DES, 1978) there was no requirement for courses to address this. Frost and Turner (1987) reported on the content and approach of a course at the London Institute of Education and Johnston (1991) reported a long term study of the impact of these courses and highlights the crucial issue of on-going support, usually from external sources, for effective long-term change.

The role of LEAs has been significant in the provision of INSET for primary science. Pennell and Alexander (1990) provide a detailed case study of one local authority’s involvement in primary science and the evolution from short courses provided by advisory staff, through the role of LEA working groups (including LEA advisory staff, HE tutors, teacher centre wardens, headteachers and teachers) to an ESG funded advisory teacher team and school-focused management of curriculum change. In many ways, this parallels my own experience with Avon LEA. A working group developed the original Primary Science Guidelines for the county (County of Avon, 1981). The Guidelines led to a variety of short courses (ranging from one twilight session to several full-days) provided by local ‘experts’ including classroom teachers, of whom I was one. Other working groups focused upon specific areas and issues (eg. Early Years, IT and science, use of construction kits, problem solving approaches) and produced
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resources for teachers, which were supported by short inservice courses based in teachers' centres, or later in a designated science centre. During this period HE-based courses such as a year-long introductory course (CAPSE6, at Bristol Polytechnic) and another year-long course designed to address teachers' scientific knowledge (CAPSE14, at Bristol Polytechnic) were being developed in collaboration with the LEA and drawing upon LEA expertise.

Primary science INSET received a significant boost (Keogh and Naylor, 1991) as a result of an increase in funding in 1985, when ESG funds were made available. Most LEAs appointed teams of advisory teachers. These teams were then the main focus for LEA inservice provision. Their work was evaluated by Kruger et al. (1990c), Initiatives in Primary Science: an Evaluation (IPSE 1988a, b, and c) and the NFER (Harland, 1990; Kinder and Harland, 1991). A local evaluation was conducted of the Avon team, as a team member’s MEd dissertation (Ollerenshaw, 1990). These evaluation reports describe the variety of strategies used to support classroom teachers including centred-based courses and school-based inservice activities. The intentions of these initiatives were generally to improve teachers awareness of and confidence to teach science, to improve their professional skills in implementing science and to encourage teachers to see science as a practical activity involving active learning for children. This process approach to the teaching and learning of science was promulgated and little evidence was found of systematic attempts to address teachers' scientific knowledge base (Kruger et al., 1990c, p136). Harland (1990) identified four modes of INSET delivery by advisory teachers:

i. provisionary mode ('I will give you');
ii. hortative mode ('I will tell you');
iii. role modelling role ('I will show you');
iv. zetetic mode ('I will ask you').

This framework will be used later in this thesis to analyse aspects of my own role as an INSET
Overall, the evaluations of advisory teacher work indicate it was generally successful in terms of achieving the aims identified above (Kinder and Harland, 1991, p9). However the IPSE team's visits to teachers who had had advisory teacher support found few teachers who “identified the scientific skills they were hoping to develop within each activity and even fewer still referred to the learning outcomes or conceptual understandings which they wished to promote” (IPSE, 1988b).

A later significant milestone in the provision of inservice education for primary science was the decision of the government of the day to fund 20-day science courses to improve primary teachers' background knowledge and understanding of science (DES, 1989c). This initiative is discussed in Section 5.8.

Another evaluation project of interest at this stage of the discussion is one conducted by Halpin et al. (1990) into teachers' perceptions of the effects of inservice education. It is of particular relevance since it involved surveying Avon teachers who had completed courses at local HE institutions (including BCHE) in the academic year ending August 1988, just prior to my own study. It involved the use of questionnaires to all teachers (199 out of 364 responded) and detailed interviews with a small sample (13). A number of findings are relevant:

i. teachers had initiated their own involvement and it was rarely linked to institutional needs or whole-school developments;
ii. their motives were; to plan better curricula and schemes of work (69%), learn more about current educational thinking (56%), discuss and share problems with other teachers (47%), develop further their teaching skills (46%);
iii. effects with the most impact resulting from the inservice were; attitudes (87%), knowledge (84%), teaching skills (67%), teaching methods (60%, pupil...
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attainment (49%);
iv. effects with least impact were: promotion (32%), departmental teaching (37%),
    school organisation (38%), school policy (38%), classroom organisation (39%);
v. in terms of other effects, increased self-confidence and enhanced status
    accounted for 16%, leading to the observation that part of the value of inservice
    lies not in changing what teachers do but in reassuring them of the value of their
    own practice;
vi. the opportunity to meet other teachers featured prominently in data on
    "unexpected" effects.
vii. nearly half the sample felt their school was positive towards their inservice activity;
viii. nearly 70% who provided data on school-responsiveness reported a take up of
    ideas;
ix. 11% claimed a 'considerable effect' on pupil attainment and a further 38% said
    there had been 'some effect'.

Overall, the work of Halpin et al. provides a positive picture of the effects of HE-based INSET
on Avon teachers, even taking account of the fact that the results depend to some extent
upon the professional self-knowledge of those surveyed. A similar outcome to INSET in
another region of the country was reported by Kruger et al. (1990c, p137).

The key issues related to this review of primary science INSET are:

i. Aims of primary science INSET

These have changed from provision intended to simply improve awareness of the place of
science and confidence to teach it in a practical way to provision intended to support
teachers' implementation of the National Curriculum which includes the development of
teachers' knowledge and understanding of scientific content as well as professional skills
such as those needed to deal with assessment and differentiation. There has also been a
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shift from providers being seen, and perhaps seeing themselves as 'experts' who will tell
teachers how to do it, to providers facilitating professional development through strategies
aimed at giving individual teachers more responsibility for that development (see Whitehead
(Joan) (1987) for an example of the latter).

ii. The content of primary science INSET

Mirroring changes to the science curriculum taught in schools and the content of initial
teacher education, inservice education has taken account of a broader and more-balanced
curriculum. Physical science topics, under-represented in the content of much inservice
activity in the seventies and eighties, are now regarded as essential elements of courses.
Relevance to everyday experience of content and the use of equipment and resources
found in primary classrooms remain common features of courses.

iii. Teaching strategies used for INSET

One of the most obvious common features of all primary science inservice has been the use
of practical activities an an element of courses. A practical workshop with some tutor input and
perhaps depending upon discovery learning or problem solving approaches was the norm
for most centre-based inservice. These workshops usually involved teachers in doing
practical activities which could be used, often without any modification, with children. The
limitations of such strategies were identified by IPSE (1988a, p39). More recently Keogh and
Naylor (1991) advocated alternative approaches, such as that being evaluated (see section
5.5). Inservice provision, provided by LEA staff with limited experience of working with adults,
was usually based on classroom teaching strategies rather than strategies developed
specifically for work with adult learners. HE providers had more experience of adult learners
and therefore sometimes a broader range of teaching strategies to draw upon. Innovative
strategies were explored by LEA advisory staff including work with children, as an integral part
of inservice courses, and the use of action research and collaborative activities on inservice
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courses (Ollerenshaw and Ritchie, 1990; Ollerenshaw et al., 1991). The nature of effective INSET will be considered in Section 5.8.

iv. The structure of INSET

LEA provision has tended to be short-term, often a single after-school session, sometimes full-day with supply cover provided or a series twilight session(s). Apart from working parties, whose work might go on for a longer period of up to three years, most LEA provision was spread over a few weeks. IPSE (1988b) found short-term provision to be of limited benefit to participants (p28). Substantive INSET lasting a term, or more commonly a whole year, on a part-time basis has been the common structure for HE-provided INSET. DES-funded INSET (4/84 - 35-day and GEST-funded 20-day courses) have been the most substantive inservice to date. A typical accredited primary science year-long course will involve about 90 hours contact, usually arranged as weekly meetings of 2-3 hours. In the eighties it was common for such courses to involve some full-days (for example at BCHE the Further Professional Studies Course in Primary Science included 3 full-days). This became very uncommon after funds were delegated to schools as a result of the Education Reform Act (DES, 1988a).

v. Providers of INSET

As we have seen, primary science inservice has been delivered by a range of ‘experts’ and ‘enthusiasts’ from classroom teachers (primary and secondary), to advisory staff and HE tutors. The experience of these providers has sometimes had an effect upon the nature of the provision and the success of its outcome. For example, secondary science teachers who were involved in Avon primary science inservice in the early eighties had no experience of primary teaching and it was difficult for them to relate scientific work to the primary classroom. The secondary influence was also evident in some HE-provided inservice when the tutors only had secondary experience. On the other-hand, advisory teacher provided inservice often lacked scientific rigour because the providers (ex-classroom teachers) lacked
background knowledge and understanding themselves (Harland, 1990). Their lack of science inevitably influenced the kind of inservice they felt confident to provide.

vi. Financing of INSET

Until the last couple of years, LEAs (sometimes through specifically allocated central funds) were able to fund primary teachers who wished to engage in inservice activities, be it short LEA-provided courses or longer HE-based accredited provision. Changed funding arrangements (Nott and Hudson, 1991) mean this is no longer the case. Most inservice teachers are dependent on school-funding for courses or, as is happening in the majority of cases, self-funding their professional development. The only funds available for substantive INSET through LEAs are now for DES-approved courses, for which, as we will see below, limited funds are available.

vii. Location

Most courses have, in the past been located in teachers' centres, purpose-developed science centres, HE institutions or perhaps in a local secondary school. Teachers' centres and science centres, run by LEAs are becoming less common and HE institutions provide the most common location for inservice courses drawing teachers from a wide catchment. However, the last few years has seen the development of much more school-based inservice activity (Eason, 1985; Preedy and Taylor, 1991), sometimes involving a whole school staff, or perhaps science coordinators from local schools. Providers, be they LEA staff or HE tutors, are now basing some inservice activity in schools and responding to institutionally identified needs. Kruger et al. (1990c) recognised the problems, however, of addressing teachers' subject knowledge through INSET which is exclusively school-based. There are limitation to school-based activities.
viii. Audience

Primary science INSET has, in the past, been focused upon individual teachers' needs and typically a teacher would decide for that s/he needed professional development in that area. It would not, however, be uncommon for the individual involved, the provider, and the staff and head of her/his school to expect the benefits of the course to extend beyond the individual teacher's classroom. This would be particularly true where the participant was a coordinator. More recently, it has been recognised that whole-school development is important and this aspect of inservice has been prioritised. But, as Halpin et al. (1990) showed, in the late eighties this was not yet the case. The situation with DES-designated courses has always been clear in this respect; aims for the 4/84 coordinators' courses and the more recent GEST-funded courses have been explicit about whole-school dissemination and development.

Another aspect of 'audience' is the way in which particular groups have been targeted for inservice by LEAs and the DES. LEA targets have sometimes been primary headteachers, whose support for primary science was seen in the mid-eighties as essential to curriculum development (IPSE, 1988b). In Avon science coordinators were also a target group regularly offered inservice to keep them up-to-date with new developments, LEA policies and curriculum changes. On other occasions early years' teachers, newly qualified teachers and Y2 teachers preparing for Standard Assessment Tasks (SATs) have been targeted for specific provision. DES-approved 20-day science courses have been approved as suited to coordinators, other classroom teachers or both (as in the case of the BCHE course).

To a certain extent HE providers have also targeted courses, for example CAPSE6 was a course targeted by Bristol Polytechnic at classroom teachers lacking confidence to introduce science into their classrooms and CAPSE14 was for more experienced teachers and coordinators wishing to develop their practice further.
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A final issue related to audience and teachers self-selecting courses is the extent to which teachers may be unaware of their INSET needs. Kruger et al. (1990c) found that it was only as a result of interviewing primary teachers about their existing scientific knowledge that some became aware of gaps in their knowledge and the implications of this for their teaching. Such individuals are unlikely to select a course based upon developing scientific knowledge as they are unaware of their needs.

ix. Evaluation

The evaluation of primary science inservice has often been of a fairly limited nature. Halpin et al. (1990) found few examples of rigorous evaluations and the national evaluations of ESG advisory teacher inservice activity (IPSE, 1988a; Harland, 1990; Kinder and Harland, 1991) found few examples of this. It is interesting that inservice evaluation did not feature as a topic in the annual advisory teachers conferences in 1987 (Leicester) or 1988 (Nottingham). That is not to suggest inservice providers have not been evaluating their courses. However, this has usually been informal and ad hoc. Evaluation is discussed in section 5.8 and is raised here to signal its significance as an issue in this review.

5.4 Constructivist approaches with adults

We promulgate constructivist thinking for students, but too often we conduct teacher education programmes that seek to give teachers fixed views and methodologies, rather than recognise their needs to reconceptualise the subject matter and pedagogical strategies as they engage in the slow process of conceptual change.

Novak, 1987, quoted in Kruger et al., 1990c, p133

The literature on use of 'constructivist' approaches in developing children's learning in science is considerable, as Chapter 2 indicated. However, there is less evidence of a similar approach being advocated for adult learning in science. This section looks at the reasons why a constructivist approach to adult learners is considered appropriate for use in initial
teacher education and inservice education. As a reminder to the reader the term 'constructivist approach' is being used to describe an approach to teaching based upon a constructivist view of learning.

Chapter 2 (Section 2.8) provided the beginnings of a rationale for justifying a constructivist approach to adult learners. The first step in a rationale needs to address the extent to which adults and children learn science in similar ways. This was the focus of the treatment in Chapter 2. Others have supported this view. Earlier in this chapter, reference was made to the view of HMI, related to ITE, which advocated a constructivist view to learning in children and stated students should experience this for themselves through their own learning (DES, 1988d). The CHATTS project, discussed in Chapter 4 (Section 4.4.2), drawing upon their experience of adults learning science, found the constructivist view of learning the most appropriate, in particular recognising primary teachers need to interpret new ideas in a framework of 'received common understandings' (CHATTS, 1992, p4). The other major research project dealing with primary teachers knowledge and understanding in science (PSTS) also adopted a constructivist view of adult learning (Kruger and Summers, 1988, p261) and found ample evidence to support their view in terms of common alternative ideas amongst teachers and the dynamic way in which those ideas developed through questioning and discussion. They claim there is little difficulty in accepting the validity of this view of learning with adults, in the light of the extensive evidence available on the nature of learning in secondary and tertiary students.

It is also, however, important to recognise that the constructivist view of learning is seen as explaining more than simply how a learner's knowledge and understanding of scientific concepts develops. The same view can be applied to the way in which learners come to understand the nature of the scientific processes they use. Learners come to scientific activities with existing ideas about the nature of those processes. The teacher's role is to help them develop that understanding in the light of the current experience, to help them appreciate how the exploration in which they engage can become more investigative or to
understand how their investigation could be made more rigorous.

The second step needed in a rationale for a constructivist approach is to consider whether the teaching approach, developed by the Children's Learning in Science Project (Needham, 1987), modified through my work with the Assessment in Science Project (Ollerenshaw et al., 1991) and discussed in Chapter 2, is appropriate for use with adult learners. My premise is that the teaching phases of orientation, elicitation, intervention and application are as appropriate for adult learners as they are for children. Like children, when adults are introduced to a new area of study they need time to orientate themselves and think about how the new area links with previous experiences and knowledge and understanding, although the nature of orientation activities and the time required may, of course, be different. Elicitation, as a time to help the learner clarify what she/he thinks and the teacher to discover the nature of those existing ideas, is also fundamental to learning with any age if the view of learning adopted is one which recognises that new learning will depend upon ideas the learner already has as well as experiences provided. Intervention with adult learners is similar in nature to that with children. If the learner is to be given some 'ownership' of their learning then teacher intervention must be based upon elicited existing ideas, not upon a teacher's preconceived notion of what those ideas might be. For restructuring to result from intervention and new experiences the learner, of any age, will need to apply new ideas in different contexts to test out their explanatory power and see if they are more useful than previous ideas she/he held. For teachers this application phase may well be in terms of applying concepts to teaching with children in the same content area.

Other providers of initial teacher education and inservice education in science are now articulating a similar view and have explored such approaches with adult learners. Keogh and Naylor (1991) adopted a constructivist approach to their 20-day course at Manchester Polytechnic, as did tutors at Liverpool University for their course (Boyce and Schilling, 1991; Russell et al., 1992, p74); Westminster College (Kruger et al., 1991c) and those at Sheffield Polytechnic (Smith and Peacock, 1992, p61). Kruger et al. (1991c) provide the strongest
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and most argued rationale, based upon their extensive study into adult learning in science. Boyes & Shilling and Smith & Peacock provide details about the practical implications of adopting such an approach. In the latter case the tutors detail teaching sessions, analysed in terms of Cosgove and Osborne's 'generative learning' model (1985, p82). Bell (1991), in the first issue of 'Science Teacher Education', advocates a constructivist approach to work with ITE students claiming:

Courses should be based upon a constructivist approach to learning, taking into account the students' existing ideas and building on their personal understanding of science concepts.

Bell, 1991, p2

To date, I have found no evidence of tutors making claims that a constructivist view of learning can be used to explain teachers' construction of an understanding of the processes of science as well scientific knowledge and understanding. In terms of using a constructivist approach to develop teachers' professional understanding about how science can be taught the only example I have found is a small-scale action research enquiry carried out by Vale (1992) related to his work as a co-tutor on the Manchester course. Both aspects of a constructivist approach (developing understanding about processes and professional concerns) have been important elements of my approach.

A final reason for adopting a constructivist approach to work with adult learners is perhaps best summed up by, 'practice what you preach'. If tutors are committed to a view of learning, which they claim leads to adopting a particular approach, then that approach should be evident in their work with adult learners. As HMI noted, in the context of ITE, 'the message is in the method' (DES, 1988d, p10). In order to encourage metacognition and adult learners' reflection upon their own learning it is vital that that learning parallels that of children in terms of their active construction of ideas.

Aspects of the approach I adopted will be outlined in the next section. However, such an approach has implications which need summarising:
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i. an orientation period/activity or equivalent should be the starting point for new programmes of work or areas of study and adults varied life experiences should be drawn upon in providing this phase;

ii. various strategies should be used to elicit adults’ existing ideas. Recording these in some way is important to enable the tutor to make formative decisions about how to make appropriate interventions. Adult learners are likely to find exposing tentative and semi-formed ideas, in front of their peers and a tutor, threatening. This phase therefore needs handling with sensitivity. Exploratory activity, where adults are engaged in self-directed and unstructured or semi-structured practical activities and encouraged to raise questions has an important part to play in this stage of the work. However, practical activity, on its own, is not enough. Discussion amongst peers and with the tutor are also essential. This enables individuals to recognise a variety of possible explanations for phenomena;

iii. intervention during which learners’ existing ideas are challenged can involve further practical activity, usually of an investigative type but sometimes of an demonstrative or illustrative nature, discussion and the use of analogies, tutor input or the use of secondary source material. Again, talk is as important as activity. The time needed for exploratory activity to lead to investigative work will vary from individual to individual and upon the previous experience the learners have had of engaging in scientific activity. Evidence of restructured understanding will need to be obtained and a variety of ‘assessment’ strategies are needed to facilitate this.

iv. adult learners, like children benefit from time to review their activities and articulate the nature of the changes that have occurred in their understanding.

v. opportunities to apply restructured ideas needed to be structured into sessions or built into follow-up work. Time for review of these activities is needed.

vi. learners should be made aware of the process of their own learning and be encouraged to take responsibility for and control of that learning. Metacognition is an aspect of active adult learning.
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Awareness of these implications informed my practice and the identification of concerns that arose from my attempts to implement a constructivist approach.

5.5 DES 20-day Courses

5.5.1 Background

This DES initiative arose from the recognition by the Government that the implementation of the National Curriculum would require the enhancement of the subject knowledge base of teachers in the core areas. Chapter 3 and 4 have provided the context in which this was seen as necessary. HMI had raised this issue over a number of years, identifying subject knowledge in aspects of physical science and mathematics as areas of particular concern (DES, 1990). In response to this the DES allocated £10 million of grant-supported expenditure for twenty-day specially-designated courses in mathematics and science for primary teachers through the LEA Training Grant Scheme in 1990-91. A similar sum (£10.6M) was available in 1991-92 through the Grants for Education Support and Training (GEST). This move indicated a significant shift in government policy regarding the best means of supporting curriculum development from the previous support available through Education Support Grant (ESG) for LEA advisory teacher teams to INSET provision provided by Higher Education, in collaboration with LEAs.

To initiate the new courses, HMI held consultative conferences in May 1989. These led to draft frameworks which were circulated to HE institutions (1989c). It was clear that only courses approved by the DES would qualify for funding, which was to be made available through LEAs. Submissions were required by September 1989 and a list of approved courses was circulated in December 1989. The first ran in the summer term of 1990. In August 1990, revised criteria, dropping the earlier distinction between coordinator and classroom teacher courses (see Appendix 2) were published. By April 1991, 3,000 primary
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teachers had taken, or were taking, science courses.

5.5.2 Aims

The main aims of the courses were specified by the DES as:

i. development of teachers' confidence and ability in the subject knowledge and understanding which will allow them to teach the programmes of study in KS1 and KS2, and to appreciate the place of science in the wider curriculum.

ii. development of teachers' practical skills associated with the subject, including the teaching approaches, the assessment of pupils' progress and attainment during KS1 and KS2 and the preparation of schemes of work.

Dissemination to colleagues of newly acquired knowledge and expertise was also seen as essential. No specific requirements were made about course structure or mode of delivery. However, participants were expected to have time to reflect on work undertaken, apply it in their classrooms and share experiences with colleagues. The use of distance-learning material was mentioned. It was stated that teaching methods should "at all times reflect good classroom practice involving a variety of approaches and the use of a range of resources" (Appendix 2, page 2).

Course content was to cover: subject knowledge; use of IT and simple equipment; understanding of the processes of science; cross-curricular links and dissemination to colleagues.

The framework made little mention of the link between the use of scientific processes and the development of scientific knowledge and understanding. There was an implicit assumption that knowledge and understanding of content and process could be developed without teachers necessarily engaging in those processes.
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5.5.3  BCHE Proposals

The local response to this initiative was a decision by tutors at Bristol Polytechnic and BCHE to work collaboratively on a joint proposal for courses taught in both institutions. This, to my knowledge, was the only joint proposal made to the DES. The collaboration resulted from the ongoing work between the two institutions in the area of primary science (outlined in Chapter 1 section 1.4). Approaches were also made to Avon and Wilshire LEAs through their science advisors who agreed to act as ‘partners’. The initial proposal (Appendix 3) was rejected because it was not clear how ‘adequate time was to be given to delivering subject knowledge, as specified in the framework document’ (DES letter to BCHE, 3 November, 1989). A revised proposal (Appendix 4) including minor changes was approved in December 1989. The initial rejection seems to have resulted from the failure of the first proposal to communicate how the course structure, which we regarded as innovative and unique, would lead to improved knowledge and understanding. It may also be evidence of the DES having an expectation that the courses would adopt a more traditional approach to developing subject knowledge, perhaps using more didactic methods. The next section will discuss the BCHE/BP model in terms of its key features and innovative elements. From now on the course will be referred to as the BCHE model since the BCHE located course is the one evaluated, although as acknowledged it was developed through collaboration with colleagues at Bristol Polytechnic, and in some important respects built upon their more extensive experience of work in this area.

5.5.4  The BCHE model

This section should be read in conjunction with the actual proposal (Appendix 4). The following aspects of the model were considered significant by the team (led by Chris Ollerenshaw then at Bristol Polytechnic and myself at BCHE) who put together the proposal and developed the course:
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i. the course resulted from collaboration between two HE institutions and local LEAs. This allowed a broader course team to draw upon wider experience on INSET and provide a pool of tutors, which could be used by either institution in the delivery of the course, with broad and balanced experience of science education (for example including 'biologists', 'chemists' and 'physicists'). The course model built upon previous HE and LEA initiatives in primary science and successful elements of these were included (for example, use of work with children and action research approaches). An existing course at Bristol Polytechnic (CAPSE14), with similar aims, had been running for several years and this had resulted from earlier collaboration between Chris Ollerenshaw and myself. I had experience of teaching on that course, and its 'predecessor', from 1984. LEA advisory teachers from both LEAs were actively involved in course development and implementation, in some cases as course tutors for sessions where they had appropriate expertise or in a more general role offering support with the planning and implementation of the school-based days;

ii. the course model was underpinned by a firm research base. In terms of children's learning in science the work of CLIS (1984-91) and Osborne and Freyberg (1985) were significant. Insights into teachers' learning in science drew upon the work of the PSTS project (Kruger and Summers, 1988). The approach to assessment and action research was based upon previous collaboration through the Assessment in Science Project (Ollerenshaw et al., 1991).

iii. a constructivist approach underpinned the course, both in terms of the model of children's learning offered to the course participants and in terms of the approach to adult learning. Making this approach explicit to teachers was fundamental to encouraging metacognition (Kruger et al., 1991c, p200) and ensuring the learners took some responsibility for their own learning (see section 5.5). A constructivist view of learning was seen as applicable to understanding of scientific concepts and scientific processes. The
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use of a model of teaching with course participants which they could use with children was regarded by the proposers as a strength of the course. It required tutors to provide appropriate role-modelling in terms of strategies and teacher questioning, behaviour and attitude;

iv. the inextricable links between processes of science and knowledge and understanding were recognised and addressed in all aspects of course delivery, be it working with adults or children. This feature, as seen later (section 5.6), is not always evident in other course models. The view of science that underpinned the course is that contained in the Science National Curriculum, ie “the way understanding is developed depends both on the existing ideas and on the process by which those ideas are used and tested in new situations.” (NCC, 1989, A7). We wanted, again, to ensure that our approach to adult learners offered a model which they could use with children. We intended teachers to come to an understanding of phenomena through exploration and investigation rather than through exposition, although the latter would be used when appropriate.

v. the course model was informed by a view of professional development which drew upon action research approaches. It was not intended that course participants became ‘action researchers’, but the purposes and methods of action research had considerable relevance to the nature of professional development intended. Approaches to classroom enquiries, informed by action research approaches, but of an action enquiry type (see Chapter 6, Section 6.1) were therefore built into the course (for example by ensuring time between day 3 and 4 of each cycle for application of ideas in the classroom) and formed the basis for assignments. Previous experience of such approaches (Ritchie and Ollerenshaw, 1989; Ritchie, 1989) had convinced the course team of its value in encouraging effective change in classrooms. An additional but linked aspect was our commitment to the value of collaborative work involving teachers working together during centre-based sessions and in schools with children. Others have found, as we had in our previous work, that this can be beneficial to professional development (Cavendish et al.,
vi. a particular view of assessment also informed the course model. This was a formative approach to assessment, which saw it as an essential and integral part of all teaching. This was made explicit to teachers and the approach was used with them in developing their own learning and as an approach to be used in school with children. The view of assessment used is discussed in detail in Ollerenshaw et al. (1991) and Ollerenshaw and Ritchie (1993, Chapter 6). The use of assessment strategies, such as floorbooks and concept-mapping, were regarded as strategies that could be used with adult learners and applied by teachers for use in their own classrooms. Formative assessment of participants during sessions was regarded as essential if the course was to cater for differential learning needs;

vii. the approach to the school-based elements of the course was innovative and I am unaware of any other DES 20-day courses using this strategy. Teachers worked in pairs, all in the same class, with a small group of children on day three of the first three cycles. This was based upon our previous experience of such a strategy helping teachers develop their teaching competence (Ollerenshaw and Ritchie, 1990). It also built upon the experience of advisory teachers' INSET work alongside teachers in their classrooms (IPSE, 1988b). In the case of the 20-day courses, the strategy was seen to have another important use. It was intended that the teachers' scientific knowledge and understanding would be developed through their identification and analysis of children's existing ideas, in the same content area as they were developing during centre-based sessions. We intended that this would help them clarify their own ideas and raise further questions that could be addressed on day 4 of the cycle. Their attempts to plan activities for children based upon the evidence of existing knowledge, collected during the first teaching session, was also intended to serve a similar purpose. HMI, in an earlier report on ITE, had recognised this potential for work with children (DES, 1988d, p4). Other course providers have recognised that work with children at the 'application' phase is important
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(Kruger et al., 1991c, p198) but not as a structured part of tutor-contact. Researchers on the SPACE Project found evidence of the benefits of teachers’ work with children impacting upon their own learning in science (Russell et al., 1992, p78). Eraut (1982) claimed that for teachers, a significant aspect of learning associated with their professional development (for example scientific knowledge) is not acquired on courses and then used but actually takes place in the context of use, for example planning or evaluating work with children. This view endorses the decision taken to build work with children into the course model;

viii. the course model had built into it a phase focused upon dissemination to colleagues. Cycles 4 and 5 involved structured, collaborative and supported school-based activity in course members’ schools when the strategies they had experienced could be explored with teachers. This also formed the basis of the third assignment;

ix. the course was accredited within both institutions’ modular inservice programmes and successful completion led to a Certificate in Advanced Professional Studies in Education (CAPSE) or could be used as credit towards an MEd., Postgraduate Diploma, or Inservice BEd. This meant that some course members were submitting work at Masters’ (M) level.

5.5.5 Course structure

The course involved 5 cycles of four full days spread over three terms. Each cycle was based on a particular scientific theme (materials, forces and their effects, light, electricity and living things). The first day and a half of each cycle involved workshops at the teachers’ own level. The second afternoon was spent planning for work with children. This was done collaboratively in pairs. Day three was spent in one course member’s school. Each pair worked with a small group of children. One observed and collected data, whilst the other worked with the children. The first session (an hour) usually involved exploratory work, eliciting the children’s ideas in the cycle’s content area. An analysis and evaluation after this
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lead to planning activities for the same group aimed at challenging or developing their ideas and skills. A second teaching session involved the pair reversing roles. The day ended with another analysis and evaluation of assessed development in the children’s skills and knowledge and understanding. There were then several weeks for related work in course members’ classrooms before the final day of the cycle which reviewed this work and provided opportunities for addressing concerns, especially related to their own knowledge and understanding, that had arisen.

The following section is intended to offer the reader some evidence of what the centre-based sessions included, drawing upon the case studies discussed later.

The centre-based workshops involved:

**Orientation** activities to introduce the area of content involved. For example, during the *forces* cycle a collection of familiar everyday mechanisms were available for course members to try out and discuss, and they watched a video sequence illustrating examples of forces;

**Elicitation** of course members existing “scientific” ideas. This involved various strategies including individual records, discussion in pairs, small groups and whole group. Numerous ways of recording these ideas were used including posters, floorbooks, annotated diagrams, word spurs, concept maps etc. The elicitation again involved questions about everyday examples of the phenomena and we tried to ensure teachers felt comfortable and unthreatened by the artefacts and materials used;

**Practical explorations and investigations** were instigated by the teachers with tutor guidance. They were encouraged to raise their own questions through open-ended explorations (in most cycles) and used these questions to devise more systematic investigations, based on the existing constructs they held. It was this stage that reinforced the importance of practical activities and the inextricable links between process and
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knowledge and understanding;

Discussion of outcomes, modification of existing constructs and possible developments played a vital part in these sessions and we referred to the social construction of ideas to reinforce the human nature of science and the tentative nature of scientific ideas;

Exposition from tutors addressed needs that could not be met through practical activities also featured. The particulate nature of matter was introduced during the materials cycle and accepted ideas about Newtonian physics during the forces cycle. This was often supported by computer simulations or video (eg MIST). The inputs of an ‘expert’s’ view were usually in response to teachers’ questions and the tutors involved attempted to present the accepted scientific ideas through dialogue;

Application of restructured ideas in different situations was built into day 4. For example teachers were asked to use ideas about particle theory introduced during day 2 to explain how heat travels during day 4 of the materials cycle.

Plans for sessions, covered by data-collection are included as Appendix 5.

Alongside the centre and school-based sessions there were other aspects of support offered within the course structure. Extensive handbooks were produced for each cycle which provided background information for the participants in a format that could be used with colleagues back in their own school. Contents included background information about the content area; references and links with National Curriculum Orders and Non-Statutory Guidance, tutor collected case studies of classroom work in similar areas; ideas for implementing activities in the classroom in the specific content area; links with topics and other curriculum areas; lists of resources. Tutorials were offered to individuals, particularly when they were working on assignments. Tutors offered to work with the staff of participants’ schools (on a consultancy basis) and this led to tutor-involvement in some inservice days and

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after-school staff meetings and workshops. LEA advisory teachers were involved in the
delivery of the courses and provided some follow-up work (where possible) in course
members' schools. Participants were also encouraged to link into other LEA networks and
meetings were arranged for course participants after the courses had finished to encourage
the development of self-help groups and networking.

The detail in this rather lengthy section has been included as I regard it as important to
establish the context in which the enquiry was set. The next section will briefly examine
evidence from evaluations of 20-day science courses which will be referred to in my later
analysis of the BCHE courses.

5.6 Evaluation of DES 20-day science courses

There have been two national evaluations of the 20-day courses. HMI evaluated courses
(including those at BCHE and Bristol Polytechnic) between April 1990 and April 1991. They
reported their findings informally to course providers in April 1991, at an invitation
conference, and formally in 1992 (DES, 1992b). NFER were commissioned by the DES to
carry out an evaluation early in 1991 and they reported their findings a year later (Harland and
Kinder, 1992). This section analyses the key findings of these two reports to inform later
discussion of the BCHE course. Overall, both reports provide evidence that the DES
courses were generally successful in meeting the aims set for them, but there were lessons
to be learnt.

During the summer and autumn terms of 1990 and the spring term of 1991 HMI visited 26
institutions providing designated courses in science. In the spring term follow-up visits were
made to schools of teachers who had attended courses. The main findings were:

i. clear evidence that courses were 'well-received' by participants, who claimed an
increase of knowledge, increased confidence and new and enhanced
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professional status;

ii. courses were given high status by headteachers, other staff and participants because they were presented under the auspices of the DES;

iii. there were many examples of good classroom practice following the courses, together with some evidence of increased knowledge having directly affected teaching;

iv. most effective courses, in terms of classroom impact, set the knowledge to be learned within the context of the NC and included sessions on teaching methods;

v. strategies for dissemination were generally not well developed and impact on colleagues' practice was rarely found;

vi. teachers who were able to affect colleagues were in schools where headteachers had attended part of the course, some non-contact time to work alongside colleagues was available, advisory teacher support was available after the course finished and/or there was follow-up work in school provided by course tutors.

The report also expressed concern that participants differing needs were often not met; found that no one course model was more effective than others; questioned the value of written assignments; noted that the best courses set limited targets and gave the teachers confidence by achieving these; all courses gave due emphasis to AT1 and helped teachers explore the relationship between processes and knowledge and understanding; school-based days were used with mixed-success, the best used the days to explore issues raised on the course, the worst lacked purpose; some workshop approaches were of limited value
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and the science teaching occurred largely when the opportunity arose and was unsystematic; learning was less likely when short intensive lectures were not supported by opportunities for the teachers to discuss ideas raised and relate them to their classroom work.

The NFER report, based on detailed case studies of ten science courses (and ten mathematics courses) was more extensive and its main findings are included as Appendix 6. This evaluation did not include evidence from the BCHE or Bristol Polytechnic courses. Their main findings, relevant to this study and not discussed above were:

i. some form of consecutive attendance ensured greater focus upon subject knowledge (p3);

ii. the quality of course venues could have a significant influence upon perceived effectiveness (this included ambience as well as facilities) (p4);

iii. calibre of tutoring was a major factor in successful impact;

iv. the use of structured school-based days could provide valuable opportunities for developments in teaching processes and dissemination skills;

v. the case studies show knowledge acquisition and awareness of good practice in pedagogy and dissemination can be achieved through practical investigative approaches;

vi. differentiation was best addressed in courses which showed evidence of interventionist and directive tutoring strategies, extended opportunities for experiential learning and favourable teacher-tutor ratios (p5);

vii. unless the problem of developing colleagues’ subject knowledge can be
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addressed the benefits of the courses will not extend significantly beyond course participants (p6);

viii. dissemination skills in science are largely indistinguishable from those in other subject areas;

ix. benefits to HE were evidenced including staff development, closer links with schools, valuable interchange between course members and ITE students;

x. there are benefits of sustained and substantial INSET (p7).

The report’s key recommendations include one which was to be used by the DES to revise the framework for course submissions. Harland and Kinder found that school-based days were rarely used to enhance subject-knowledge (p9) and consequently the DES set a limit of 3 days as the maximum school-based number allowable. This view is in direct conflict with the experience resulting from the model under discussion and Ollerenshaw (1993) has used evidence from our experience to challenge the recommendation. Harland and Kinder also recommended that evaluations of the long-term effects of knowledge-based or process-based courses are needed to contribute to the debate about appropriate balance. The present study, although not evaluating long term effects systematically, is intended to contribute to the debate.

Harland and Kinder's finding concerning modes of delivery are particularly interesting in the light of the general 'consensus' claimed within the science education community about the relevance of constructivist approaches.

Compared with the mathematics sample, fewer applications of reflexive small group discussions were evident in the science case studies. One course however, linked this mode in an attempt to use constructivist approaches to science education in the hope that the course attenders would internalise a sense of the 'medium is the message'. The reactions of some teachers
suggested that constructivism can be a high risk INSET strategy for primary teachers:

I didn’t like all the diagnostic exercises at the beginning, like ‘write down all you know about forces’ ... somebody could tell us!

The emphasis on constructivist and reflexive approaches appears to have waned over the course, with more ‘lectures’ being reported towards the end of the course.

Harland and Kinder, 1992, p94

There is no other evidence of constructivist approaches in the courses evaluated. However, anecdotal evidence at the DES-invitation conference (April, 1991) for course providers indicated the vast majority of providers espousing a constructivist approach. Is this evidence of ‘espoused theories’ and ‘theories in action’ being different? Some providers have provided evidence of constructivist approaches in action (see Section 5.5). The present study is also intended to provide evidence of a constructivist approach in action to inform the debate about whether the approach is practical and effective. What the above quote, and informal conversations with other providers, has confirmed is the difficulties involved in adopting constructivist approaches. It is not an easy strategy to use, but I hope to provide evidence that it has considerable benefits if used appropriately.

The NFER evaluation concludes:

On balance, the designated course model has done much to further primary teachers’ professional development in the National Curriculum core subjects of mathematics and science. It has many positive facets which commend its use in the training programmes required for other areas of the curriculum. For the teachers attending the course, the model provided INSET experiences which were welcomed as sustained and substantial, particularly in comparison to the more normal short ‘one-off’ training events of recent years.

Harland and Kinder, 1992, p130

The BCHE course was evaluated, beyond this particular study, as are all accredited courses at the institution, through a variety of informal and formal strategies, some intended to provide formative information (for example, unstructured written comments at the end of a cycle) and
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other for summative purposes (such as an end of course questionnaire (see Appendix 7)).
An evaluation report is produced by the course team which is processed through the institution's course monitoring and evaluation procedures. The report for the courses covered by this study are included as Appendix 8. The evaluative outcomes from the courses have been an important source of data for my research and will be discussed in detail in later chapters.

5.7 Other approaches to DES 20-day science courses

This section will examine what other course providers have claimed for their courses in an attempt to provide evidence for a comparison to be drawn with the BCHE model.

The PSTS-based model at Westminster (Kruger et al, 1991c) was based upon the inservice materials that resulted from the project ((Kruger et al., 1991a & b). It has a very similar rationale to the BCHE model (Kruger et al., 1991c, p198) but has adopted a somewhat different approach. The materials used incorporate information about teachers' common alternative ideas (obtained from the research phase) in such a way that individual teachers, it is claimed 'can identify their own, possibly unique, understanding in the conceptual area in question' (p200). Thus rather than teachers engaging in exploration as an element of elicitation they are presented with examples of other teachers' ideas in which to locate their own. The PSTS course model gives much less emphasis to the processes of science as a means of developing knowledge and understanding. The practical elements of their courses are much more focused upon illustrative activities where teachers are working within tutor-imposed constraints related to the purpose and nature of the activity. They make extensive use of analogies and this is based upon the work of Clement (1987). The emphasis given to teachers raising questions that will lead to investigative science in the BCHE model is not evident in the PSTS model. The team have conducted their own evaluation into the effectiveness of the packs during inservice sessions (PSTS, 1991, Working Paper 12) and found the most successful aspects to be:
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i. improving teachers’ own understanding through an approach in which theory was coupled directly with relevant practical work;

ii. the way in which metacognition and the constructivist approach to learning was appreciated by the teachers;

iii. the inclusion of the ‘expert’ view;

iv. finding out what their children and they themselves thought about and understood in a given situation.

A key concern resulting from the evaluation was the time factor; teachers complained about insufficient time to consolidate learning in one area before passing on to another. This concern is addressed again later in this thesis. The PSTS team are currently carrying out a long-term evaluation of their approach.

Smith and Peacock’s (1992) case study of a 20-day course session has much in common with the BCHE model. They make the valid, and often neglected point, about how necessary “concentrated work by the course tutor on his (sic) own conceptual understanding” is prior to a course session. However, their model again provides no evidence of teachers engaging in self-initiated and designed investigative activity. The practical work in their model was illustrative or demonstrative and of a very short duration. The tutor offered and ‘demonstrated’ the scientist’s view in the absence (apparently) of any investigative science (p61). The authors note that some ‘scientific ideas may be hard to illustrate with first hand experience’ (p66). This is undoubtedly true, but this does not mean that other scientific ideas cannot be developed effectively through investigative approaches. The inherent danger of the two approaches discussed above is that they do not encourage teachers to see the important links between processes and knowledge and understanding. The implications of this are that the teachers may then implement an approach to science in their classrooms which does not reflect or build upon these links. This can lead to teachers not valuing practical activity and whilst the use of analogy and ‘interview about instances/events’ may have value with adult
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It is less useful in the classroom. In the absence of being able to use strategies used with them there may be a tendency for them to revert to a more didactic approach to the development of children's knowledge and understanding (see page 143).

Another documented approach to 20-day courses (Russell et al., 1992, p74) recognised the place of processes in adult learning:

To utilise science process skills as the means of supporting the development of teachers' understanding is to make manifest important assumptions about their role in effective learning.

However, Boyes and Schilling's (1991) treatment of course sessions provides evidence of the use of a circus of activities which are used for illustrative purposes and no mention is made of any investigative work, unless it was within 'some opportunity to apply any new ideas' (p6). A useful feature of this case study is its use of concept mapping, and discussion of the importance of assessment during sessions. Views and strategies such as these are in line with those developed on the BCHE model.

Russell et al. (1992) in evaluating this course noted that not all participants' expectations were met.

Some felt that the set of facts (sic) which they anticipated taking away and forwarding to the next set of recipients had not been handed over. Perhaps such courses result in two different sorts of product: a set of teachers who rediscover the joy of learning at their own level - and those who finish the course inspired to find out more science; another set who might have been able to select a few facts from the explorations and discussion which they could share, with children in their class.

The DES held an invitation conference for all providers of Designated Science Courses in April 1991. Some course providers, including me, were invited to provide papers outlining particular approaches (see Appendix 13 for the BCHE paper). These papers provided me
with another source of evidence. Two covered the Liverpool model discussed above, based upon Boyes and Schilling’s published account, and the PSTS model at Westminster. Another paper by Malvern described the course at Reading University which was mostly based in a laboratory “to underline that the course is for them (the teachers) and we take their aspirations in science seriously, and to remind them where their pupils are heading”. This contrasts with the BCHE course which we chose to base in a ‘professional’ room. The Reading model made extensive use of the SPRITE material which was developed there. Concept-mapping was cited as a key strategy to involve teachers in their own learning and these were used before and after a topic to indicate progress and changed understanding. Malvern claimed to be “informed by the alternative framework research”, however, there is no explicit claim to be constructivist in approach. There is an important recognition that “there are differences between the misconceptions (sic) of children while their science is inchoate, and the notions of adults in a professional setting trying to make sense of science”. These differences are of significance to the present study.

A paper from Keele University provided another distinctly different course model where considerable advisory teacher support was available and, according to the paper, a great deal of the course dealt with ‘professional’ issues such as resourcing, school policy, schemes of work and topic development. Little is indicated about the way in which subject knowledge is tackled and in many ways the description seems more applicable to the original DES 35-day courses than to the aims of the 20-day initiative.

Consequently, considering this review of other courses, some of which claim to be ‘constructivist’, a significant feature of the BCHE model, not apparently given emphasis elsewhere, is the use of investigative activity as part of a constructivist approach to learning science. The other unique element is the use of school-based work with children.

This chapter ends with a consideration of the nature of evaluation of INSET.
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5.8 Evaluation of INSET

There is an extensive literature available concerning the evaluation of inservice education for teachers and although some of this relating to science education has already been discussed there are other general considerations to address. The starting point for this discussion is to recognise that the use of a summative evaluation questionnaire which has so often been used to evaluate INSET is of limited value. In some respects it does nothing more than give information that might be seen as ‘the feel good factor’ or perhaps ‘the feel worse factor’. More sophisticated approaches are necessary to evaluate the impact of inservice activities, particularly in terms of the impact the inservice has had upon a teacher’s classroom practice and the quality of learning provided by that teacher for her/his pupils. My own understanding of the nature of evaluation has been considerably informed by my work on courses provided for advisory teachers by the Association for Science Education called INSET for Professional Development (IPD). These courses approached evaluation as an integral aspect of the whole course delivery and gave course participants a key role and responsibility for the evaluation aspects. On one of these courses I took a major role in evaluation and produced an extensive summative report (Ritchie, 1990c). This report illustrates the extent to which effective strategies can be used for monitoring (Are we carrying out our plans?), formative evaluation (Do we need to adjust our plans and how we are carrying them out?), summative evaluation (Was the process and the outcomes worthwhile and valuable?) and review (Should we change our assumptions, aims, priorities and approach?) functions. The principles adopted were:

i. participants must be involved in the evaluation process;
ii. data must be collected in a variety of ways from different sources;
iii. long term evaluations must be used to determine changes in practice;
iv. all data must be analysed before making evaluative judgments;
v. always include supporting evidence when reporting judgments.
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However, the instruments used to measure impact upon practice needed refining and this is one of the key issues addressed by Bolam's (1987) paper *What is effective INSET?*. This provides an excellent overview of the issues involved. Bolam draws upon the work of Joyce and Showers (1980) who identified four potential levels of impact for training. They were originally concerned with the impact of initial teacher education but they and others, as Bolam showed, have found evidence of this in inservice contexts. The levels identified were:

i. general awareness of new skills;
ii. organised knowledge of the concepts and theory underlying the skills;
iii. learning of principles and skills ready for action;
iv. transfer and application of the new skills to the classroom and integration into the teaching repertoire.

The latter needs to be reached before impact upon pupil's learning can be expected. This framework has become common in the literature and in my experience of the IPD courses has considerable value in helping participants and course providers analyse the outcome of inservice activities. Joyce and Showers also distinguish five teaching strategies which have different potential outcomes:

i. presentation / description;
ii. modelling of new skills;
iii. practising new skills in simulated or controlled conditions;
iv. feedback on performance of new skills;
v. teaching for application, transfer and integration.

The extent to which the BCHE course model provides these will be explored in detail in a later chapter. Joyce and Showers claim:

If any of these components are left out, the impact of training will be weakened in the sense that fewer numbers of the people will progress to
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the transfer level (which is the only level that has significant meaning for school improvement). The most effective training activities, then, will be those that combine theory, modelling, practice, feedback and coaching to application. the knowledge base seems firm enough that we can predict that if those components are in fact combined in inservice programmes, we can expect the outcomes to be considerable.

Joyce and Showers, 1980 quoted in Bolam, 1987, p42

Although the basis for much subsequent work on evaluation of INSET the approach of Joyce and Showers has been found to be limited. Kinder and Harland (1991) criticise the Joyce and Shower's framework since it focuses upon capability and cognitive outcomes and ignores affective outcomes such as motivation and value-orientation. They also highlight other weaknesses about research into INSET evaluation such as:

i. researchers often come from the same institution as that providing the INSET;
ii. time-scales following input is often quite short;
iii. data collected is often based upon self-reports with few checks on authenticity;
iv. teachers tend to be the only source of perceptions about effects;
v. classroom observations and pupil interviews are rare;
vi. the institutional context in which teachers are expected to implement changes is often neglected;
vii. emphasis is on documenting outcomes with insufficient complementary attention to process factors;
viii. the reporting of findings often lack an appropriate conceptual framework for discussing outcomes.

Kinder and Harland's contribution to the last point was to construct a new tentative typology of INSET outcomes. These were: Materials and provisionary outcomes; informational outcomes; new awareness; value congruence outcomes; affective outcomes; motivational and attitudinal outcomes; knowledge and skills; institutional-strategic outcomes; impact on practice. Their analysis of the outcomes evident as a result of the work of science advisory
teachers led them to propose a hierarchy for these outcomes (Figure 5.1).

Figure 5.1: INSET outcomes
from Kinder and Harland, 1991, p163

3rd Order provisionary information new awareness

2nd Order motivational affective institutional

1st Order value congruence knowledge and skills

**IMPACT ON PRACTICE**

They provide case studies of individual teachers and the combination of outcomes that were effective in improving a teacher’s practice. First Order outcomes (the highest!) were essential, but not enough on their own. They recognised the complex inter-dependency of these factors. Their analysis has been helpful in considering the impact of my own work and will again be used in a later chapter.

5.9 Conclusions

There are parallels between the developments related to science in initial teacher and inservice education. These developments have reflected and sometimes influenced the changes in the approach to science evident in primary schools. Individuals involved in initial and inservice education have often themselves been involved in curriculum development projects either locally or nationally. The introduction of science as a core subject in the National Curriculum has had a major impact on initial and inservice education as well as requiring changes in schools. This has had some very positive effects in terms of the approach to science education. During the period of considerable change resulting from the
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introduction of the National Curriculum both teachers and providers of initial and inservice education were required to reorientate themselves to different priorities. In terms of initial teacher education science 'curriculum' courses generally became more substantial and more balanced in terms of 'processes' and 'content'. They provided a broader and more balanced content covering all aspects of science and the need to address students' subject knowledge base was recognised. Inservice education has undergone similar changes and the effect of the DES 20-day initiative was to cause providers to develop new courses which addressed teachers' subject knowledge. INSET of this nature had not been widely provided before 1989, although there were examples that had been developed in a number of localities. The use of substantive INSET provided by Higher Education institutions represented a significant shift in government thinking about the best way of supporting the development of science in primary schools. Since 1985 the strategy had been to fund, through Education Support Grants, teams of advisory teachers to work alongside teachers in their classrooms. This approach had been successful in raising teachers awareness of the importance of science and to some extent improving their confidence to teach science, although usually in terms of a 'process' approach. The use of advisory teachers had failed to address the issue of teachers' subject knowledge base, hence the need for a different approach.

The research base that informed initial and inservice education, covering the nature of children and adult's learning in science, expanded during the late eighties and providers were making use of this evidence in their courses and support for teachers. Different providers adopted different approaches and the impetus of the DES 20-day initiative led to considerable dialogue amongst those involved about the advantages and disadvantages of these approaches. Constructivist views concerning the nature of learning in science for adults and children were common in these exchanges but the extent to which this view of learning was evident in the resulting courses in terms of the approach adopted to adult learners is debatable. Constructivism was, in some respects, the 'espoused' paradigm in which initial and inservice education was developed but the extent to which these 'espoused
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theories' were turned into 'theories in action' is less clear. There was however, a consensus that implementing a constructivist approach to work with adults was difficult and demanding for tutors and participants.

The course developed at BCHE in collaboration with colleagues at Bristol Polytechnic was an attempt to develop a course which was a committed attempt to put our understanding of constructivism into action. The course model that resulted and is discussed in this chapter is the focus for the main part of my enquiry. My evaluation of the model and my use of it is informed by the existing literature concerning the evaluation of INSET but adopts a different approach, based upon action research. Action research is one form of practitioner-centred research which is the theme of the next chapter.
6.1 Introduction

This chapter provides a discussion of types of research carried out in educational contexts by practitioners into their own practice. It is mainly, but not exclusively, concerned with what has become known as 'action research'. It is offered at this stage of the thesis for two reasons:

i. to provide a context for the later discussion about methodology used in my research;

ii. to provide a view of teacher professional development which has informed, and in some respects underpinned, the course model used on the BCHE DES 20-day science course.

Practitioner-centred research is an approach to teacher professional development which I have found effective over a number of years, as the early bibliographic section indicated. My understanding of the nature of practitioner research has developed from my first introduction to it in 1986, through my work as an advisory teacher and college lecturer, and crucially during the period of this research. This account, written after my experience of engaging in such activity through this research, indicates a broader, and I hope deeper, understanding than that which I had before I started this research.

Practitioner-centred research such as educational action research has potential for all ‘practitioners’ be they classroom teachers, headteachers, advisory staff or HE tutors. However, throughout I will refer to ‘teachers’ as a term to cover ‘practitioners’ since in this chapter most references are to those working in classroom contexts. The term educational action research is used at the start of the chapter to describe action research in education contexts; the extent to which it is ‘educational’ in the other meaning of the word will be
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I will begin with a general discussion of my understanding of ‘action research’ and locate that understanding in the perspectives of others interested in this field. It is important to remind the reader, as I did when dealing with epistemological issues in Chapter 2, that as a ‘constructivist’ I recognise that this analysis represents my current understanding which is dynamic and will change; indeed has changed during the writing stage. It should therefore be viewed as tentative.

6.2 Action research in educational contexts

What is educational action research? This question is capable of generating a range of answers from ‘action researchers’, possibly as many variants as there are those claiming to engage in action research. This may indeed be a strength, indicating its flexibility, but it can also be a weakness, leading to it meaning all things to all people.

The origins of action research can be found in the work of Lewin (1946), however, at this stage, a definition of action research by Halsey offers a suitable starting point:

Action research is a small-scale intervention in the functioning of the real world and a close examination of the effects of such intervention.

Halsey (1972) quoted in Cohen and Manion, 1989, p217

This identifies the key features of action research as: process-based (involving ‘action’ as an integral aspect of the ‘research’); situational (dealing with specific local contexts); involving active participation of practitioners (although this is implicit in the definition and could, in Halsey’s view, be in collaboration with researchers which raises the issue of control and roles); self-evaluative (actions taken are continuously evaluated in an ongoing way).
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Carr and Kemmis (1986) make the role of the practitioner more explicit and extend the purposes and potential outcomes,

Action research is simply a form of self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own practices, their understanding of these practices and the situations in which these practices are carried out.

This view focuses upon the need for the practitioner to be reflective, in order that decisions about future action are informed by past and current actions. Crucially, it also claims the outcome of action research to be more than improved practice; an improved or better understanding indicates the fundamental link between educational theory and practice that will be explored later. It stresses the need for the research to be carried out by the practitioner. Although within the literature this is a definition widely accepted (McNiff, 1988, p2), there are alternative views to this (for example, Lomax claims that facilitating or supporting action researchers can, themselves, be engaging in action research (Whitehead and Lomax, 1987, p185) which will be considered. However, all views recognise the direct involvement of practitioners in action research usually carried out to improve their own practice.

Implied in these ‘definitions’ is the view that educational action research is a systematic and rigorous process for enabling teachers to deal with concerns that they have about their professional practice.

6.2.1 Action learning, action enquiry and action research

Before looking in more detail at the nature of action research I will address my understanding of other terms which are relevant to the discussion. ‘Action learning’ and ‘action enquiry’ are two terms associated with professional development which can be seen, in some ways, as a
continuum leading to action research. This section draws upon the views of Whitehead (1991). Action learning is taken as that which results from a form of professional problem solving when a practitioner's attempts to improve her/his work. This involves “a systematic form of experiencing problems when your values are not fully lived in practice, of imagining ways of improving your practice and choosing one to act on, of action, and of modifying your ideas and action in the light of your evaluations” (p2). Action enquiry has a different starting point in that rather than a way of dealing with ‘problems experienced’ it is as much concerned with problem raising as problem solving. It is “a conscious attempt to answer, in a systematic way, the question, ‘How do I improve my practice?’”. Both terms refer to a process; both involve systematic action and both locate responsibility for the learning and control of the process with the practitioner. The latter, however, has more potential for enhancing the quality of pupil learning and adding to a teacher’s understanding of her/his practice. Action research takes this further and requires the practitioners to submit their accounts to public scrutiny in order to test their validity. Action learning and action enquiry are essentially the professional development activities which teachers were encouraged to undertake as part of the DES 20-day courses, although as discussed in Chapter 5, they were loosely described, in the course proposal and information, as ‘action research’ approaches. Indeed, much of the inservice work that I have supported in the past, described as ‘action research’, is in terms of the above more accurately action enquiry. The experience of writing up these activities as assignments and sharing these with others has provided a stimulus for some to go on to more explicit action research activities as will be shown later.

6.2.2 The nature of action research

Action research has developed as a way of making research more meaningful to teachers, as a way of bridging the gap between researchers and teachers and as a means of enabling teachers to become researchers into their own practice. There is a view of educational research as something done by outside researchers (operating within a positivist paradigm), who carry out projects (often large-scale) in classrooms, generalise their findings and then
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‘tell’ teachers how they can improve their practice (McNiff, 1988, p10). Examples of this include the Oracle study (Galton et al., 1980) and Bennett’s study on teaching styles (Bennett, 1976). Dissemination of this kind of research rarely has the impact in classrooms that its advocates desire (Hopkins, 1985, p26). Critics of these researchers claim that they tend to regard teachers as suitable subjects for research rather than colleagues with whom they might collaborate or even share research questions, methods and data analysis. Teachers have no ownership or control of the research and are therefore often not sufficiently motivated to make changes, especially when those changes may involve considerable effort and anguish. Educational action research has, in some senses, much more limited aims although in other ways these might be regarded as more fundamental. It is concerned with teachers finding specific solutions to their own particular concerns, which have arisen from their individual classroom experiences. Unlike some research approaches, action research does not set out to generate ‘conclusions’ and ‘recommendations’ that can be generalised, although again, as discussed later, there are ways in which action research can be regarded as generalisable. Action research is focused upon particular social contexts, for example, a teacher may identify a concern when considering how she/he might improve her/his practice, about the involvement of girls in practical work with a particular class. The concern arises as a result of the teacher becoming dissatisfied with an aspect of her/his practice and consciously exploring ways of improving it, and as a result the quality of pupil learning. This concern can also be seen as the result of the teacher attempting to resolve the dilemmas professionals face everyday (Pollard and Tann, 1987, p5) when their values are denied in action. According to Whitehead, who goes further than Pollard and Tann, teachers are ‘a living contradiction’ (Whitehead, 1989a) when their values are denied in this way. This concern is perhaps most appropriately seen as a question, for example, “How can I ensure the girls in my class get more involved in practical work?” The emphasis of the ‘I’ (Whitehead and Barrett, 1985) reinforces the personal nature of the concern, although others may, of course, share similar concerns about their own practice. The teacher as researcher sets out to find better ways of working in his or her own situation but it may be that the strategies s/he finds successful in improving the quality of pupil learning will work for others. The teacher's
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main purpose in engaging in the research process is to address her/his own concern, not to find generalised ‘truths’ for others to take on. However, as discussed above, to justify the claim to be an action researcher, the above ‘enquiry’ would need to be made public in order for the researcher to validate her/his claims, even though they will be claims relating to the specific not the general. It should also be noted that the ‘validity’ of action research is not solely concerned with the published outcome, as I will discuss later. There are also other reasons for writing up workplace enquiries. Many action researchers write up their work in order to encourage others to engage in a similar process, rather than as an attempt to offer guidance to someone else about teaching.

So what are the features of a process that characterise action research? At its simplest, as we have seen, it can be regarded as a process which begins with a commitment to improve what goes on in a teaching context. This leads to a concern that a teacher has identified, perhaps with the help of someone else. This concern is then thought about and possible ways of addressing it considered. This stage may well involve eliciting the views of others in an attempt to gain new perspectives on the teacher’s own concern, considering a range of options and the strengths and weaknesses of each in order to decide, perhaps again with the collaborative support of others that imagined solution which offers the most potential for improving the situation. That chosen ‘imagined’ way forward is then turned into some form of action plan. This indicates how the teacher intends to try out a novel approach or something new in the classroom. The action plan will normally involve consideration of how the teacher will be able to decide if the strategy has been successful. In other words, before trying something out, the teacher will decide what evidence, or data, to collect to help her/him to decide on its success. The next stage involves trying out the imagined solution in the classroom. This is the phase when the teacher is usually involved in collecting data about what is happening. This may be evidence of her/his utterances or those of the children. It may involve recording her/his own actions, observing children’s behaviours or collecting in their work. Following a period of classroom work, the data has to be analysed. This is the stage of reflecting upon what occurred in an attempt to gain insights into the success or
otherwise of the new strategy. Analysis of the data collected needs to be rigorous and
honest. In research terms it should be valid and stand up to the scrutiny of someone else.
Does the evidence support the statements a teacher is making about a classroom episode? It
is at this stage that collaboration with a colleague, or group of colleagues, can be valuable.
Trying out one’s ideas and testing the conclusions drawn from the evidence against the
professional views of others can be threatening but extremely useful if conducted in a climate
of mutual respect and collaborative support. It is unlikely that this analysis and reflection will
result in the teacher feeling that her/his concern has been finally resolved. In the complexity
of real classroom situations the likely outcome will be a refined concern or perhaps a new
concern and a revised action plan. In this way, action research is on-going, involving a cyclical
process in which evaluation leads to new action. The word cyclic may not be ideal if it implies
returning to the starting point. Action research ‘cycles’ certainly do not return you to where
you started, except perhaps in the sense of T.S. Eliot,

We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.

from Little Gidding, The Four Quartets, 1944

As Lewin (1946) proposed in his early treatment of action research, it is a spiral of steps
where each step involves phases of plan, act, observe and reflect. Others have looked at
more sophisticated models to describe (or in some case prescribe) the process involved (see
Section 6.4).

To ensure that decisions about teaching are based on evidence rather than on impressions it
is vital that evidence is collected in a systematic way. It is in this area that the teacher as
researcher can draw profitably on more conventional research methods (Hopkins, 1985). In
order to look closely at classroom episodes data can be collected in a variety of ways,
including: field notes (written during or straight after the session); tape recording;
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videotaping; pupil diaries or work; interviews; questionnaires; sociometry; photography (p58). It is necessary for data to be as objective as possible, but the action researcher's epistemological basis (discussed in Section 6.3) enables her/him to recognise that no classroom data is totally objective. The subjective views of teachers and their interpretations of particular situations are an essential and justifiable aspect of action research, as they are of other interpretivist methodologies. Action research is rarely concerned with exclusively quantitative methods, and issues related to sampling, control groups and careful control of all variables are less important than in other forms of research (Cohen and Manion, 1989; Hopkins, 1985). It is a qualitative approach to research in which an individual teacher is attempting to build up as accurate a picture of what goes on in the classroom as is necessary for making professional decisions. It is, by definition, a form of educational research which impacts upon a teacher's professional practice.

To summarise, action research has the following features:

i. it is situational and focuses upon specific concerns in specific settings;

ii. it is participatory and involves the teacher as a researcher;

iii. it involves the teacher in reflection and self-evaluation;

iv. it aims to improve a practitioner's practice for the purpose of enhancing the quality of pupil learning;

v. it adds to the teacher's professional knowledge;

vi. it is flexible and adaptable;

vii. it usually involves collaboration with other professionals;

viii. it is holistic and not discipline based.

6.2.3 The reasons for engaging in action research

What are the features of action research that make it particularly suitable for teachers? Perhaps most significantly it is a spur to action. It is a means of getting something done and improving the way in which it is done. In this sense, it is a tool for teachers' own problem solving which is preferable to the more subjective and impressionistic approach to problem
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solving so often used by teachers in dealing with day to day professional concerns (Cohen and Manion, 1989, p220). Because it is open-ended and flexible it is claimed it can be adapted to suit the style of any teacher and be used in any teaching context although I agree with Elliot (1991, p14) when he challenges this. Action research is flexible, but is not an appropriate approach for all teachers or situations. Teachers engaging in action research need to be in sympathy with the ontological, epistemological and methodological implications underpinning it (see section 6.3) and demonstrate appropriate professional and personal qualities (see Section 6.2.4). Action research is intended to do more than just change practice, in that the process can add to teachers' working knowledge of that practice. As researchers, teachers can gain new and valuable insights into how they go about teaching. It can help teachers make their own value systems more explicit and helps overcome the distance between 'espoused theories', which teachers use to talk about what they say and think they do, and 'theories in action' which reflect what actually goes on in their classrooms (Easen, 1985, p6). As previously noted, Whitehead sees this as dealing with the 'living contradiction' teachers face when the values they hold are negated in their teaching activity (Whitehead, 1989a). In enabling teachers to examine the extent to which their values are represented in their practice it can throw light on classroom relationships and behaviour (of children and teachers). Action research has the potential to bring into question that which is taken for granted by teachers. In the way that it is sometimes said that a scientist 'looks at the world like everyone else but sees it differently', it might be claimed that an action researcher aims to see their own classroom situation differently. Engaging in action research can help teachers to know themselves better as professionals. In Schon's term, they develop 'knowledge-in-action' (1983, p50). Action research can lead to innovation through the adoption of new perspectives, especially if it involves a collaborative dimension. However, to lead to such innovation the teachers involved must approach their research in an open-minded way, prepared to be self-critical and recognising that they can learn from others. For teacher-researchers, their research activity is not something they do 'to', nor 'on' their practice, it is inextricably linked with practice, not somehow separate from it (Elliot, 1991, p14).
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Action research has potential as a means of facilitating staff development (County of Avon, 1991) and providing INSET for teachers (Ritchie and Ollerenshaw, 1989; Whitehead (Joan), 1987). It can be a means of encouraging innovation in teaching and learning (Elliot, 1991, p15) and as a means of improving communications between teachers and academic researchers (Whitehead (Joan), 1987).

It is not, however, 'action research' which can provide these outcomes, it is the way in which teachers engage in action research; the way in which they make use of the approach which will affect the outcomes. Action research is not a panacea to solve all teachers' professional problems. Like other 'tools' and approaches action research can be used badly and misused. In such situations its effects will not necessarily enhance the quality of learning. It is therefore appropriate to consider, in the next section, the teacher.

6.2.4. Desirable qualities for an action researcher

This section considers the personal qualities required by a teacher if they are to become effective action researchers. As noted, an openness to new perspectives is essential for any teacher-researcher, but there are other qualities and skills that are desirable. Teachers wishing to improve their practice have to make a personal commitment to that improvement; someone else cannot do it for them. In a similar way to that by which children actively construct their scientific understanding of the world, teachers actively construct an understanding of their own professional practice (see Section 6.4). To raise concerns about one's own practice requires a degree of curiosity, honesty and confidence. As noted, for many teachers, the values upon which their practice is based remain implicit. Raising concerns requires those values and the dilemmas we face everyday as teachers to be made more explicit in order for concerns to be identified and diagnosed. A teacher-researcher needs to be creative and to think of new ways of doing things which can be tried out and analytical in selecting the most appropriate. During the implementation of these new ideas a
teacher needs to have appropriate observation skills; to be an active listener and responsive questioner. It is not as easy to observe one's own practice. Looking closely at what goes on demands a teacher to be alert to all sorts of implicit and explicit cues (Rowland, 1984). When data has been collected the teacher needs to be able to analyse it critically and this demands a degree of integrity. Continuing with an enquiry and coping with the disappointments as well as the successes requires perseverance and resolution. This is not to suggest all action researchers demonstrate all of these qualities throughout their enquiries. However, it is to recognise that action research is a demanding process to undertake that should not be attempted without an awareness of the implications for the individual involved.

This first part of the chapter has been intended to provide a general overview of action research, as a form of practitioner-centred research, and its value to teachers. It is now appropriate to look at the relationship of action research to other research methodologies.

6.3 The relationship of action research to other methodologies

Research methodologies can be distinguished by the different ontological and epistemological assumptions that underpin them. This section explores these assumptions in order to locate action research within the broad spectrum of approaches to research and, in particular, research in education. These issues are complex and addressed more extensively in key texts which have informed this treatment (Cohen and Manion, 1989; Carr and Kemmis, 1986; McNiff, 1988; Hitchcock and Hughes, 1989). There are important parallels and links with the early treatment on the nature of science (Chapter 1, Section 1.9) and the treatment of knowledge in Chapter 2. These strands will be brought together towards the end of this thesis, but in this context the intention is to focus upon research approaches.

There are two main schools of thought, 'positivist' and 'interpretist' which are often referred to as different research 'paradigms', although not used in Kuhn's (1970) sense, since there
could only be one paradigm at any one time. The first has its origins in the natural sciences and the second has social science roots. Researchers operating within these paradigms hold very differing views of ontological and epistemological issues. I will summarise and compare these views and criticisms of them before discussing their relationship to action research.

The positivist 'scientific' paradigm (sometimes referred to as normative) is based on a certain view of the nature of science. Firstly, its ontological assumptions are based on a deterministic view that all effects have causes and are predictable. Social reality is seen as external to the individual. The epistemological assumptions involve a view of knowledge as objective. It is empiricist in that it sees knowledge as coming from experience and requires theories to be based on such evidence. Positivists would see research, as defined by Kerlinger, in these terms: “the systematic, controlled, empirical and critical investigation of hypothetical propositions about the presumed relations among natural phenomena” (quoted in Cohen and Manion, 1989, p4). This leads to the role of the researcher as one of remaining ‘objective’ when looking for evidence. The positivist paradigm is a search for generalised statements to explain phenomena. This usually involves the gathering of evidence and using it to produce a coherent conceptual framework that can enable predictions and explanations of phenomena in other situations. The reasoning process involved in this can be inductive (where individual observations lead to generalisations), deductive (where generalised statements lead to specific explanations that can be tested) or hypothetico-deductive. The third of these approaches involves proposing a hypothesis (sometimes based on hunches or vague notions, on other occasions as a result of exploratory work) as a formalised set of ideas and then subjecting the hypothesis to a series of tests in order to prove or disprove it (Hitchcock and Hughes, 1989, p21). In educational contexts there is an implication this that theory, so derived, would determine practice (McNiff, 1988, p13).

In the context of research into social situations this paradigm requires the researcher to accept that human behaviour can be observed and somehow measured. It assumes
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behaviour is predictable and caused by certain effects. In other words it is subject to internal (for behaviourist psychologists) and external pressures (for positivist sociologists) (Hitchcock and Hughes, 1989, p18). This provides the basis for one of the main criticism of positivists. Anti-positivists argue, "The social world ... is a meaningful world where actors constantly construct and reconstruct the realities of their own lives. Any order found there is created by the actors themselves who make use of concepts, rules, and interpretations." (p22). This raises the key distinction between causes (evident in the natural world) and meanings and interpretations (of individuals involved in social relationships). Investigation of the social world, anti-positivists argue, requires the researcher to take account of meanings and actions rather than cause and effect. Others would criticise the epistemological foundations of the positivists approach with arguments that knowledge cannot be shown to be 'objective' and that notions of the neutral, objective researcher are suspect (see Chapter 1, Section 1.9 and Chapter 2, Section 2.2).

The nature of evidence collected when investigating the social world is also distinctly different to that collected by a scientist exploring natural phenomena. The latter usually involves quantitative data whereas in the social world the evidence collected is usually, although not exclusively, qualitative. The collection of quantitative data in the social world can be problematic, for example the use of rigid or poorly worded questionnaires can lead to responses from individuals that do not represent their views or attitudes. There are a number of ways in which qualitative data can be collected for educational research and these are discussed later. In classroom-based research some of the evidence is incomplete, fragmentary, sampled, dependent on context and varied and therefore a useful methodology needs to reflect this and allow the data be used to inform decisions.

Another key concern is related to the nature of generalisation. "Generalisation refers to the process whereby a particular set of observations or findings can be applied to a much larger set of circumstances or population" (Hitchcock and Hughes, 1989, p26). Positivists would argue generalisation is essential to research whereas those adopting an anti-positivist
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approach would recognise the place of generalisations in some aspects of research but not argue it is essential (p37). Indeed such a position, based on generalisations being essential, would inevitably devalue the small-scale, local and particularistic educational research that is endorsed by many interpretists. However, Hitchcock and Hughes (1989) suggest, that for interpretists, "any move towards generalisation must begin from the particular circumstances of individuals and groups" (p27).

Positivism is based on an assumption described as the principle of parsimony (Cohen and Manion, 1989, p14) which requires phenomena be explained in the most economical way possible. In social contexts, such as classrooms, the complexity of the real world of human relationships is under investigation and precise explanations would, in interpretists' terms, be inappropriate.

The place of hypothesising in positivistic research is important. Kerlinger described a hypothesis as "a conjectural statement of the relations between two or more variables" (quoted in Cohen and Manion, 1989, p18). The natural scientist uses the hypothesis as a tool for searching out generalisations. To the interpretist, the hypothesis has a less fundamental role to play, but may still prove to be a useful tool for exploring specific situations and looking for specific explanations of what is observed. This again reflects a view of science distinctly different from that of positivists but nonetheless scientific.

In consequence, a positivist approach "fails to take account of man's unique ability to interpret his experiences and represent them to himself" (Cohen and Manion, 1989, p26) and its results can be "of little consequence to those for who they are intended".

The above analysis has already indicated some criticisms of positivistic approaches to research in education, the last perhaps being the most significant.

Positivist approaches to education have not been particularly fruitful as Carr and Kemmis
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(1986) state:

Of course the actual achievements of the positivist search for these laws (governing educational situations) are not very impressive and theories that could be used to predict and control educational situations are almost non-existent.

There are, therefore, sufficient and sustainable criticisms of positivist approaches to educational research which provide, for me, reasons for rejecting the approach as inappropriate and 'uneducational'.

The interpretist paradigm, sometimes called the 'interpretative ethnographic approach' (Hitchcock and Hughes, 1989, p28) offers a more humanistic perspective, which rather than aiming to be explanatory and predictive attempts to be descriptive and interpretive. It has its origins in the social sciences and reflects a different view of 'science' in which the scientist is neither neutral nor objective in the positivists' sense. Its ontological assumptions are based on social reality as the result of individual consciousness rather than as external to the individual. In terms of epistemological assumptions in requires the researcher to gain knowledge through involvement rather than objective observation. In contrast to the deterministic view of human nature implicit in a positivist approach, interpretists regard individuals as playing an active part in initiating actions and therefore assumes a voluntarist and intentionalist view. It includes notions of choice, purpose, freedom and moral responsibility. It allows concern for the individual to be expressed as it recognises that behaviours include meanings that need to be considered when describing and explaining social situations. Indeed, it has been suggested that,

.. the social world can only be understood from the standpoint of the individuals who are part of the ongoing action being investigated" and further that understanding of the individual's behaviour involves, "... sharing his frame of reference" since, ".. understanding of the individual's interpretations of the world around him has to come from the inside, not the outside.

Cohen and Manion, 1989, p27
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The role of theory is significantly different since theory is regarded, by interpretists, as something which emerges from particular situations (Cohen and Manion, 1989, p39) and follows from the research but does not precede it. If theory is regarded as "sets of meanings which yield insight and understanding" then it will, unlike those that result from positivist approaches, make sense and be useful to "those to whom it applies" (loc. cit.). The theories of interpretists are firmly grounded in the data of specific instances that has been collected and analysed. Theories developed in this way have the potential to encourage practical changes on the part of those researched upon, since "practices are changed by changing the ways in which they are understood", (Carr and Kemmis, 1986, p91) but those changes are by no means certain.

The interpretist paradigm therefore leads to a view of research such as that offered by Mouly:

> Research is best conceived as the process of arriving at dependable solutions to problems through the planned and systematic collection, analysis and interpretation of data. It is a most important tool for advancing knowledge, for promoting progress, and for enabling man to relate more effectively to his environment, to accomplish his purposes, and resolve his conflicts.

quoted in Cohen and Manion, 1989, p41

Consequently, the interpretist researcher engages in the systematic and rigorous analysis of particular social episodes in an attempt to search for meaningful relationships and understand their implications for human actions.

Within the interpretivist paradigm, Cohen and Manion identify three distinct movements; phenomenology, symbolic interactionism and ethnomethodology (p31). The first is the study of direct experience at face value and the second is concerned with the nature of interaction between individuals. The latter, ethnomethodology, is concerned with how individuals make sense of their world, from within. As one of its proponents, Garfinkel, states,
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it sets out to "treat practical activities, practical circumstances and practical sociological reasonings as topics of empirical study, and by paying to the most commonplace activities of daily life the attention usually accorded to extraordinary events, seeks to learn about them as phenomena in their own right" (quoted in Cohen and Manion, 1989, p32).

The interpretist paradigm has its critics. Positivists criticise the interpretists failure to be able to produce wide-ranging generalisations or to provide 'objective' standards for verifying or refuting theoretical accounts (Carr and Kemmis, 1986, p94). Others, sharing the same ontological and epistemological assumptions, see interpretists as unnecessarily restrictive in being satisfied with 'understanding' a social situation without attempting explanation. Hitchcock and Hughes (1989) claim some interpretists' work is explanatory (p39). Carr and Kemmis (1986) develop their criticism to question the relationship between theory and practice that interpretists articulate. This they claim is flawed as will be discussed later.

Interpretists are criticised for failing to take sufficient account of the unintended consequences of social actions, about which the participants, themselves, may be unconscious. This leads to an over-reliance on accounts of individuals and an unjustified rejection of explanations which are incompatible with these (p95).

McNiff (1988) criticised interpretists in terms of her claim that case studies are 'woolly' and the approach lacks rigour and a recognisable methodology (p17). She also allied interpretists with those who attempt to perpetuate the unnecessary divisions created by a disciplines approach to educational theory and called for a more holistic approach. Most fundamentally she suggested, that in common with positivist approaches, it is in some ways 'uneducational' in that they both regard 'educational knowledge as a controlled commodity' (p18). In both paradigms the researcher is an outsider with control of the research question, methods used, the means of analysis and dissemination. Both, grounded in subjects which are not educational, have the methodological aim of describing social reality in a neutral and disinterested way, rather than providing educational explanations of the type needed by practitioners.
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Responses to dissatisfaction with research based in the two paradigms outlined above led to the development of a more ‘educational’ approach to research - action research. Action researchers generally share the ontological and epistemological assumptions that underpin an interpretist’s approach (Whitehead and Lomax, 1987, p188), although there are differences, such as a view of the relationship between theory and practice. There are significant differences in the resulting methodological implications. Action research aims to provide an approach which adopts a new perspective on the relationship between theory and practice, relocate the control of research activity with practitioners rather than external researchers and provide a methodology that has a direct impact on practice. It is an approach that is not distinguished by the use of particular research techniques but by its method, based, as we have seen earlier, on the notion of a spiral of self-reflection.

Carr and Kemmis (1986, p129) argued for five formal requirements for an adequate and coherent ‘educational science’, which they claimed contemporary action research to be:

i. it must reject positivist notions of rationality, objectivity and truth;
ii. it must employ the interpretive categories of participants;
iii. it must provide ways of distinguishing ideas and interpretations which are systematically distorted by ideology from those which are not;
iv. it must be concerned to identify and expose those aspects of the existing social order which frustrate rational change, and must be able to offer theoretical accounts which enable participants to become aware of how they might be overcome;
v. it must be based on an explicit recognition that it is practical, in the sense that the question of its truth will be determined by the way it relates to practice.

The claim to be a ‘scientific’ approach is significant. An alternative to the positivists’ science was discussed in Chapter 1 (Section 1.9) as one to which I subscribe. It is that more
humanistic view of science, as a process of developing tentative theories about natural phenomena in social contexts, that informs the claim being made. This view of science shares the epistemological assumption of interpretists that absolute knowledge is impossible to know. The alternative scientist, as we saw in Chapter 1, recognises that all her/his observations are theory-laden; that what she/he looks for and sees will be informed by existing personal understanding; that she/he is not a passive, neutral observer. Cohen and Manion (1989) see action research as interpreting 'the scientific method more loosely (than other methods), chiefly because its focus is a specific problem in a specific setting' (p218). Whitehead claims his enquiry to be scientific (Whitehead and Lomax, 1987, p189) and includes 'scientific' amongst four criteria he identified for self-validation purposes (along with logical, ethical and aesthetic ones) (p188). Carr and Kemmis (1986) regard their approach to action research as 'critical educational science' (p155). This theme will be returned to in a later section.

The development of this 'educational' approach to research and the extent to which it can address these requirements will be explored in the next section through a critical analysis of the ways in which different approaches to action research have become evident, most claiming the work of Lewin, who first coined the term 'action research', to be the origin of their current thinking. This will be followed by a discussion about issues that have been identified such as: the relationship between theory and practice; the use of schemata; dealing with multiple concerns; relevance, rigour and validity; generalisability; inward or outward looking; political context; ethical concerns.

6.4 The development of action research in education

Lewin's (1946) approach, which he labelled action research, involving a spiral of steps of plan, act, observe and reflect was not developed for use in an educational context, but has been adapted for use in education (McNiff, 1988). However, some have expressed serious reservations about this application and a mismatch between Lewin's original intentions and
values and those espoused by later action researchers. Hopkins (1985) summed these up by reminding would-be advocates of a Lewinian approach that Lewin regarded action research as “an externally initiated intervention designed to assist a client group; functionalist in orientation; prescriptive in practice” (p39). The values implicit and the features of this approach are at odds with later derivations as will become evident.

Lewin’s ideas were taken up, in educational contexts, by Corey (1953) in the USA where he used action research to improve school practices. There was a decade during which action research as small-scale enquiries flourished. This growth was checked, according to Carr and Kemmis (1986) by the development of a different approach to educational innovation and change which they label a ‘Research, Development and Diffusion’ model. This model successfully challenged the action research approaches that were, by definition, localised small-scale self-evaluative initiatives (p166).

There was a resurgence of interest in the seventies, Kemmis (1982) attributes this to demand for a more ‘professionalised’ teaching profession; a perceived irrelevance to the concerns of practitioners by contemporary educational research; a revival of interest in the ‘practical’ curriculum (Schwab, 1969); the development of interpretive approaches to research, placing the practitioner at centre-stage in the research process (p38).

The resurgence of action research in Britain was considerably supported by the work of Stenhouse (1975) who introduced the notion of ‘teacher as researcher’, signifying the dependence of pedagogical change upon teachers’ capacities for reflection. His ideas were put into practice through the Schools Council Humanities Project which he directed from 1967 to 1972. This project aimed to change teachers’ styles of teaching and Stenhouse regarded teachers as those in the best position to make decisions about such pedagogical developments. His statement “The idea is that of an educational science in which every classroom is a laboratory, each teacher a member of the scientific community” (p142) has been widely quoted. However, the project was rooted in the interpretivist paradigm, with
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Researchers involved as external agents of change. Teacher control of the research, despite Stenhouse’s writing advocating a more ‘democratic’ view, was limited. According to McNiff (1988) the researchers were giving “little credibility to, or attention to the interpretations by teachers of their own practice” (p25). The results of the project’s research, Stenhouse claimed, depended upon teachers testing out the tentative hypotheses of the research team through research in their own classrooms, which was within the constraints of the project’s overall approach (p141). Elliot (1991) provides an interesting perspective as one of the researchers involved in the project. He saw the central achievement of the project as the specification of “a set of principles to guide teachers in translating educational aims into concrete pedagogical practices” (p15). He was critical, however, of the role of the ‘outsider’ claiming, “no amount of feedback in this context will foster the self-understandings generated from teachers’ self-initiated reflection on their practices” (p19). He claimed Stenhouse wanted teachers to generate action-strategies from classroom data, whilst Elliot wanted to go further and formulate the action-strategies for them. This significant change, although in some respects to a more rigid approach, marked a move from ‘teachers as researchers’ to ‘teachers as action researchers’ in Elliot’s view (p24).

Returning to Stenhouse’s contribution, he criticised the notion of an ‘extended professional’ proposed by Hoyle (1972) as lacking autonomy and established his own criteria for ‘extended professionalism’:

i. the systematic questioning of one’s own teaching as a basis for development;
ii. the commitment and skills to study one’s own teaching;
iii. the concern to question and test theory in practice by the use of those skills;
iv. a readiness to allow other teachers to observe one’s work) - desirable (p144).

These form a sound framework for analysing later action research initiatives.

Kemmis, who worked with Stenhouse when they were both at the University of East Anglia
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(after the Schools Council Humanities Project), made significant contributions to the development of action research from his base at Deakin University in Australia. There are several aspects of his work that deserve attention. Together with a colleague he refined Lewin’s model of action research and produced a new version that has been widely reproduced. It was published in a practical guide (Kemmis and McTaggart, 1982) and is reproduced below as Figure 6.1. Criticisms of this schema and others developed from it will be addressed later, but key to the criticisms is the implication that professional development follows a single, almost clinical root of separate easily distinguished steps.

Figure 6.1: Action research process
from The Action Research Planner, Kemmis and McTaggart (1982)
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Another contribution of Kemmis to action research was his work with Carr (from the University of North Wales) aimed at providing a sound intellectual base for what they called 'educational action research' (Carr and Kemmis, 1983; 1986). This text, drawing upon the later version, will be considered in some depth. In Becoming Critical, Carr and Kemmis traced the traditions in educational thinking from its philosophical origins with Plato, through grand theorizing (such as Froebel's), foundations approach, educational theory (Hirst, 1966), applied science or technical perspective, practical approaches (Schwab, 1969), teachers as researchers (Stenhouse, 1975) to an emerging critical tradition. They provided a thorough criticism of positivist and interpretist views on research in order to redefine the problem of theory and practice (p103) and established a rationale for an approach to research which was 'educational'. The theory-practice gap is overcome by redefinition as praxis: informed action guided by a moral disposition to act truly and justly. The basis for a new approach was seen to exist within critical social science, which Carr and Kemmis claimed "has a constructivist epistemology, seeing knowledge as developing by a process of active construction and reconstruction of theory and practice by those involved" (p148). Critical social science owes much to the epistemology of Habermas, introduced in Chapter 2. He saw, as stated earlier, knowledge as constituted by virtue of three knowledge-constitutive interests: technical, practical and emancipatory. The first accounts for instrumental knowledge such as scientific concepts referred to throughout this thesis, based on the natural sciences and empirical approaches. He recognised the significance of this knowledge but claimed that "knowledge of the symbolically structured domain of 'communicative action' is not reducible to this 'technical' form. This is where the 'practical' form of knowledge, obtainable from interpretive understanding is significant. However, Habermas went on to recognise that there are limitations in this form of knowledge since it does not take account of the extent to which individuals are constrained by the social, cultural and political context in which they live and work. It is to liberate them from this that he advocated the need for 'emancipatory' knowledge, which critical social science serves and discourse provides the means to obtain (Carr and Kemmis, 1986, p136). Social science is 'a social process that combines collaboration in the process of critique with the political determination to act to overcome
contradictions in the rationality and justice of social action and social institutions' (p144). Carr and Kemmis saw educational action research as the means of implementing critical social science in educational contexts and led to their definition quoted above (Section 6.2). Carr and Kemmis identified constructive and reconstructive elements in the cycles and showed the place of discourse and practice (Figure 6.2).

**Figure 6.2: The ‘moments’ of action research**
from Carr and Kemmis, 1986, p186

<table>
<thead>
<tr>
<th></th>
<th>RECONSTRUCTIVE</th>
<th>CONSTRUCTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISCOURSE among</td>
<td>4. Reflect ⬆</td>
<td>1. Plan ⬇</td>
</tr>
<tr>
<td>participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRACTICE in the social context</td>
<td>3. Observe ⬇</td>
<td>2. Act ⬆</td>
</tr>
</tbody>
</table>

Carr and Kemmis (p189) also drew upon Polanyi's view of 'personal knowledge' as an appropriate one for accounting for aspects of action researchers' understanding of their own practice:

Insofar as the personal submits to the requirements acknowledged by itself as independent of itself, it is not subjective; but insofar as it is an action guided by individual passions, it is not objective. It transcends the disjunction between subjective and objective.

Polanyi, 1962, p330

Carr and Kemmis made considerable claims for the potential for the "discourse of self-reflective communities of action researchers" as the means to develop educational theories from the basis of personal knowledge (Carr and Kemmis, 1986, p191). Action research was, to them, essentially collaborative, democratic and emancipatory and in that context they were critical of projects (such as the *Schools Council Humanities Project*) which involved teachers.
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in working on externally-formulated questions. This they labelled as 'technical action research', which may be a valuable starting point for further 'practical action research' based upon the formation of co-operative relationships. But these forms they suggested have less potential for effective educational change than 'emancipatory action research' which involves practitioner groups in taking joint responsibility for the development of their practice (p201-204). Kemmis (1982) suggested it was possible to see a shift from technical to practical to emancipatory action research from the late 40s to the early 80s, with a shift from cooption to cooperation to collaboration (p.41). The emancipatory outcome of action research introduced an overtly political purpose to action research, which led Carr and Kemmis to claim action researchers should ...

...intervene critically in all patterns of action which fragment communities and isolate individuals (whether in the isolation of wealth and power, or in the isolation of poverty, alienation and powerlessness.

Carr and Kemmis, 1983, p182

Stenhouse saw the political potential of classroom-based research as a means of giving teacher-researchers more autonomy, but Carr and Kemmis claimed greater potential for action researchers who according to them could change the world on a macro scale. This claim led to considerable criticisms.

The original Carr and Kemmis text (1983) generated a lively debate in the literature based on criticisms cited by Gibson in his review of the book (Gibson, 1985), incidentally listed in what must be the longest sentence in the literature reviewed for this thesis! He claimed the book was:

i. immensely uncritical;

ii. its prescriptions are likely to result in increased conformity (and a new rigid orthodoxy);

iii. it is naive about group processes;

iv. it prefers the group over the individual and the in-group to the out-group;

v. it is bedazzled by the notion of 'science';

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vi. it rejects objectivity, yet privileges its own view of reality;

vii. it is characterised by hubris;

viii. it is highly contradictory;

ix. it has far too much respect for the authority of critical theory;

tax. it is an elitist text masquerading as an egalitarian one;

txi. it insufficiently acknowledges that action research at the three levels of interpersonal, institutional and structural involve different activities and levels of difficulty;

txii. its seeming preference for the structural level sets action research on a different course to present practice.

Kemmis responded to all of these, according to Whitehead (1991, p57) and Whitehead and Lomax (1987) contributed to the debate with a criticism of both Carr and Kemmis and Gibson for using a propositional rather than dialectical form to communicate their ideas. The recognition of different levels of action research in terms of technical, practical and emancipatory, as identified by Carr and Kemmis (1986) is helpful in some respects and will be considered in terms of locating my own enquiry and those of teachers I have worked with towards the end of this chapter.

To return to other key contributors to action research, Elliot, previously mentioned as a collaborator with Stenhouse, added his version of a schema for action researchers to the literature in the eighties and reviewed its use some years later (Elliot, 1991). It was more elaborate and refined than the Kemmis model, with emphasis placed on a reconnaissance phase (see Figure 6.3). Elliot’s model resulted from his extensive work with teachers on the Ford Teaching Project (1973-75) and the Teacher-Student Interaction and Quality of Learning Project (TIQL) from 1981-83. However Day, in an introduction to Elliot’s book expresses concern about the use of the schema advocated and the extent to which the technical approach restricted practitioners in maximising the potential of their research activity, claiming that Elliot shared these doubts as a result of feedback from teachers.
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Figure 6.3: A revised version of Lewin's model of action research.
from Elliot, 1991, p71
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A key feature of Elliot's work was his *collaboration* with teachers on 'teacher-based action research', where teachers generated as well as tested diagnostic and practical hypotheses. Teachers were expected to develop pedagogical theory alongside its exploration in practice and the research was to be co-operative rather than individualistic. Significantly the researchers (on the *Ford Project*) defined a 'second-order' action-research role for themselves, aimed at facilitating 'first-order' action research (p30). This attempt to 'practice what they preached' is a theme I intend to explore related to my own work and is an approach to action research which led to Lomax's concern about the earlier definition (see section 6.2).

Another significant feature of the team's approach was to explore the technique of triangulation as a means of developing teachers' understanding of their practice. This involved comparing the accounts of teachers, their pupils and the participant observer (the researcher) in order to ensure the 'validity' of the account. Unfortunately, the researchers' attempts to reduce their control of the teachers' research seems to have resulted in little evidence of action research continuing after the project period (p39). The problem of how to institutionalise action research in schools was evident. Elliot recognised the importance of facilitating discussion amongst action researchers and helped establish the *Classroom Action-Research Network* (CARN) in 1976 which contributed to the development of action research throughout the eighties through its journal and conferences.

Before leaving this review of Elliot's contribution it is necessary to note his criticisms of Carr and Kemmis' claims about emancipatory action research,

*All the passages (about emancipatory knowledge) appear to deny the possibility that teachers' self-understandings of their practices can alone constitute a source of critical self-reflection and emancipatory action. The authors neglect the ambiguities, conflicts and tensions contained within these self-understandings and therefore do not seriously entertain the possibility of self-generating, reflexive and critical pedagogy emerging as a form of action research. It is a possibility which renders false the distinction Carr and Kemmis draw between a 'practical' and 'emancipatory' paradigm of action research.*

Elliot, 1991, p117
He argued that a ‘self-generating critical pedagogy’ is possible as a form of ‘creative resistance to the hegemony of the state’ and cited the examples of approaches to teacher appraisal included in his book as evidence of this.

Ebbut, a colleague and collaborator with Elliot, added yet another example of a schema (1983) to the literature, this time as a result of dissatisfaction with Elliot’s interpretation of Kemmis’ ideas and a criticism of the ‘spiral’ notion. He claimed that the

... appropriate way to conceive of the process of action research is to think of it comprising of a series of successive cycles, each incorporating the possibility for the feedback of information within and between cycles. Such a description is not nearly so neat as conceiving of the process as a spiral, neither does it lend itself quite so tidily to a diagrammatic representation.

Ebbutt, 1983, quoted in Hopkins, 1985, p35

His proposed schema is Figure 6.4 below.

**Figure 6.4: An idealised representation of the process of action research** from Ebbutt, 1983
A different contribution to action research has been made by Jack Whitehead at the University of Bath, who like Elliot, has been instrumental in encouraging communities of action researchers to collaborate. His approach to action research is underpinned by the notion of a ‘living education theory’ (Whitehead, 1989b) which can be created by action researchers attempting to answer the question, ‘How do I improve what I am doing by living out more fully my values in my practice?’. It is created, he claimed, from the explanations which individuals give for their own educational development when answering such questions. It is not, in contrast to Carr and Kemmis’ perspective, underpinned by a reliance upon critical theory, although Whitehead acknowledged the need for teachers to adopt a ‘critical stance’ (Whitehead, 1991, p60). He has constantly emphasised, in his writings and work with teachers, the importance of the practitioner being at the centre of the enquiry and having control of it. To reinforce this he introduced the concept of the ‘living ‘I’’. It is interesting to note this concept resulted from reflection upon a videotape he watched of his science teaching (which is very similar to my own experiences described in Chapter 1). He was ‘shocked’ to see himself having the opposite effect on some pupils to the one intended (1989a, p5). He saw himself as ‘living a contradiction’ in his practice, a contradiction in terms of holding together ‘two mutually opposite values in action’. This led him to recognise that the ‘I’, which he went on to see as fundamentally included in action research questions was not simply a pronoun subsumed under a general concept such as person or teacher. The individual’s uniqueness in terms of values and her/his “unassailable and inalienable integrity” must, in Whitehead’s view (reported in McNiff, 1988, p37) be paramount in any approach to action research. Whitehead’s approach leads to the need for teachers’ values to be made explicit when they engage in action research and changes resulting from that engagement must be embodied in their practice. He rejected the schemata proposed by others and used a set of statements to describe the process, which informed the earlier more general section on the nature of action research:
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i. I experience a problem when my educational values are denied in practice;
ii. I imagine ways of overcoming my problems;
iii. I act on a chosen solution;
iv. I evaluate the outcomes of my actions;
v. I modify my problems, ideas and actions in the light of my evaluations (Whitehead, 1989b).

Although not explicitly a 'constructivist', Whitehead has recognised the active and constructive nature of the development of his own knowledge, for example when he referred to 'constructing an explanation for my own professional practice' (Whitehead, 1989a, p5). However, he has placed considerable emphasis upon the social construction of knowledge by referring to the importance of discussion and dialogue amongst communities of action researchers as a means to creating a 'living educational theory'. Like Carr and Kemmis, he found the view of personal knowledge articulated by Polanyi (1962) appropriate to inform his epistemological assumptions.

It is also a key feature of his work to advocate the use of a dialectical form of communication about enquiries as opposed to a propositional form, such as that adopted in this thesis (Whitehead and Lomax, 1987). The authors claim that that paper provided an example of a dialectical mode of communication which helped them develop their understanding. Lomax states:

... the logic of question and answer can incorporate different world views, different propositional content. We have been able to emphasise the similarities in our different approaches and at the same time use the differences as a stimulus for further self-reflection. The logic of the form of discourse has helped me expose views about practice ...

Whitehead and Lomax, 1987, p187

Whitehead established the four criteria for self-validation, mentioned in the previous section, concerning methodological (scientific), logical, ethical and aesthetic standards (Whitehead
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and Foster, 1984). This leads to questions such as:

i. Was the enquiry carried out in a systematic way?
ii. Are the values used to distinguish the claim to knowledge as educational knowledge clearly shown and justified?
iii. Does the claim contain evidence of a critical accommodation of propositional contributions from the traditional disciplines of education?
iv. Are the assertions made in the claim fully justified?
v. Is there evidence of an enquiring and critical approach to an educational problem?

These provide another appropriate framework for considering my own enquiry later in this thesis.

Winter (1989) provided another informative guide to would-be action researchers which focused upon the significance of the process of reflection, which he claimed others had treated as unproblematic (p25), the ‘positivist echoes’ within some variants of action research (p31) and crucial practical questions about the extent to which action research procedures can be economical, specific, accessible and rigorous and how the research might be appropriately written up and communicated. To answer these he proposed a set of principles for action researchers. These were:

i. reflexive critique, based on the premise that "a reflexive judgment is inevitably bent back into the speaker's subjective system of meanings, but creates an illusory straight line which suggests that the judgment is an objective description of a reality external to the speaker" (p41). He recognised that in everyday communications reflexivity must go unnoticed; but for the action researcher “the recognition and analysis of reflexivity (through the questioning process of a research stance) is a way of increasing its validity by showing more
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...fully its foundations" (p42). This means accounts need to be collected, the reflexive basis made explicit and claims transformed into questions and a range of alternatives suggested;

ii. dialectical critique - proposed as a method of analysis which "genuinely prises apart our familiar ideologies, without suggesting that we have available an infinite choice of alternative interpretations" (p46). It entails "investigating the overall context of relations which gives them a unity in spite of their separateness, and the structure of internal contradictions - behind their apparent unity - which gives them a tendency to change" (p52). This echoes Whitehead's belief (see above) in the dialectical form of communicating action research;

iii. collaborative resource - concerning the relationships between the researchers and others and the recognition that the process of mutual challenge between accounts allows "modest claims to 'objectivity'" (p59);

iv. risk - in terms of the researcher's provisional interpretations, the researcher's decisions as to questions at issue and the researcher's anticipations of the sequence of events through which the investigation will pass;

v. plural structure - action research accounts cannot be reduced to a consensus and "must be presented in terms of the multiplicity of view points" (p62);

vi. theory, practice, transformation - recognition that "theory and practice are not two distinct entities but two different and yet interdependent and complementary phases of the change process" (p66).

These principles provide another framework for analysis, although let me warn the reader
that acknowledgement of the framework does not at this stage mean it is endorsed as appropriate for the particular research activity in which I engaged. It is also interesting that Winter’s ideas are expressed in a propositional form and there is limited evidence that they are grounded in his own personal experience of engaging in action research.

A member of Whitehead’s community of action researchers was McNiff, who produced another useful and practical guide for classroom researchers (1988) in which she addressed a problem with previous approaches to action research: the way in which the schemas proposed fail to indicate how a teacher might deal with multiple concerns. Her solution was to propose a new derivative of action research which she described as ‘generative’. This recognised the reality of classroom contexts as one where practitioners will raise and want to address a variety of related concerns. Her model allows this. Her approach also, she claimed, provided the need, lacking in some other approaches, for explanatory adequacy. It allows one theory to create new ones. It resulted from her dissatisfaction with other approaches to theory, including Kemmis and Elliot, since they failed to provide explanatory adequacy. What she considered was needed was a theory “with generative capacity to allow for spontaneous, creative episodes” (McNiff, 1988, p43). Figure 6.5 illustrates graphically the generative model. This model is the one which I intend to develop in later chapters.

Figure 6.5: Generative action research model
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The next section discusses an alternative view of practitioner-centred research to inform the discussion about some of the key issues that have arisen so far. Hopkins (1985), whose guide to classroom research has been used as a key text on courses I have run, provided a critique of action research (p39). This was based upon his interpretation of the values, purpose and practice of its originator (see Section 6.4) and the prescription and constraints imposed by schemata. In an earlier paper (1984) he was also critical, like Gibson (see above), of the developing rigid orthodoxy resulting from Carr and Kemmis which had the potential for as much control and conformism as action research advocates were trying to overcome. He also criticised teachers’ accounts of their classroom research as lacking rigour and falling into what he called ‘the Self-Monitoring Trap’ by claiming the accounts do not need to be validated (p97). This is a criticism also made by Solomon (1992a, p137). Hopkins preferred the term ‘classroom research by teachers’ (p41). This reconceptualisation of the teacher-as-researcher is significant, and in the view of Denley (1987), provides a perspective which is closer to Stenhouse’s original notion than “the possible orthodoxy suggested particularly by the Deakin (see Section 6.4) variant of action research” (p187). Rather than teachers using the complex and prescriptive schemata (as Hopkins saw them) he advocated the use this sequence which was, however, still cyclic:

i. Data gathering;
ii. validation of hypotheses (against further data);
iii. interpretation by reference to theory, established practice or teacher judgment;
iv. action for improvement that is also monitored by classroom research techniques
(adapted from Hopkins, 1985, p114).

In some senses he accepted a conventional social science rationale for the collection and interpretation of data and placed less emphasis on the nature of problem generation (Winter, 1989, p14). However, his was a more pragmatic approach to practitioner-centred research which does not lead to an overtly political claim for its potential which characterises some other perspectives.
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He established criteria for such activities which address ethical and pragmatic issues which are relevant in the context of my own enquiry and the enquiries linked to inservice activity. They were:

i. the research activity should not interfere or disrupt the prime role of the teacher, which is to teach;

ii. the method of data collection must not be too demanding on the teacher's time;

iii. the methodology employed must be reliable enough to allow teachers to formulate hypotheses confidently and develop strategies applicable to the classroom situation;

iv. the research problem should be one to which the teacher is committed;

v. the researcher has addressed ethical issues relating to the work.

I find these useful although the use of the term ‘reliable’ causes me some difficulties which I will explore in Section 6.5.

Hopkins provided, according to Denley (1987), an example of how Schon’s ideas of the reflective practitioner might be interpreted in an educational context (p172). Schon (1983) offered a view of professional knowledge that contributed a great deal to various approaches to practitioner-centred research. His criticism of ‘technical rationality’, discussed by Denley (1987, p172), led him to recognise the importance of ‘problem-setting’ as opposed to ‘technical rationality’s’ emphasis on professional problem-solving. He set out to understand professionals’ knowledge based on a close examination of what they actually do:

Competent practitioners usually know more than they can say ... they often reveal a capacity for reflection on their intuitive knowing in the midst of action and sometimes use this capacity to cope with the unique, uncertain, and conflicted situations of practice.

Schon, 1983
Consequently, he proposed an epistemology that recognised practitioners' tacit knowledge, implicit in their patterns of action. This epistemology was based upon professional's 'reflection-in-action', used in their daily lives and involving stepping back from the action, and 'reflection-in-practice', occurring later and also involving reflection on the 'reflection-in-action'. Reflection-in-action is a criterion, in Schon's view, for a practitioner becoming a researcher in their professional role. Winter took this concept further in his treatment of 'reflection' as we saw above.

The attempt to provide a sound intellectual basis for action research, which has developed in various academic institutions around the world has led to other concerns. Somekh (1989) raised an issue that I came to share as I attempted to bring together a wealth of different perspectives for this chapter;

I am concerned that the definition of action research has somehow narrowed ... I find myself wondering how we have come to see it as something complicated. By some perverse process we seem to have built an ivory tower around it and turned it into something exclusive ... I want to reaffirm action research as belonging to teachers.

Somekh, 1989, p1

Elliot (1991, p14) also expresses considerable concern about labels like 'educational action research' and 'teachers as researchers' in terms of the way academics use them.

And so we find teacher educators and educational researchers propagating ideas like 'educational action research' and 'teachers as researchers' as if they could be applied to any sort of practice in schools, regardless of teachers' conceptions of education, knowledge, learning and teaching, and regardless of the institutional and social context of their practices.

He is not proposing a different label, but a need to return to teacher ownership of these activities.
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The next section highlights the key issues that have arisen as a result of this review.

6.5 Key Issues in practitioner-centred research

6.5.1 The nature of theory and practice

It is claimed in the literature that action research offers a different concept of the relationship between theory and practice to that offered by either positivist or interpretivist paradigms. For the positivist, theory precedes practice and indeed an aim of positivist researchers is to generate theories that will inform practice. Interpretists regard theory as arising from practice and being generated from the accounts of participants in social situations. It is also intended to influence future practice but as with positivists' research this is dependent upon the practitioner appreciating the relevance and significance of theory and applying it in her/his own unique way to the particular context in which she/he works. By contrast action research leads to a view of theory and practice as two inextricably linked elements as we see in the view of Carr,

> The relationship between theory and practice is not one of applying theory to practice; nor is it a matter of deriving theory from practice. Rather by recovering self-reflection as a valid category of knowledge, the critical approach interprets theory and practice as mutually constitutive and dialectically related. The transition is not from theory to practice or practice to theory, but from irrationality to rationality, from ignorance and habit to knowledge and reflection.

Carr, 1986

Self-reflection is therefore a means, according to action researchers, of generating theory. Carr and Kemmis saw discourse as the most valuable vehicle for this. Whitehead placed emphasis on the use of dialectics as fundamental to creating 'living educational theory'. His view of educational theory was:

A living theory in that the explanation contains evidence of an evaluation of past practice, evidence of an intention to produce something not yet in
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existence and evidence of the present practice through which the intention is being realised ..... Educational theory is being created through the theorising of individuals about their own professional practice as they attempt to improve the quality of their own and their pupils' learning.

Whitehead, 1989a, p6

The view of theory and practice adopted by 'educational action researchers' is related to the concept of 'praxis', in that practice is understood by action researchers as informed, committed action. Such action arises from the practitioner's commitment to be 'wise and prudent' (Kemmis, 1982, p38). It is, as stated above, action which is informed by 'practical' theory, and which in its turn may inform and transform the theory which informed it. Whitehead (1991, p108) sees 'living educational theory' as 'embodied' in the sense that practitioners' descriptions and explanations of present practice contain both evaluations of past practice and an intention to produce an improvement in practice which does not, as yet, exist.

There is a recognition that practitioners act in the light of their existing knowledge and understanding. This consists of their 'theoretical' understanding originating from their own personal experience and from the experience of others, perhaps communicated through the literature or professional development activities. It also comprises their specialist professional knowledge of a subject or pedagogy and finally, but not less significantly it includes their "common sense conceptions, categories and rules, concerning what is normal and what makes up the range of foreseeable possibilities" (Winter, 1989, p66). All of this is organised in a 'unique' way by each individual who must personally and actively construct her/his ideas. This informs the practitioner's action and as a result of action the personal knowledge and understanding is transformed and restructured. In this sense a constructivist epistemology can be used to account for the action researcher's view of theory and practice.

Linked to the discussion related to theory and practice is the issue of generalisability, introduced in section 6.3. Action researchers do not make claims to generalisability that are
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of the same order as those of positivist researchers. The ‘findings’ of action researchers are not intended necessarily to be applicable to others, although as I hope will be the case with the present research, the insights an individual gains into her/his own practice can be helpful to others in informing decisions they might take about how to improve the quality of learning.

To return to Stenhouse’s concept, research findings are “provisional specification claiming no more than to be worth putting to the test of practice” (Stenhouse, 1975, p142), if, of course, the individual practitioner considers them an appropriate means of enhancing their own practice, in the context of their attempts to answer the question “How do I improve the quality of my practice?”. Another aspect of the issue of generalisability is to recognise the extent to which the approach is generalisable (Whitehead, 1989a, p6). It is this question I wish to address later in terms of what I see as innovative about my own attempts to be an action researcher.

These views of the nature of educational theory derived from practitioners’ action research do not negate the value of other educational theories, be they derived from positivist or interpretive perspectives. Indeed as noted in the last paragraph such ‘theories’ are personally constructed by individuals to become part of the overall knowledge-base upon which they can draw.

The research in which I engaged did, I hope to establish later, lead to a development of my own professional knowledge and understanding through my attempts to structure my existing constructs and restructure them in the light of experiences. Whether this generation of ‘personal educational theory’ contributes to the overall corpus of educational theory is for the reader to decide. I should at this point, however, not make claims for my contribution which are inappropriate. My intentions at the beginning of this research were to improve my practice, to improve the quality of adult learning for those with whom I worked, and add to my own understanding of that practice. This understanding was intend to make a useful and constructive contribution to the body of tentative knowledge available to other practitioners. In that sense, I aimed to contribute to the ‘technical’ and ‘practical’ domains (in Habermas’
terms). I did not, however, have intentions of contributing to the ‘emancipatory’ domain, if
indeed that is possible. It may be that there is a contribution evident in my account, but it was
not a purpose identified at the outset. Similarly, the process in which I engaged and the
means of my communication of that process were not intended to contribute to the creation
of ‘a living educational theory’ in Whitehead’s sense. Again if the community of action
researchers find in my account, despite its propositional form of communication, evidence of
that it will not have resulted from an explicit intention. In conclusion, I have set out to make a
theoretical contribution through action research but recognise that contribution to be
focused upon the ‘technical’ and ‘practical’ domains. In doing this, I do not, necessarily reject
the political potential for action research at a macro level, although I have considerable
doubts about this potential, particularly in a political climate that has led to centre-dominated
curricular policy on an unprecedented scale. My claim is to use action research in a more
pragmatic way as an appropriate approach to a particular concern related to my professional
activity.

6.5.2 The use of schemata

The review of approaches above introduced a variety of different ‘models’ to describe the
process of action research. However, all models of this type are problematic for a number of
reasons. For a start they imply there is only one way of doing action research, that life follows
one particular route and that each stage is sequential. The world of educational practice,
which action researchers claim is what their approach attempts to explain, is complex and
does not lend itself to the straightforward use of such processes. Encouraging teachers to
use this ‘technology’ of action research may lead to inappropriate adherence to the model
and consequently inhibit their autonomy and independent action - hence negating one of
the key claims for action research. The models proposed, however complex, are all
essentially prescriptive in terms of stages, but offer little in terms of what each stage involves
in terms of what the practitioner does and how. McNiff (1988) saw them as “prescriptive rather
than descriptive, observational rather than explanatory” (p33). This is not to say that the
models have no value. I have found them helpful in recognising some essential elements of action research. They provide a useful starting point for 'new' action researchers as long as they are approached critically and it is recognised that some teachers find them rigid and confusing. They do provide a means to share with others the nature of action research, which I have found useful. However, my own naive view of action research, as an activity essentially tied to such a schema, has changed considerably during the 'process' in which I actually engaged, which does not lend itself to such simple analysis. It is appropriate at this stage to reflect upon one of my previous attempts to support teachers in action research enquiries. The classroom research course I ran in 1987 (Ritchie and Ollerenshaw, 1989) was one in which was in retrospect clearly 'technical action research' with an attempt to move to 'practical action research' (in Carr and Kemmis' terms). Although the teachers involved were encouraged to identify their own concerns, this was within a fairly rigid framework provided by the tutors. Our intention was to give the teachers 'ownership' of the enquiry but it was in the mode of cooption rather than cooperation or collaboration (Kemmis, 1982, p41). That is not to say that towards the end of the project cooperation was not evident, and aspects of collaboration were developing and were fundamental to our original aims. Indeed follow-up support groups and on-going enquiries which went on at least two years after the 'course' are evidence of this (see Ollerenshaw and Ritchie, 1993). The extent to which this early attempt at encouraging practitioner-centred research was successful in changing teachers' view of professional development is evident in these quotes from participants:

It's the first time I've ever felt I had control of my own professional development.

It was something of a surprise to find, on the first day of a course, that we were to learn about classroom research by starting straightaway on our own projects (a reflection perhaps, on what we expect from inservice courses). However, in spite of, or perhaps because of, encountering many problems on the way, this has proved to be a very exciting and effective way of learning.

Ritchie and Ollerenshaw, 1989, p23
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This form of inservice education, which provided me with my first experience of attempting to facilitate classroom research, was based upon the schemas outlined above. Although no rigid adherence to a particular model was required, a process constraint related to the structure of the course and time available for collaborative classroom activities was more problematic. However, we did encourage the classroom researchers to focus closely upon one key concern. This proved difficult and most pairs (since they worked collaboratively) found related concerns 'interfering' with their enquiries.

The majority of schemata do not allow for novel situations within the main focus and consequently with multiple concerns. This became a key issue during my research. My own work with teachers on inservice activity based upon action research had encouraged them to focus on a key concern to the exclusion of others that arose. This I found inappropriate during my own research as I will explore later. McNiff's attempted to deal with this by proposing a new model is helpful and does not suffer from being prescriptive like others. It is essentially descriptive and as discussed above her notion of 'generative' action research does provide for explanatory adequacy.

Denley (1987) also recognised the problems with schemata and added, tentatively and with reservation, his own representation as a Venn diagram (see Figure 6.6), stressing the overlap between phases. This has value in stressing the phases inter-relate, but it still runs the risk of implying a strict sequence.
During my own research I found myself reflecting upon the similarities between these schemata and those used to describe children's problem solving and design and technology (County of Avon, 1986). This is an area addressed in some depth by Haywood (1992). I recognised the limitations of the models used to illustrate the nature of design and technology, as did others (APU, 1987), and my own contribution to that debate (see Figure 6.7) was to propose a model that indicated the fundamental interaction between thought and action (drawing upon the APU's view) and illustrating that there were key phases in design and technology but they were phases that were not necessarily tackled sequentially and indeed a learner could be engaging in two simultaneously. The purpose of the model was to indicate phases of the activity in which the learner would engage without suggesting they were hoops to be jumped through in a particular order. It was an attempt to be descriptive but not prescriptive. It seems the model could be adapted for action research (see Figure 6.8) and it is offered as a tentative contribution to be revisited in the light of my reflections on the 'real' activity of action research. A key difference with the action research diagram is the way the circular arrows are used to indicate the key sequence is Plan, Act, Observe and Reflect although the phases interact in complex and non-linear ways.
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Figure 6.7: A model of the design and technology process
from Ritchie, 1989, BEd Course materials (unpublished)

<table>
<thead>
<tr>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>(about a perceived need or opportunity)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Generate a design</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>ACTION</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Evaluate</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Plan</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>THOUGHT</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Implement</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Outcome/product</td>
</tr>
<tr>
<td>(Artefact, environment or system)</td>
</tr>
</tbody>
</table>

Figure 6.8: A model of action research

| An intention to improve the quality of learning |
|                                              |
|                                              |
| Plan                                          |
|                                              |
| **PRACTICE**                                  |
|                                              |
| Reflect                                       |
|                                              |
| Act                                           |
|                                              |
| **THEORY**                                    |
|                                              |
| observe                                      |
|                                              |
| Improved practice /                          |
| improved understanding of that practice      |

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To conclude this section, I recognise the limitations of schema as a means to communicate the nature of action research and consider a broader description such as Whitehead’s more useful (see page C6: 35). I also recognise the need for action research approaches to allow for practitioners to deal with multiple concerns if they so choose.

6.5.3 Validity of action researchers’ claims

The review of the literature and discussion of approaches to action research has indicated that validity is a key concern of action researchers and those attempting to provide a sound intellectual basis for action research have approached this in different ways. There is no doubt that action researchers should strive to make their claims valid and the literature provides numerous approaches to this. In particular Winter (1989) and Whitehead’s (Whitehead and Lomax, 1987) frameworks have particular relevance to action researchers who are making claims to have generated ‘emancipatory’ theories or ‘living educational theories’. The approach to validity for my own work will be considered in the next chapter. A related issue is whether action researchers should address ‘reliability’. By this term I mean the extent to which results could be replicated by another researcher adopting the same or different techniques. Reliability concerns the question of whether the data is a product of the research technique employed (Hitchcock and Hughes, 1989). This seems to raise considerable problems for action researchers. The uniqueness of social situations makes replication impossible. A scientist investigating the behaviour of a material under load will certainly want to ensure the results could be replicated by another scientist working in a different laboratory with different tools. Hopkin’s (1985) proposed teachers engaged in classroom research should adopt a social science interpretive approach to reliability and validity (pp105-115) However, the purpose of action research, as we have seen, is distinctly different from that of the positivist scientist or the social scientist and therefore the question of reliability needs addressing differently. When an action researcher is using a particular technique, such as a structured interview, it is appropriate to consider its reliability. However, data collected to produce as accurate a picture as possible of a classroom situation to allow
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informed decisions about practice will never be complete and in that sense reliability becomes a less straightforward aim for the researcher. In terms of both reliability and validity the crucial aspect is the extent to which an action researcher can claim to have been rigorous and conducted a relevant enquiry (Haywood, 1992, p150). In terms of rigour, the extent to which an action researcher has been systematic in data collection, analysis and interpretation is the key, and validity is more significant than reliability.

6.5.4 The action researcher’s use of other perspectives

A possible criticism of an action research approach is the extent to which it may be regarded as ‘inward-looking’. The emphasis upon the practitioner as the centre of the process; as the autonomous ‘owner’ of the process assuming full control of its aims and methods, and its reliance upon the generation of theory through the individual accounts of specific classroom experiences means action researchers should be alert to the issue. One response to this is to reiterate the extent to which advocates of action research endorse the importance of collaborative work and the significance they attach to communities of action researchers striving to engage in discourse or dialectical communication. However, the extent to which action researchers draw upon experience from others, beyond their community and particular subject domain is also significant. My own work has been informed by a variety of different perspectives, some based upon research developed within a positivist paradigm, others from interpretists’ work. Fellow professionals, within my own institution and beyond, have provided me with insights that have played an important part in my professional development through this research. These different perspectives have been supportive in a number of ways. The use of data collected by and from colleagues and students has enabled a form of triangulation to add to the validity of my claims. Other perspectives on my analysis of this data has been informative and the contribution of others (directly and through the literature) to my thinking about the range of options available to me in addressing my concerns has been vital to ensuring I have adopted the most appropriate changes to my practice. Indeed ongoing discussions with colleagues who are critical of action research
have informed my thinking about this particular issue. McNiff claimed action research is ‘holistic’ and not subject-based (McNiff, 1988). My use of action research as a tool for my own professional development has been based upon a desire to retain an holistic perspective and therefore I recognised that my work would necessarily draw upon a wide field. I intended to indicate in the contextualising chapters (2 to 6) that my own practitioner-centred research has been outward looking and has drawn upon a diverse but relevant field of literature and experience.

6.5.5 Ethical concerns for action researchers

Action research is an approach which like any other research activity required due attention to be given to ethical considerations. Fundamentally, it is essential for an action researcher, or anyone engaging in practitioner-centred research, to ensure that the activities are compatible with other professional responsibilities. This was the first criterion established by Hopkin’s (1985, p41). For example, action researchers should not implement suspect or inappropriate teaching strategies in order to test out ideas. Their primary responsibility is to ensure that they teach children in their care as well as they can at all times. At no times must action research lead to exploitative or destructive activity (Winter, 1989, p23). Action researchers who recognise that their practice almost inevitably involves a denial of their values in action are placing ethical considerations at the centre of their enquiries. The values which underpin a practitioner’s approach are made explicit and in that process the ethical foundations for the enquiry are firmly established. Elliot states that “since ethical choice implies an interpretation of the values to be realized, reflection about means cannot be separated from reflection about ends” (Elliot, 1991, p51).

A more traditional ethical issue concerns the way in which an action researcher deals with data collected and the accounts of others. The openness of an action researcher’s approach is pertinent here. Unlike some positivist or interpretist researchers who consciously attempt to disguise the purpose of the data collection the action researcher is more inclined to make
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explicit to other participants in the social context what is going on and why, in order to encourage their involvement. This is certainly the case in my own work with adult learners and most ‘guides’ to classroom action research encourage would-be researchers to share data with those involved (Elliot, 1991, p58), not least to improve the validity of claims resulting from the data. This does not mean that ethical issues about the use of data are unimportant and the next chapter will address my own response to these issues drawing upon the useful guidelines produced by Winter (1989, p24) and Kemmis and McTaggart (reproduced by Hopkins, 1985, Appendix B).

6.5.6 ‘Process’ and ‘content’ concerns of action researchers

In this chapter the process of action research has been central to the discussion and the focus for the intellectual foundations for the approach. However, there is a parallel to the discussion in Chapter 3, about the relationship between ‘process’ and ‘content’ in terms of the science curriculum and approaches to implementing that curriculum. The emphasis on ‘process’ in primary science prior to the late eighties devalued the importance of scientific content and the importance of developing scientific knowledge and understanding. In a similar way there are aspects of action researchers’ focus upon ‘process’ which tend to devalue the ‘content’ of their enquiries. Let me clarify the way I am using these terms in relation to action research. The ‘process’ is taken to be the way of approaching and conducting the enquiry and the issues involved in this; ‘content’ is the focus of the enquiry. In my enquiry the ‘content’ is primary science INSET and initial teacher education, and in particular a constructivist approach to work with adult learners. I do however recognise that some would consider the ‘content’ of action research to be concerned with the literature concerning different approaches and its intellectual underpinning. In terms of my meaning, all action research enquiries have ‘content’ in that they are about, for example, some aspect of the curriculum or pedagogy. In my view, the discussion about this ‘content’ should not be seen as of secondary importance. My enquiry and the way I have presented it are an attempt to value the process in which I engaged, and highlight issues related to that process that I
consider may be of interest to others, and the content of my enquiry and the insights it has given me into an approach to teaching which I regard as relevant in the current educational climate.

6.6 Action research and evaluation

My enquiry is both self-evaluative, in that I am concerned with improving my own practice, and an evaluation of an approach to teaching. This chapter has dealt so far with the self-evaluative aspects of practitioner-centred research and in particular the way in which action research can enable this, although the use of action research as part of the evaluation of projects such as the *Schools Council Humanities Curriculum Project* and *Ford Teaching Project* has been explored. This section considers the use of action research as a means of evaluating a teaching approach and inservice activities.

The discussion in Section 6.3 concerning different approaches to research in educational contexts can be paralleled by the way in which evaluation has been approached. Munro (1977) identified two ‘paradigms’ for evaluation which he labelled ‘experimental’ and ‘illuminative’ (p1). These can be seen as paralleling positivist and interpretist approaches to research. An experimental approach to evaluation adopts a similar approach to a positivist researcher and can therefore be criticised as inappropriate in the same way as the approach to research was dealt with in Section 6.3. It was developed and has been used to evaluate ‘objectives-based’ curriculum developments, which are themselves the subject of considerable criticism (see Chapter 3, Section 3.9). The illuminative approach draws upon interpretive research methods and recognises the significance of participants’ views and meanings related to the innovation. Rather than standing outside the innovation to observe and collect data, the evaluator adopting Munro’s illuminative approach will become more directly involved as a participant-observer. However, like the interpretive researcher, the illuminative evaluator is usually an outsider carrying out an evaluation in collaboration with a practitioner. Denley (1987) provides a more detailed treatment of this in contextualising his
own practitioner-centred evaluation project. The essential difference for the action researchers carrying out evaluations is their direct involvement in the innovation. This can have advantages and disadvantages as I will discuss below.

Historically, the work of Stenhouse (1975) was the first to recognise the significance of the teacher in evaluating curriculum innovation and as we have seen his approach to this was to conceptualise the ‘teacher-as-researcher’ and see the contribution made by the teacher as key to evaluative decisions. He and his team were carrying out a large-scale evaluation of a major curriculum innovation, the *Schools Council Humanities Project*. The individual action researcher interested in evaluating an approach or activity has less wide-ranging intentions. For an action researcher, the process in which she/he engages to improve her/his practice has potential for providing evidence of an illuminative type which can be used to make evaluative judgments about the approach s/he is using, especially if as part of their enquiry they are drawing upon evidence of others using similar approaches or working collaboratively with others on a common innovation or approach. Although the insights gained are situational and are not intended to be generalised to other situations there is, I consider, value in sharing those insights in the context of discussing a particular approach or activity to inform others working in a similar area. An action researcher intending to make evaluative comments about an approach may also wish to collect more extensive data, than that considered needed to make specific decisions related to changes in practice, in order to look for illuminative evidence to extend the scope and nature of insights gained and subsequent decisions taken. Stenhouse’s early work on curriculum evaluation was an attempt to avoid the “separation of developer and evaluator” (1975, p121). The use of action research can go further and avoid the separation of developer, implementer and evaluator. The practitioner is responsible for developments to her/his practice, must make those developments work in practice and should be responsible for evaluating their success. An advantage of using action research as a tool for evaluation is that it leads to formative as well as summative evaluation and avoids the disadvantage cited by Kinder and Harland (1991) of evaluation reports documenting outcomes rather than process factors (see Chapter 5, Section 5.8).
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The disadvantage is the danger that it does not draw upon sufficient data from a range of sources and other perspectives to inform evaluative claims. The solitary individual evaluating her/his own innovation, could simply look for evidence to support her/his own preconceived ideas and expectations.

My own enquiry was intended to explore further the dynamic relationship between self-evaluation and evaluation of an approach through the use of practitioner-centred research.

6.7 Conclusions

This chapter is entitled practitioner-centred research and yet its main focus has been upon action research. This reflects a tension in my view of the nature of my approach to this enquiry. The chapter title is intended to emphasise the importance I attach to the role of the individual practitioner in educational research. Throughout the discussion this has been taken as one of paramount importance. My interest in and understanding of the value of educational research is based upon its potential for improving the quality of learning for children, in the case of schools, and for adults in the case of higher education and INSET. Placing the practitioner at the centre of the research and encouraging her/him to take responsibility for and control of it are therefore important. However, although action research provides an approach to practitioner-centred research that I consider to have most potential for my own enquiry my adoption of the label is not without reservations. Action research is, to me, a means for improving my own practice and, in so doing, enabling me to improve the quality of learning of those with whom I work. It also provides a process which I consider offers potential for evaluating an approach to teaching, which I am developing, and for improving my understanding of my own practice and that approach. This chapter has outlined my understanding of this potential and in particular the nature of the practical issues involved and the ontological and epistemological basis for the approach. That epistemology has a constructivist dimension and is based upon a view of knowledge congruent with that which I discussed in Chapter 2. It leads to a view of the relationship between theory and practice...
which I endorse and one that overcomes the problems I have in accepting the view of theory and practice assumed by positivists and interpretists. It is the latter, social science-based, view which causes me to reject Hopkin’s approach to classroom research by teachers’, although its pragmatic aspects are in line with my own thinking. My reservations about the use of the term action research and seeing myself as an action researcher are related, as I noted earlier, some of the claims made for action research which go far beyond my own intentions. The use of action research, as advocated by Carr and Kemmis (1986), as a means to emancipation is not one I have adopted. Similarly, whilst I recognise the use of a dialectical form of communication (Whitehead and Lomax, 1987) as having potential for some action researchers in the course of and as a means of reporting their enquiries, I do not consider my use of a propositional form of reporting inappropriate to my enquiry and its intentions. Whitehead’s concept of a ‘living educational theory’ (1989b) is another aspect of the contribution of action research which at this stage of my professional development goes beyond my own aspirations. In saying this I recognise the nature of the limitations I have accepted whilst working on this enquiry and intend at the end of this thesis to consider those limitations and the extent to which they may have been lessened and the extent to which my future professional development might follow a different route.

In conclusion, I recognise action research to be the most appropriate approach to my enquiry, but my understanding of the nature of action research is one which I have actively constructed as a result of the enquiry and it does not conveniently fit within a specific variant of the action research ‘paradigm’. My understanding of my own approach has been informed by my attempt to examine these other variants and the intellectual basis for them which has been the subject of this chapter. The next will look in detail at my own approach and explore the methodological considerations I addressed in constructing that approach.
Chapter 7 - Methodological considerations

7.1 Introduction
Methodology is more than just the selection and justification for a set of methods and procedures. It is, of necessity, related to the values, epistemology and ontology that prompt and underpin that selection. This chapter addresses the methodological decisions taken in relation to my research activity and the reasons for those decisions. In that those decisions are based upon the values I hold as a professional and my understanding of the nature of knowledge, professional practice and research, this discussion should be read in the context of Chapters 1, 2, 5 and 6. Chapter 1, Section 1.8 included a section in which I stated the values I hold as a professional; Section 1.9 outlined the view of science that I hold; Chapter 2 provided the background for my epistemological assumptions; Chapter 5 highlighted issues related to the professional context in which the research was conducted; Chapter 6 addressed my understanding of action research and its relationship to other research approaches. This chapter provides a more detailed treatment of the practical implications of my research activity and how I intended to address issues raised in Chapter 6 related to action research.

As I have reminded the reader at the beginning of other chapters the chronological difficulties of writing an account of an action research enquiry need to be remembered in the light of reading this discussion. This chapter was written after most of the research activity had been completed, although before Review 4 (see Chapter 9). It is based upon notes and journal entries made before and during earlier ‘cycles’. I have indicated throughout where the dynamic nature of the enquiry led to decisions that were taken during rather than before the research. The chapter begins with a brief return to ontological and epistemological assumptions since decisions about methods are crucially concerned with these issues.

7.2 Ontological and epistemological considerations

In research related to social situations, ontological assumptions about the nature of being are
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fundamental to other decisions. These assumptions will give rise to a related set of epistemological assumptions concerning the nature of knowledge. It is only after a researcher has established these two sets of assumptions underpinning the research that the methodological implications can be addressed. Decisions about methodology will then inform a researchers choice of particular techniques for data collection and analysis.

The ontological assumptions I tentatively accept are:

i. Social reality is, at least in part, the result of individual consciousness;

ii. Individuals' actions are a result of their capacity to choose with purpose and with moral responsibility within the freedom allowed by the social and cultural context in which they operate;

iii. Human behaviour results from meanings that must be accounted for in describing and explaining social situations.

These assumptions cause me to reject a positivistic approach to research and recognise the extent to which aspects of an interpretive approach, which takes due account of an individual's standpoint, should inform my enquiry.

The epistemological assumptions which I have tentatively accepted to inform my decisions about a research methodology are outlined in Chapter 2 and 6. They were assumptions which were explicit in my original proposal, and although my understanding of them has developed during the enquiry I have essentially retained them throughout.

In summary I hold a 'constructivist' view that:

i. Human beings cannot know with certainty that any knowledge is objective and describes 'reality'. It is therefore appropriate to consider knowledge as tentative and subject to change;

ii. An individual actively constructs her/his own unique understanding of natural phenomena and social phenomena, based upon existing ideas she/he holds and
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new experiences or reflection upon existing ideas or those of others.

iii. The social context in which an individual operates significantly affects the knowledge and understanding she/he constructs.

This view of knowledge is again incompatible with a positivist view of research as I discussed in Chapter 6. It is however compatible with the interpretist paradigm. These assumptions lead me to a rationale for my choice of methodology.

7.3 A choice of methodology

As well as this decision being informed by the assumptions established above, it is also dependent upon the purpose of the research and the constraints under which it is carried out.

The fundamental aim for this research activity was to improve the quality of learning for adults I was teaching by attempting to improve my practice, in collaboration with colleagues. In doing this I also aimed to evaluate the effectiveness of a particular approach to teaching being used by my colleagues and I, in order to offer insights to other professionals including my colleagues who might be considering the use of or already using a similar approach. In this sense the research was both self-evaluative and an evaluation of an approach to teaching. Another aim concerned the desire to have an improved understanding of my professional practice and the nature of adult learning. Finally I was interested in developing my understanding and use of practitioner-centred research, again with the aim that the insights gained may inform others who wished to use practitioner-centred research in their own professional contexts.

The research was to be carried out in a way that enhanced and contributed to my teaching and did not interfere with or impede my teaching or that of colleagues. It was also essential that the research activity was practical in terms of the time available for data collection and analysis. It
also needed to avoid putting unacceptable pressure and demands upon my colleagues with
whom I wished to collaborate. This collaborative aspect was particularly significant in the
context of the DES 20-day Course where many of the sessions involved more than one tutor.
With the cooperation of these co-tutors I intended to use data from their work with the groups
as well as that of my own teaching to inform decisions I took.

I wanted to build upon my previous experiences of practitioner-centred research and clarify
and develop my understanding in order to better facilitate classroom enquiries with teachers
with whom I was working on inservice initiatives, such as the School-based Action Enquiry
Unit (CA380) at BCHE.

All of these points led me to choose action research as a method to adopt for the research in
which I intended to engage. I recognised that co-teaching offered the opportunity for me to
gain insights to my own practice by observing and analysing the practice of my colleagues.
This approach would provide additional benefits to those gained by practitioners who limit
their action research enquiries to their own practice. This dimension of the enquiry would also
contribute to my evaluation of the approach to teaching as well as my particular use of it.

My understanding of action research at the outset was less well-developed than the previous
treatment (Chapter 6) may suggest. At the outset of this research I understood action
research to be practitioner-centred and a cyclic process of plan, act, observe and reflect with
the intention of improving practice; I recognised it was not distinguished by the use of a
particular set of research techniques, but by its method; I was aware of the variety of schemata
that were proposed and I had experience of a variety of data collection techniques and data
analysis. I was, however, less familiar with the intellectual basis being established by some
workers (for example Carr and Kemmis (1986), Whitehead and Foster (1984) and Winter
(1989)). My understanding of educational theory and the relationship between theory and
practice, my understanding of the significance of ‘values’ in educational research and my
awareness of the claimed potential of action research for ‘emancipatory’ purposes have
Chapter 7 - Methodological considerations

changed during the enquiry.

Of most significance however is the refinement of my approach during what I came to
recognise as the 'exploratory' and 'investigative' phases (see below). At the outset I was aware
from previous experience (Ritchie and Ollerenshaw, 1989) of the issue of dealing with more
than one concern at a time during an action research cycle. This problem of 'multiple
concerns' that arise for teachers when they look closely at their practice was also raised by
McNiff (1988). During the exploratory phase of my enquiry I was unclear how this might be
dealt with in a practical way - Should a practitioner be single-minded and ignore other
concerns in order to focus upon the 'main' one, should she/he look for ways of dealing with all
of the concerns or find a way of deciding which are most important? To indicate to the reader,
at this stage, that the enquiry was developmental I intend to briefly note one or two references
from my journal. The particular significance of these will become clearer later in the context of
the account of the enquiry (Chapters 8 and 9). My journal indicates the implications of the
issue related to 'multiple concerns' became clear to me in April 1990 when I carried out the first
'review' and I had the idea of a framework for analysing multiple concerns (although at that
stage I called it a 'taxonomy' - I recognised it as a 'framework' in March 1991). The multilevelled
analysis I subsequently carried out, through reviews, evolved during the research and was not
explicitly planned at the outset. A journal entry in October 1989 indicates that a review after
Case Studies 1 and 2 was planned, in the context of planning for the DES 20-day Course, but
the later reviews were natural developments of the research. I recognised the significance of
this approach to analysis in April 1991 as I prepared for a seminar in June. This seminar, at the
University of Bath, was a requirement at the point of transferring from an M.Phil to Ph.D. My
insight into the relationship between the research process and the phases used in my
'constructivist' approach to teaching was first noted in my journal in July 1990 when I was
revisiting the early case studies and working on Review 1. This became clearer over the next
few months as I discussed it with colleagues and my supervisor.

The above, although not obviously material to include in a section on methodology in more
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'traditional' accounts, is essential in the context of this account to remind the reader that the
enquiry was not as sequential and 'tidy' as the following treatment might suggest.

In the following discussion the term 'case study' is used to cover the data collection,
presentation and analysis from specific learning episodes which vary from 2 hours in length
(Case Studies 1, 2, and 3) to 4 days (Case Studies 4, 5, 6, 7, 8 and 9). However, in the case of
Case Study 1, the data and analysis includes interviews and classroom observations carried
out some time after the teaching session. Each case study was also regarded as the
equivalent of an action research cycle of plan - act - observe - reflect. The term 'cycle' is also
used to describe course cycles on the DES 20-day Course. This refers to a four day cycle
(see Chapter 5) of work with a particular content focus.

7.4 Scope of research

My research involved work with several B.Ed. Year 4 student groups at Bath College of Higher
Education (BCHE), from October 1989 to 1990. These groups involved 12-18 students in the
final year of their course. The particular groups were chosen because they were the 4th Year
groups that I was teaching. I selected 4th Year students since I intended to evaluate my use of
a 'constructivist' teaching strategy in terms of developing students' knowledge and
understanding of science concepts, in the context of their use of scientific process skills. The
autumn term of the 4th Year was focused upon improving the students' knowledge and
understanding in the conceptual area of 'energy'. The focus of my other B.Ed. work with third
years, which would also have been possible for research during the autumn term, was
concentrated on the 'processes of science' and was therefore less appropriate. I chose to
collect data during sessions with Year 4 students dealing with concepts related to electricity.
My reasons for this choice were related to the difficulty I had witnessed other adults (both in
previous B.Ed. groups and during inservice sessions) having with this particular conceptual
area. It was one often cited, in my experience, by teachers as an area of science which typified
the reasons that they lacked confidence in teaching science. There is evidence of this in the

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literature (Wragg et al., 1989) which is discussed in Chapter 4. Electricity is an area where I lacked confidence in terms of my own knowledge and understanding and it was therefore an appropriate content area in which to consider my 'concern' about the quality of my teaching.

The sessions during which I collected data lasted 2 hours and were within a weekly series of sessions throughout the autumn term when I had contact with the same group. The groups were of mixed ability in terms of their scientific knowledge and understanding. A small number of the students had studied environmental biology at degree level in the first two years of the B.Ed. course and were taking a concurrent science specialism course (designed to prepare them to be curriculum coordinators in science). They were therefore more confident with science and to some extent had a firmer knowledge base. Others had no science qualifications and limited experience of formal science. Electricity had not been covered previously in any part of the course. The outline for the term's work, the aims for each session and the nature of teaching strategies to be used resulted from planning meetings with the other two tutors involved in teaching Year 4. In that way planning and evaluation of the work was collaborative although I taught all sessions on my own (in contrast to the later DES 20-day Course work).

In addition to data from these student groups I also interviewed a small sample of 2 students five months after the teaching session to elicit any long-term restructuring of their understanding. The same students were observed working with children six months after the teaching session in college to look for evidence of my teaching impacting upon their practice. The time-scale chosen was the result of my intention to use the information to inform planning for the DES 20-day Courses which was taking place in the late spring and summer of 1990. I wished to wait the maximum time after the session within the constraint of analysing the data prior to those planning meetings. The students were selected for two reasons. The first was to do with the nature of their responses during the teaching session and the ideas they held which did not match accepted scientific thinking. The second reason was because, as their Professional Studies Tutor, I was aware of their different approaches to teaching; one being
thoroughly organised and planned, the other more spontaneous and relaxed in her approach. I considered this would provide an interesting comparison. The work with children was set-up by me in a local school and was not part of their school experience. They did not know the children and were asked to introduce simple circuits to a group of 4. They were asked to plan the 45 minute session in any way they chose several days before the session.

Work with B.Ed. students (Case Studies 1 and 2) provided the first two cycles of my enquiry and was the basis for the first review. In retrospect I recognised this as the ‘exploratory’ phase of the research.

The next phase involved work with two inservice groups. These were classroom teachers and science coordinators who had chosen to take the DES 20-day Science Course at the College, outlined in Chapter 5, from September 1990 until July 1991. I was the key tutor for both cohorts throughout the course. My enquiry focused upon the first, second and fourth four-day cycles for each cohort. The third cycle involved me in limited contact with the groups and no direct teaching. I therefore decided not to include it in terms of data collection. The last cycle focused upon dissemination to colleagues and was considered less directly relevant to my purpose. The cycles chosen for my enquiry were those during which I had a significant teaching role, although this varied from between cohorts and cycles as the case study evidence indicates. One cohort was made up of 14 teachers who taught in LEA X, half of whom were science coordinators and one was a headteacher, and the second cohort comprised 16 teachers from LEA Y, most of whom were, or became during the course, science coordinators. I decided to collect data concerning the whole groups rather than concentrate on a smaller target group because of my intention to approach the work holistically and use data collection techniques that reflected my normal teaching strategies. Each course cycle included 3 days based centrally (usually the College) and one day in a course participant’s school (see Chapter 5, Section 5.5.5). Data was collected during all parts of the course cycles. The plans for the sessions are included as Appendix 5. The science conceptual areas covered were identical for both cohorts which allowed me to use insights
from the first group to inform teaching on the second. In that way the case studies can be seen as linked pairs - Case Studies 4 and 5 cover materials, Case Studies 6 and 7 cover forces and Case Studies 9 and 10 cover electricity. The reasons for this choice were dictated by course planning, which was a collaborative exercise involving colleagues at BCHE and Bristol Polytechnic. In the context of the research enquiry the decision provided me with the opportunity to collect evidence of my approach to three different content areas. Materials (AT 6) was selected as the first content area to be addressed by the DES 20-day Course because, unlike electricity (AT11), it was regarded as less threatening to teachers but involving, nonetheless, abstract and difficult conceptual understanding. It was an area of content where it was considered relatively easy to resource and provided ample potential for relevant practical experiences. The first course cycle was intended to provide a content area where the links between processes and knowledge and understanding could be addressed explicitly and where investigative, rather than illustrative, activities were particularly appropriate. Forces (AT10), by contrast was perceived, like electricity, as more difficult in terms of conceptual understanding because of the abstract nature of some of the concepts involved. It was also an area where quantitative work might be explored. The third cycle, which is not included as case studies, covered work linked with the concepts of light and sound. The fourth area chosen for the DES 20-day cycles was electricity which allowed comparison with the B.Ed. sessions and provided opportunities to apply more directly ideas resulting from the first case studies. Follow-up interviews were conducted with a small sample of five teachers (4 from one cohort) in school four to nine months after the final teaching session that had involved data-collection. This data forms Case Study 10 and informed Review 4. The sample for the follow-up interviews was opportunistic, but provided me with a sample of teachers from different phases in rural, urban and suburban schools who had provided evidence during the course of limited confidence for teaching science, limited experience of implementing science in their classrooms and limited background knowledge. The sample, as with the student sample before, was intended to provide illustrative evidence to inform my understanding of the approach that I was adopting and its outcomes, rather than a representative sample that would allow me to make claims of a more generalisable type.
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It will be evident that this research was conducted over a relatively long period from September 1989 until the spring of 1993. The period from October 1989 to March 1991 was the period when data from teaching sessions was collected and analysed. The gap between Case Studies 1 and 2 and later ones was intended to provide time for reflection, analysis and, crucially, to identify a range of potential strategies I could implement and discuss their strengths and weaknesses with colleagues in order to select the most appropriate. This occurred formally as part of DES 20-day course planning meetings during the spring and summer of 1990. Data was, as noted, also collected from interviews in July 1991. The period between October 1991 and January 1993 involved further reflection, background reading and work on the contextualising chapters (2 to 6). The results of other related activity from that period are also in the public domain (Ollerenshaw and Ritchie, 1993). My work on that publication related to classroom application of constructivist approaches and the collection of case studies drew upon and informed this enquiry in a dynamic and constructive manner. Crucially it was also a period when the ideas developed during the earlier phases were applied in a variety of other teaching contexts. January 1993 to February 1993 was an intense period of writing and final analysis.

The following flow diagram illustrates the chronology of my enquiry:

- Research (M.Phil) proposal (September 1989)
- Case study 1 - teaching session B.Ed Yr.4 Group 1 (Electricity, October 1989)
  - Analysis of evidence, identification of concerns and formative evaluation
- Case study 2 - teaching session B.Ed Yr.4 Group 2 (Electricity, November 1989)
  - Analysis, formative evaluation, identification of concerns and action planning
  - Student interviews linked to Case Study (CS) 1 (March 1990)
  - Further analysis of evidence
  - School-based observation linked to CS 1 (April 1990)
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Further analysis of evidence

Review 1: Evaluation of exploratory phase - development of 'framework for analysing concerns' (April 1990)
Planning for DES Course (April - October 1990)

Case study 3 - teaching session B.Ed Yr.4 Group 3 (Electricity, October 1990)
Analysis, formative evaluation, identification of concerns and action planning

Case studies 4 & 5 - DES 4 day cycles (Materials, October 1990)
Analysis, formative evaluation, identification of concerns and action planning

Case studies 6 & 7 - DES 4 day cycles (Forces, November 1990)
Analysis, formative evaluation, identification of concerns and action planning

Review 2 - reflection on progress and proposed action, evaluation of framework (December 1990)

Case studies 8 & 9 - DES 4 day cycles (Electricity, February 1991)

Review 3 - reflection on progress and proposed action, evaluation of framework (March 1991)
M.Phil. to Ph.D. Transfer seminar (June 1991)

Case study 10 - Interviews and classroom observations based on CSs 4 - 9 (July - December 1991)
Reflection / reading / writing / application of ideas in other teaching (October 1991 - December 1992)

Review 4 - revisiting analyses and overall review of progress
Final write-up (January - March 1993)

7.5 Ethical considerations

The significance of ethical issues to action researchers was discussed in Chapter 6; this section addresses the way in which those issues were dealt with in my enquiry. As that
discussion highlighted there are two aspects of ethical considerations related to action research enquiries. They are both equally important. The first relates to the ethical basis for the enquiry in terms of the researcher’s values and the extent to which the research activity is supportive of those values. The second concerns the way in which others involved are affected by the research and the responsibilities of the researcher to those participants, including colleagues involved in collaborative aspects as well as students and teachers about and from whom data was collected.

Practitioner-centred research activities should under no conditions lead to a conscious or premeditated reduction in the quality of teaching or the learning opportunities provided by the researcher. This fundamental principle underpinned my approach. The purpose of the research was to improve my practice and at no time did that purpose get over-ridden by attempts to ‘test out’ strategies which I did not consider were in the best interests of those with whom I was working. At each stage decisions about action were predicated on the assumption that the action would improve the quality of learning for those involved. Any obvious indications that this was not happening, even during the implementation rather than analysis phases, led to modification of the action. This reflected my professional role as a teacher whom, I consider, must respond flexibly in the light of on-going formative evaluation of the situation in which she/he is working. The values I hold as a teacher concerning: respect for individual learners; the right for individual learners to take responsibility for their own learning; the responsibility for a teacher to maximise the learning opportunities and potential for learners, have been the basis for my decisions throughout this enquiry.

In terms of the second area, I adopted the following set of principles (based on those established by Kemmis and McTaggart (1982, pp43-44) concerning my activity:

i. The purpose of my research and the nature of my enquiry was made explicit to all concerned. The nature of the enquiry demanded this openness in order that the views of colleagues and participants could be elicited and used to inform
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decisions.

ii. Colleagues with whom I collaborated in terms of planning, course delivery and evaluation were informed at each stage what I was doing. Data was shared with them and was available for any who wished to look at it or discuss it with me. It was used as the basis for planning meetings and provided evidence for evaluative discussions. This involved colleagues at BCHE during the B.Ed. case studies and with colleagues from BCHE, Bristol Polytechnic and the University of Bath in the case of the DES 20-day Course data.

iii. Permission was sought from students (B.Ed. and inservice) to collect data during sessions and they were told it would be used for research purposes. I pointed out, however, that the collection of data and evidence of their learning was an essential element of the teaching process and would be, and indeed in the case of B.Ed. students had been, part of my normal teaching practice. The difference was the use I intended to make of the data in a research report. They were invited to look at the data and my analysis if they wished. This was available during subsequent sessions, referred to, and on occasions reproduced and circulated during sessions for comment and discussion.

iv. Permission was sought from colleagues to include data related to their work on the DES 20-day Course during enquiry cycles. However, in the reported data confidentiality was ensured by using different names.

v. Concerns that arose as a result of data analysis were shared, when appropriate, with students and colleagues and their advice sort on the nature of the concern and possible actions that could be taken.

vi. Colleagues were kept informed of progress and the outcomes of the enquiry
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were reported during planning meetings and informal discussions.

vii. Although data had been collected in an open way and shared with students, and their permission to use it had been obtained, I decided to maintain the anonymity of individuals involved by the use of initials and changed first names in Case Studies 1, 2 and 3, first names in Case Studies 4 to 9, and not identifying groups, cohorts, LEAs or schools. This was to avoid any unnecessary embarrassment to individuals who had been encouraged to expose their existing and sometimes naive understandings of the natural world as well as share details of their own classroom practice.

viii. Permission was gained to work with children in schools (as part of the DES 20-day Course and linked to Case Study 1) and anonymity was guaranteed in terms of the individual children involved.

7.6 Data collection techniques

This section discusses the variety of data collection techniques used during this research. Not all were chosen at the outset as the case studies will indicate. For example concept-maps were selected as a result of attempting to address a particular concern.

7.6.1 Research journal

From the time I took the decision to engage in a research activity for the purpose of obtaining a higher degree I maintained a journal. This is a technique I had previously used in the context of research activity and the benefits of being able to track the development of the enquiry and my own thinking had become obvious. My ‘journal’ took several forms. I had a bound hard-covered A4 book which was used during discussions with colleagues and during teaching sessions to keep notes of proposals and ideas. This I treated as my ‘working journal’. I wrote
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‘current’ notes on the right-hand page to leave the left-hand page free for later more reflective and analytical notes. I also maintained a much more substantial ‘journal’ in a lever-arch file. This was used to keep a ‘diary’ of the enquiry which contained regular entries reporting key activities and my thoughts about them. This was used to reference sections of the ‘working journal’ and recorded significant ideas that occurred to me during the analytical and reflective stages of the work. The larger ‘journal’ also included notes from reading I had done, useful articles, papers from colleagues, session plans, tutorial notes, action plans and a list of questions related to my research. It was in this that my action plans for each cycle were retained. These were usually (in the case of the DES 20-day Course) integrated into the session plans. This journal was a ‘tool’ used throughout in a dynamic and interactive way. It enabled me to deal with the difficulty of maintaining an enquiry over a long time-scale and hold on to the ‘chronology’ involved in the development of my changed practice and my understanding of that practice.

7.6.2 Field notes

Field notes are a means of retaining information about teaching episodes. They are notes written during a teaching session or immediately afterwards. They provide a source of evidence of what happened, an individual’s response to it and a means of highlighting problems or concerns that were immediately obvious. In the case of my work with B.Ed. students (Case Studies 1, 2 and 3) the main form of data collection was audio-taping (see below). As this was impractical with sessions of the DES 20-day course, due to their length and the amount of movement of individuals during practical work, field notes became more significant. However, field notes were kept during all teaching sessions and used to inform the analysis phase. The field notes taken during the exploratory cases studies (1 and 2) provided evidence of students’ practical activity and also covered my general impressions. Later field notes, during DES 20-day sessions were more detailed, noting individuals’ utterances and actions where considered significant and focusing upon issues identified as concerns during Review 1 or previous case study analysis. Field notes are subjective and were not used as the
only source of data in any case study. They complemented other data and provided a useful starting point for identification of concerns during data analysis.

### 7.6.3 Verbatim data collection

Audio-taping was the main source of data for Case Studies 1, 2 and 3. The transcripts made provided specific and accurate data of the teaching episode, although inevitably visual evidence of the students practical activity and body language are not obtained. The length of sessions (1.5 hours) made it more practical than was possible during DES 20-day Course sessions to audio-tape the majority of the session. A tape-recorder can be intrusive and when I asked permission of student groups to record a session their initial reactions indicated they considered it likely to inhibit their talk. However, the data indicated that this inhibiting effect was soon overcome and there was no evidence, comparing their contributions to other non-recorded sessions, that the activity did limit or inhibit responses. Only once or twice is there evidence of their awareness of the tape-recorder. It was placed centrally so that it recorded all my utterances made to the whole group, all of the whole group discussion and the informal talk of one small group. The data collected by this means proved extremely valuable in providing ample evidence of the sessions' content, my role, pacing and the students' responses. However, there are disadvantages, particularly related to the time needed for transcription. Some of the data is of little relevance and the practical problems of operating (for example, changing the tape) did disturb the continuity of the sessions. The transcription problem although time-consuming had some benefits. I found it necessary to listen to the whole tape before starting transcription (often in the car on the journey home after a session) and this 'orientated' me to the data. The slow process of transcription (directly into a word-processor using a 'Walkman' device) provided me with ample thinking time and the process of typing up the data became an important part of analysis. My ideas began to be clarified and concerns considered before a formal analysis began. Indeed during transcription I often made journal entries of significant points.
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Audio-taping provided one method of obtaining verbatim data. During the school-based days of the DES 20-day Course the teachers were also required to collect verbatim data of their work with a small group of children and analyse it. Time did not allow the use of audio-taping for this and so a technique for data collection developed during the Assessment in Primary Science Project (Ollerenshaw et al., 1991) was used. This involved the use of data books in which an observer (one of the pair of teachers who were collaborating) wrote down utterances and actions attributed to individuals involved on pages with numbered lines and space to indicate the time at the top of each. These pages were in three columns. The first was for the initial or name of the person speaking or acting, the second wider column was for data of the utterance and the third was left blank to be used during analysis (see Appendix 9). This means of data collection was extremely demanding upon the observer and usually lasted for a maximum of 45 minutes. However, with the cooperation of the ‘teacher’ (slowing discussion down and allowing only one child to speak at a time) it proved practical and provided a valuable source of data for later analysis and decision-making based upon what actually happened rather than impressions of what happened. The course participants repeated this data collection during each cycle and this provided a source of evidence about their work with children which was used extensively in their assignments and also informed my insights into their practice. Many of them went on to use the technique with colleagues in their own school to support their own enquiries or to provide a professional development activity for the colleague.

The technique was trialled by the tutors on the course during the planning period (June 1990). A group of 6 tutors from BCHE and Bristol Polytechnic worked in pairs with a small group of children in exactly the same way as that implemented on the course. This pilot activity was intended to make us aware of the difficulties involved and ensure all tutors had direct experience of the purpose and benefits of such intensive work with children.
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7.6.4 Collection of student outcomes

As an integral part of the teaching and learning process students (during all case studies) were encouraged to record evidence of various kinds to enable them to track their own learning and to enable me to use the evidence for formative purposes - to inform decisions about tutor actions and ways in which an activity could be developed further. This evidence took a variety of forms and again provided data for research as well as teaching purposes. The advantages and disadvantages of these different strategies is discussed as part of my later account of the enquiry and therefore at this stage the strategies will simply be outlined.

Students often kept personal notes during their practical exploratory and investigative work in their own journals and files. These were made available on request to the tutors to inform one-to-one discussions with students and provide assessment evidence for formative purposes. This process of recording information was sometimes made more explicit by asking the students to maintain a ‘think book’ for themselves, a pair or small group, recording the development of the activity and ideas related to it. In the case of pair or small group work a scribe was identified and individual ideas attributed by the means of different coloured notes or named contributions. The outcomes of small group discussions were also kept through the use of ‘think books’ or ‘floorbooks’. The latter strategy was already common in Wiltshire schools as a means of recording children’s contributions to discussion (see Ollerenshaw and Ritchie, 1993, Chapter 3, for a fuller treatment). They are called floorbooks because they were originally developed for use on the ‘carpet’ with the children sitting around the teacher. The strategy has several advantages: allowing individuals to see their contributions are valued; slowing down the discussion to give teacher and learners thinking time; providing evidence for the teacher of the learners’ current ideas; providing an ongoing record of the development of an activity and the development of the learners’ ideas; avoiding the problem of a teacher editing or altering a learners’ utterances (they are written as they are said without alteration); providing evidence of learners existing language use. All of these advantages apply to adult learners and so the strategy was used during course sessions, initially with the tutor acting as
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scribe, but in later sessions with a group member scribing for the rest of the group.

During large group discussion the outcomes of brainstorming were retained as flip-chart sheets and whenever practical the contributions of individuals were attributed.

Some activities involved students in producing annotated drawings and posters. These provided another source of evidence. On occasions these were modified after exposition or tutor input and students were encouraged to use a different coloured pen to indicate changes made post-tutor-input.

In later case studies DES 20-day Course students were encouraged to produce concept maps (sometimes before an activity or exposition and afterwards to track changes in understanding). A concept map (Boyes and Schilling, 1991; Brodie, 1992; Novak and Gowin, 1984) is a means of gaining insight into the nature of a learner's unique understanding of concepts and links between them. It involves an individual selecting key words associated with the concepts which are the subject of the teaching and linking them in a diagrammatic form. The nature of the link is made explicit by adding further words above the linking line to articulate the perceived link.

The participants on the DES 20-day Course were encouraged to collect similar evidence from their own classrooms related to children's learning. This evidence of children's work and floor-books of children's ideas were regularly brought to sessions and shared within group discussions and analysis. My field notes often drew upon this evidence. As noted in the last section, the school-based days during each cycle provided evidence of the teachers' work with children and some of the children's outcomes from those days were retained by the teachers concerned for later analysis and inclusion in their assignments.

The written assignments (of approximately 2000 words) were another significant source of data for me. The course involved three assignments as follows:
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1. With reference to collected case-studies of work with children and further reading illustrate the way in which the development of children's knowledge and understanding is linked to process skills. This should identify alternative frameworks that children hold in a chosen area of science content and discuss strategies for dealing with them.

2. The production, implementation and evaluation of appropriate assessment activities and procedures for science.

3. The production, implementation and evaluation of an INSET package that is designed to develop the scientific knowledge and understanding of teachers in the course members' school.

These were intended to encourage the course participants to apply aspects of the course to their own school contexts and provide evidence of that application. The support offered them in producing these was intended to help them carry out their own action enquiries based upon course-related concerns, within the constraints imposed by the assignment. All of the assignments submitted (94% for one cohort and 79% for the other) were marked by me and 25% were double-marked by a colleague. A 25% sample was seen by an external examiner. The evidence from the assignments is considered in Review 4.

7.6.5 Other data obtained from students during sessions

At the end of teaching sessions linked to Case Studies 1, 2 and 3, students were asked to produce written evaluative comments about what they considered they gained from the sessions, what they contributed and what 'feelings' they had about it. These were collected and a sample is included in the case study.
Other data was collected from DES 20-day Course participants. During the introductory session they were asked to complete two proformas (see Appendix 10 and 11). The first was intended to elicit basic information about course participants and to provide some indication of their perceived needs. The other was intended to provide evidence of their perceived confidence level in different areas of science in terms of their own subject knowledge base and the professional and pedagogical difficulties of teaching particular content. This was based upon the content areas designated particular attainment targets within the National Curriculum for Science statutory at that time (DES, 1989a). They were asked to rate these on a scale of one to five (good to poor when rating their own subject knowledge and straightforward to difficult when rating how easy the content was to teach). This procedure was repeated at the end of the course and results analysed. This procedure is similar to that used by Qualter and Schilling (1991) and to one reported by Smith and Peacock (1992, p55). Wragg et al. (1989a) collected similar data as part of their study. This data collection and analysis is one of the few aspects of my enquiry which has a quantitative aspect. However, the analysis was based upon calculating mean values and was not intended to be statistically valid. Since data was collected from the whole group of teachers involved in the DES 20-day Course it provided useful data at the start of the course for formative purposes and the comparative data at the end provided evidence for a summative evaluation. However, the results are to be viewed critically as I discuss in Review 4 (Chapter 9).

DES 20-day Course participants were also asked to provide written evaluative comments at certain points during the course (included in the case studies) and at the end asked to complete an evaluation proforma (see Appendix 7). This is similar to those used on other courses at the college for providing evaluative evidence of inservice provision. However, the disadvantages and weaknesses of this form of course evaluation, discussed in Chapter 5 (Section 5.8) are recognised and the data is again used tentatively in the later discussion.

Other informal evaluation data from course participants, co-tutors and visitors (including advisory staff, headteachers and HMI) is referred to in the later chapters.
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7.6.6 Interviews

The section on scope of the research referred to two stages when I collected data from interviews. On both occasions these involved semi-structured interviews intended to elicit evidence of the individual's knowledge and understanding of science in the content area covered by a previous teaching session and (in the case of the interviews linked with Case Studies 4 to 9) elicit insights into the individual's approach to teaching science. The interview schedules are included as Appendix 12. Interviews were necessary to obtain the data I required of the extent to which students retained restructured ideas and allow me to probe language used and explanations given. The choice of semi-structured interviews was to allow me the flexibility to probe responses but ensured that each interview covered similar material to allow comparisons to be drawn. I decided not to provide the schedules to interviewees in advance since I did not want them to prepare responses. I was interested in restructured understanding which informed their everyday decisions and consequently was looking for more spontaneous responses or responses modified during questioning. This reflects the approach used by Kruger et al. (1990a). My understanding of the nature of interviewing for research purposes was informed by Hitchcock and Hughes (1989, p79), Hopkins (1985, p66) and Wragg (1984).

The first interview schedule was focused upon key questions linked to the students' knowledge and understanding of simple circuits and was directly related to the aims of and content covered in the teaching session included in Case Study 1. The last question was included because of a 'alternative idea' evident in the comments made by one of the students who was interviewed. In each interview the same questions were asked but the use of individual words and ideas were probed as appropriate with additional questions. These interviews were not intended to cover the teaching of science to children since with the B.Ed. students that was to be the focus of later observation activities. The interviews were arranged at mutually convenient times with the students involved. They were carried out in the
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The interviews were conducted in an informal manner, intended to provide a relaxed atmosphere. The whole of each interview was taped (with the students' permission). They were carried out on different days and in private. They lasted about 20 minutes. Informal discussion took place after the interview, based upon the case study data, exploring the development of the research since the original session and discussing the student’s memories of the session. The nature of her responses to the interview questions was discussed in terms of accepted scientific understanding.

The interviews with the DES 20-day Course participants were more extensive, usually lasting 45 minutes, and were conducted in the interviewees' classroom, at their convenience. Again it was informal and a general chat took place to relax the interviewee. I asked the teachers for permission to audio-tape the interview and use the subsequent transcript for research purposes. The purpose of the research was reiterated and it was stressed that the interview was not a 'science test', but an attempt to elicit changed understanding as a result of the course. The interview began with a question focusing upon teaching science, either directly related to a comment made on the final evaluation questionnaire or more generally about how the teacher had used ideas from the course. Reference was made by me, if appropriate, to classroom layout, displays or resources. The interview then focused upon the conceptual areas covered by the case studies. Question 2 was based upon an 'interview about instances' technique (Kruger and Summers, 1990, p18; Osborne and Gilbert, 1980a). An initial focus question was asked about a phenomena which is an instance of a particular scientific concept (change of state, in the case of question 2, linked to Case Studies 4 and 5) and further questions were framed according to the responses until the interviewee's ideas have been expressed. Question 3 covered a similar concept again focusing upon an instance. Question 4 dealt with forces (linked to Case Studies 6 and 7) and was based upon the same technique and a similar instance to that used in the PSTS research (Kruger at al., 1990a, b and d). Question 5 was based upon the concept-mapping technique (referred to above) and was intended to provide evidence in a similar content area (forces) that could be compared with
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count concept maps the same students had produced during teaching sessions. The last two questions focused upon the content area of electricity and the same concepts as those covered in the B.Ed. student interviews. Question 6 is based upon annotated drawings, introduced in the teaching sessions. The 'torch' task was the only question which was a direct replication of a session activity. The others required application of concepts in different contexts to those met on the course. For example, a course session covered the changes of state involved when a candle burns and this understanding needed to be related to a paraffin lamp. The final question was an open invitation for the interviewee to identify other examples of changed scientific understanding that resulted from the course.

The data from all interviews was transcribed and written outcomes retained. The data was analysed. Because of the purpose of the interviews, the nature of the verbatim evidence collected and the informal discussions afterwards I decided, with the agreement of interviewees that it was unnecessary to discuss the transcript of the interviews with them. Discussing data with interviewees when opinions are involved is important. However, the data collected was of a more transient, dynamic nature concerning phenomena and therefore of a different type. The analysis of the B.Ed. student interviews informed Review 1 and the later interview analysis informed Review 4.

7.6.7 Classroom observation data

Two students involved in Case Study 1 were observed working with children, as discussed in Section 7.4. The data from these classroom episodes was collected by me using the data collection technique described in 7.5.2. The activity was also audio-taped. The resulting transcribed data, including student and child utterances and data about actions forms part of Case Study 1 and informed Review 1. The transcript of this data was discussed with the students involved.
7.6.8 Other informal ‘data’ collection

Other evidence which has informed my decisions during this enquiry and has contributed to my understanding of my practice has resulted from other informal contact I had with those involved in the groups that I worked with during the enquiry. These have included B.Ed. students I supervised on school experiences and tutored in other contexts; teachers from the DES 20-day cohorts who have taken other inservice courses with me; teachers from those groups I have supervised on other school-based enquiries, an Inservice B.Ed. long study and an M.Ed dissertation; follow-up meetings from the DES 20-day courses (autumn 1991, spring 1992); contact with headteachers and other teachers in their schools on other inservice activity; visits to their schools linked to ITE and inservice activities; telephone calls and visits. Colleagues and advisory staff have also given me informal feedback after having visited a school or had contact with an individual. Although this ‘data’ has to be treated with caution and does not have the validity of that obtained by more direct means it has contributed to the enquiry in a manner, that in the context of a practitioner-centred research activity drawing upon the widest range of evidence available to inform decisions, is appropriate.

7.6.9 Issues concerning data collection

As this section of the chapter has indicated, this research activity has drawn upon a wide variety of different data sources and techniques for data collection. Key to decisions about these techniques has been their practicality and the decision to avoid the use of any technique which would interfere with the teaching and learning process. The most appropriate data collection techniques were those which were an integral part of the teaching activity. These were practical to implement and had the added advantage of teachers being provided with a role model, by me, of how evidence could be collected in their own classrooms for assessment purposes (especially formative assessment). Other data collection, such as audio-taping and interviewing, were not an integral part of the teaching but did not inhibit the teaching significantly, as the student responses to the techniques indicate. However, it is evident that some of the data is first-hand and its validity is reasonably
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It was straightforward to establish, particularly when several different accounts are collected. The data from my field notes, from students and from colleagues co-teaching the DES 20-day Course enabled a form of triangulation (Elliot, 1991, p82; Hopkins, 1985, p110). Comparing the accounts and data led to a more authentic version of events, which increased the validity of the account. Other evidence, such as teachers' accounts of their own classroom experiences in assignments and in information offered during teaching sessions, is more problematic and will be discussed in the section on validity (7.7). In all cases, however, I ensured data collected to inform decisions was as accurate and 'authentic' as it was possible to obtain in the complex social context in which it was collected. The transient nature of much of the evidence, in terms of utterances about tentative ideas, meant that questions of reliability, in terms of whether someone else would have elicited the same utterance (i.e., could the data be replicated by someone else or using different techniques?) were inappropriate.

7.7 Data analysis

The process and techniques used for data analysis evolved during the enquiry. This section discusses the way in which the wealth of data collected was used to inform decisions about my practice and enable me to construct an improved understanding of that practice.

My first consideration of the data collected from the first teaching session (Case Study 1) led me to identify several themes to organise my analysis of the data. This approach was based on Hitchcock and Hughes (1989) analysis of data during ethnographic studies (p74). The themes I identified were:

i. the nature of the teaching approach;
ii. encouraging socially constructed understanding;
iii. the nature of science implicit in the session;
iv. alternative frameworks held by individuals;
v. supporting students' work in the primary classroom;
vii. other general concerns.
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These themes were not simply the result of listening to and transcribing the data. They were also the result of previous experience I had had of working in this way and were based upon my values as a science educator in initial teacher education about the nature of science, the nature of learning and the nature of teaching. These themes were used for analysis of Case Study 1 and this informed decisions taken related to Case Study 2. The same themes were then used to analyse Case Study 2. Throughout the analysis, observations, claims and the origins of concerns are line referenced to allow the reader to consider the evidence upon which I based my decisions. The analysis led to the generation of a number of questions or concerns which were made explicit in the analysis. Some of these I was able to take action on during the teaching session documented in Case Study 2, others needed more thought. In this sense these case studies were exploratory and led to question-raising in the same way that children and adults practical exploration of phenomena, artefacts and materials during science activity is intended to raise questions for later investigation. The analysis of Case Study 1 was revisited and added to after the interviews (March, 1990) and the classroom observation (April 1990), informed by the new data available. At that stage, when detailed planning of the DES 20-day Course was beginning and I wanted to clarify the next action phase, I decided to review the situation and find a way of systematically addressing the variety of concerns that had arisen. I could find no examples of how this could be approached in the literature and therefore decided to devise my own way of dealing with the problem. This led to the identification of several sets of categories to analyse my concerns. The reasons for the choice and the nature of each category and sub-division is discussed in Review 1.

They were:

i. Predicted time-scale required to address concern -

   Short term (next session)
   Medium term (several sessions over a period of weeks)
   Long term (over a period of months)
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ii. Nature of change required -
- Structure of sessions
- Tutor's role
- Tutor's knowledge and understanding of science
- Tutor's knowledge and understanding of professional issues
- Ethos of sessions
- Teaching strategies

iii. Relative difficulty of identifying and making appropriate changes -
- Straightforward
- Possible with effort
- Possible with professional support from others
- Impossible because of constraints.

I then revisited each concern and analysed it in terms of the above and produced a diagram summarising the nature of each concern with an indication of action where taken and where intended. More detailed action plans were maintained in my 'journal'. The diagram was intended to be an accessible reminder of the range of concerns and my intentions. The action plans resulting from these concerns became the plans for the next session, negotiated in a collaborative way with co-tutors. The review included reference to case study analysis, not to original data. This, however, was intended to allow the reader to track back concerns and ideas through the particular case study analysis to the data via the line reference included in the analysis. At the stage of carrying out Review 1 my journal entries indicate I considered the individual case study data and analysis would be collected together in a separate volume from the main thesis. Therefore the review, which would be a part of the main thesis and tell the story of my enquiry, would need to be relatively free-standing, although it would ideally be read alongside the other volume. The review was first recorded in written note form (at the time indicated on the flow diagram) and word-processed over the following weeks using those notes.
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Analysis of Case Studies 4, 5, 6 and 7 was carried out using the same themes as in the first case studies but reference was made to the concerns that had been raised, during the earlier case studies, within those theme headings. New concerns were raised when they became evident. Case Study 4 involved two stages of analysis (after day three and after day four) and action planned as a result of the first analysis was implemented during the fourth day of cohort 1 and also informed work with Cohort 2. The Cohort 2 sessions (Case Study 5) were analysed once and this analysis links closely with that carried out in Case Study 4. It will be evident that the data is different from that collected during Case Studies 1, 2 and 3 in that there are less verbatim tutor utterances. The response of the students to the structure and strategies used were seen as increasingly significant to inform analysis and the nature of data collection techniques meant that the detail available during the early case studies was not practical to obtain and present. Case Studies 7 and 8 (concerning forces) were both analysed once using a similar approach to that discussed above.

December 1990 was identified as an appropriate time for another review. Two DES 20-day Course cycles had been completed for each cohort and the Christmas vacation provided me with some time to carry out the review, reflect upon progress and consider the use of the framework for analysing concerns.

Review 2 was structured around the concerns that had been identified and the extent to which progress had been made towards addressing those concerns. The review involved reference to case studies again rather than specific data although as above a reader could track back any claims to the original evidence. Having revisited the concerns from early case studies and added concerns from Case Studies 4 to 7, I used the framework to analyse them and produced another summary. The rest of the review is then a discussion of current concerns structured in terms of the concerns, not the themes used in case study analysis. In this way my analysis had, by that stage, been approached in two distinct ways, which I intended should add to the rigour of my approach and to the nature of the insights I was
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gaining. At the end of this review I reconsidered the appropriateness and value of the framework for analysing concerns.

Two further case studies followed resulting from course cycles on electricity. These analyses were structured around the original themes, included references to line-numbered data and addressed previously identified concerns.

Review 3 was the natural conclusion to the intense data collection phase. It was again structured in terms of concerns and the revisiting of earlier analyses and consideration of the use of the framework for analysing concerns led to the identification of key concerns and a discussion of progress, conclusions that had be drawn and intended future action. This was the third occasion that I had revisited case study data and my initial analyses in an attempt to refine and develop my understanding of my practice.

The final review (Review 4) which was part of the final write-up phase is structured differently. It includes consideration of data from interviews, course participants' assignments and course evaluation data. I discuss the extent to which there is evidence that the approach had improved the teachers' scientific knowledge and understanding and impacted upon their classroom practice. My concerns are then revisited in a more logical way, structured in terms of the 'phases' of the constructivist approach and focusing in particular on the key concerns that arose during Review 3. Consequently, Review 4 involves yet another level of analysis and an attempt to revisit my concerns from a different perspective, in the light of other evaluative data, to look for new insights and understanding.

Figure 7.1 illustrates the levels of analysis and the relationship between case studies and reviews.
Figure 7.1: Levels of analysis during the enquiry

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Figure 7.1: Levels of analysis during the enquiry

Exploratory Phase

Review 1
April 1990

Investigative Phase

Review 2
December 1990

Application Phase

Review 3
March 1991

Review 4
January 1993

Figure 7:1
Research Process

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In summary, the exploratory phase of my research (Case Studies 1 and 2) involved analysis structured around key themes. The analysis includes line references to specific evidence and led to the identification of a range of concerns of different order. These concerns, formulated as questions, were analysed during Review 1 using a framework of several sets of categories. The review involved revisiting the data and was structured according to the concerns and the order in which they arose. Individual case studies are referenced. Further case studies and reviews involved similar analysis and led to key concerns which became a focus for the final review (Review 4). This was based upon a more logical order, structured according to the phases of the constructivist approach and draws upon other evaluative data. This structure to my thesis means evidence can be traced back from the general to the specific. The different approaches to analysis have required the development of my analytical skills throughout the process of the enquiry.

The treatment of data collection and data analysis has indicated a systematic approach that I adopted in this enquiry. It is not possible to relate my approach explicitly to any of the schemata for action research evident in the literature. The process was developed as the most appropriate to the purposes and scope of my enquiry and the constraints imposed by the context in which it was conducted. It is not a process that lends itself to analysis in terms of a simple diagram illustrating phases of plan, act, observe and reflect, although those elements are clearly evident in the approach adopted. In this sense it has helped me to see my research in terms of the model proposed in Chapter 6 (Figure 6:8). There was a dynamic interaction between phases. As I intend to discuss in more detail in Chapter 11 the extent to which my enquiry can be seen as involving phases of orientation, structuring, restructuring and application has also been helpful to me. The next section discusses the extent to which I have addressed the issue of validity in my enquiry.
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7.8 Validity

Validity, as discussed in Chapter 6, is a concern for all researchers. It is related to the extent to which claims a researcher makes are justified. However, for action researchers validity needs to be addressed in a different way to the way that it is addressed by positivist researchers. Quantitative data resulting from particular tests can be statistically analysed and the results of this analysis are often claimed to prove the validity of the data. However, this tends to see validity as concerned with the test rather than the claims being made. For an action researcher it is the validity of the claims which is of most significance. Claims of validity should also involve demonstrating that the process adopted and the data collection and analysis techniques used were suitable for the purpose and that the researcher had not neglected important factors or areas in the enquiry that should have been considered. The following outlines the procedures and practices I adopted which I consider provide evidence that my claims can be considered valid.

i. The collection of data was as thorough as possible and the techniques I used were used as effectively as my experience and the constraints of the situation would allow. Triangulation was used to authenticate my accounts (see Section 7.6). As Section 7.7 indicated my approach to analysis was systematic and thorough. Analysis occurred at at number of levels and the data was revisited using different frameworks and perspectives. I have made claims in the light of that analysis which can be traced back to specific evidence. In particular, Case Studies 1 and 2 included very comprehensive evidence of my interactions with students. They provide as detailed and authentic account of the session as was possible using practical techniques that I could implement on my own. The analysis of this data was intended, in some senses, to ‘validate’ my skills as a practitioner capable of selecting significant evidence from all that available in order to analyse a social situation and make claims. The reader can judge this by considering the evidence. In later case studies the data is not so comprehensive in terms of all my utterances and actions. The reader is required to accept, based on the evidence of those earlier analyses, that I am capable of making decisions during a teaching situation of
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what is significant in terms of utterances and actions. The validity of those decisions taken
during later teaching sessions is based upon that premise. I also hope that the account of my
enquiry indicates the integrity I brought to the enquiry and my reporting of it. I have attempted
to make my values as a teacher explicit and therefore my claims resulting from my observations
and analysis can be judged in the context of those values to decide if the claims are
educational.

ii. The collaborative aspects of my work linked to this enquiry play a very significant part in
my approach to validity. The data co-tutors and I collected, my analysis, concerns and claims
were regularly shared with my colleagues and used to inform collaborative decision-making
during formal and informal meetings. The co-tutors involved colleagues from BCHE, Bristol
Polytechnic (where an identical course was running), University of Bath and LEA advisory
staff. Not all of these colleagues were convinced of the value of a constructivist approach and
therefore brought a critical perspective to the discussions. They were all, however, committed
to improving the quality of learning for the teachers involved in the courses and this
underpinned our approach to planning and implementation. My data and analysis from Case
Studies 1 and 2 were circulated to all tutors involved in the DES 20-day Courses at both
institutions and formed the basis for an early planning meeting. I also circulated this material to
other colleagues for comment and discussion, both formally at B.Ed. planning meetings and
informally.

iii. The validity of my claims is also based upon the role of the students who had regular
opportunities to view the data I was collecting and respond to my analysis, identification of
concerns and claims. The concerns and my proposals for addressing them were often made
explicit during subsequent teaching sessions and the response of the students was
significant in informing decisions about future developments.

iv. My supervisor (who was also coincidentally a co-tutor during a course cycle) was given the
data and my analysis at each stage and his thorough responses were helpful and another
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element of the validation procedures I used.

v. My ideas and claims were tested out against my professional peers in a number of seminars which I ran, including the following: DES Invitational Conference (April 1991); University of Bath (June 1991); ASE Advisory Teacher Conference (April 1992); BCHE (June 1992). At several of these I provided participants with evidence of my data and analysis to form the basis of discussion.

vii. An HMI visited and observed my work during a full-day on both DES 20-day Course cohorts. His feedback provided further evidence from a new perspective against which to test my claims and this will be discussed in Chapter 9.

viii. During a lengthy enquiry such as this I had various contacts with many other professionals interested in science education with whom I discussed my work and findings. These included meetings I set up specifically for the purpose of comparing experiences with other DES 20-day Course providers; science education researchers (PSTS) and other action researchers. On a study trip to America, in September 1991, I used data and analysis from my enquiry with American educators and teachers to explore the nature of constructivist approaches and their responses contributed to my understanding and provided further support to validate my claims against the experiences of those working in very different contexts.

ix. My collaborative writing (Ollerenshaw and Ritchie, 1993) with a colleague involved in the DES 20-day Courses also provided regular opportunities throughout the enquiry period to share ideas in the light of my data and analysis. This on-going discussion was a very significant dimension of my research. We had worked collaboratively on numerous initiatives since 1985 and our understanding of constructivist approaches to science education had developed as a result of our collaborative reflection upon and evaluation of those experiences. It was therefore of particular significance to me that my claims and insights were shared with her and 'tested' in the light of her similar but different experiences. As the tutor in charge of the parallel
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course at Bristol Polytechnic her experiences were directly relevant to my enquiry.

x. Finally, the step of making my account public is in itself an aspect of validating my claims. The public scrutiny that follows, be it from supervisor, examiners or fellow-researchers and their response is inevitably related to establishing the validity of my claims.

Before concluding this section on validity it is appropriate to discuss a change in my approach to validation during the early stages of the enquiry. My original intention was to set up a 'validation group' involving colleagues from my institution. From talking to other action researchers and my supervisor I was aware that validation groups are sometimes formally established by action researchers as a means of validating their work. They usually consist of colleagues, fellow research students and academics (in the case of accredited enquiries). The purpose of the group meetings is to critically consider the researcher's data and analysis in order to decide, usually through discussion or discourse, the validity of the claims and help the researcher move forward in her/his understanding of those claims. There is a second purpose which is creative and concerns offering the researcher support in identifying ways forward in terms of future action or direction for the enquiry. I was aware from talking to other action researchers that these groups were valued and helpful. After informal discussions with my colleagues I realised that the high demands in terms of time were unlikely to be met by them and the motivation to attend meetings would not be high if the purpose was solely to validate my research. However, I realised how significant my colleagues' views were to the validity of my enquiry. I therefore opted to use the regular tutor planning meetings as a more practical and effective forum for discussing data and concerns and gaining ideas for new action and ways forward. In this way the purposes of a validation group would be met through the tutor meetings. Sometimes these meetings would be explicitly related to my data and on other occasions my concerns and ideas were dealt with more generally in the context of planning decisions. These meetings, with their purpose clearly focused upon practical teaching concerns, did not run the risk of lacking purpose, of being unstructured, of being dominated by like-minded action-researchers or of being more concerned with intellectual
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and academic matters than practical ones. These were all potential weaknesses of validation
groups cited at a University of Bath Action Research Seminar in October 1991. I considered
that meeting the purposes of a validation group through the planning group would ensure
that the research was firmly grounded in the context of the professional concerns it sought to
address and would provide an example of a validation process that other action researchers,
not benefiting from a link with an academic institution could adopt. There were however
disadvantages which I will discuss later in Chapter 11.

My claims to validity for my enquiry are not based upon the adoption of a single procedure but,
reflecting the holistic nature of the overall approach, upon the rigorous use of numerous
procedures. These range from some which were formal (planning group meetings and
seminars) and others which were informal, but nonetheless significant (meetings with my
supervisor and other professional peers). The most important criterion to apply however is the
extent to which the claims are educational when viewed in the context of my educational
values.

7.9 Measuring Impact in classrooms

In Chapter 5, evaluation of INSET was discussed and the importance of measuring impact
upon the practice of teachers was highlighted. During my enquiry this evidence was collected
in a number of ways. Some was collected first hand and therefore I can make claims for its
authenticity. Other evidence of impact comes from secondary sources or is based upon
teachers' self-reports. The authenticity of this data is less easily shown. However, the nature
of the evidence produced by teachers to support their statements, including verbatim
evidence collected in their own classrooms, floorbooks, children's work, photographs and
sometimes video tapes provides me with the basis for claiming it is authentic. Such evidence
is almost impossible to fabricate and the teachers would have no reason for doing so. The
case study evidence indicates their commitment to improving the quality of pupils' learning
and in most cases their enthusiasm for scientific work with children. The range of evidence
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collected to indicate impact upon teaching included:

i. My observations of teachers and students working in classroom situations. This occurred during school-based days on the DES 20-day courses; during visits to B.Ed. students during block school experiences; during specific classroom observations (linked to Case Study 1); during visits to schools for interview purposes.

ii. Feedback from teachers on the DES 20-day courses during sessions based upon work carried out in school between centre-based sessions. This evidence comprised of a variety of different forms discussed above and detailed in the case studies.

iii. Evidence contained within assignments produced by students on the DES 20-day courses. These assignments (particularly assignments 1 and 2) were based upon classroom enquiries carried out in their own classrooms and were required to include detailed evidence of pupil's learning. These assignments were all marked by me and an analysis of this is included in Review 4.

iv. Informal feedback from course participants, advisory staff, fellow-tutors, colleagues of participants during and after the course provided the evidence which was least easy to authenticate. However, its spontaneous, unsolicited nature is evidence, particularly when it came from sources other than the participants themselves, that it is unlikely to be fabricated or exaggerated. Sometimes this evidence, for example in terms of long studies or dissertations, is clearly authentic in terms of the evidence of children's learning included and discussed.

v. The end of course evaluation exercise also provided self-reported evidence of
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impact in the classroom.

This variety of evidence from a range of sources allowed me to make claims about the extent to which the courses and my teaching impacted upon the practice of those involved. However, it is naive to suggest that only one factor leads to changed practice. The changes evidenced in teachers’ practice resulted from a variety of factors of which participation in a course is only one. Consequently any conclusions drawn from this evidence are tentative and intended to provide me, as a practitioner, and any other practitioners interested in improving their practice, with insights to inform future decisions. The evidence is not sufficient, and it might be claimed no evidence could ever be conclusive enough to generalise about the success or otherwise of teaching.

7.10 Conclusions

This chapter has addressed the methodological considerations that face all researchers in educational contexts. However, the distinctive features of action research require methodological considerations to be treated in an appropriate manner. The rigour with which an enquiry is conducted is a factor in any evaluation by a reader of its value. This chapter has set down the systematic approach I adopted to my enquiry. The decisions I took about the approach I have used is firmly grounded in ontological and epistemological assumptions which I have made explicit. The epistemology I have adopted applies not only to the research approach but underpins the view of learning that informs the teaching approach I used and the view of science that is being encouraged through my teaching.

Throughout this chapter the relationship of the research enquiry to my practice as a teacher has been the basis for methodological considerations. The scope of my enquiry, the time-scale, the techniques used for data collection, the ethical principles adopted and the approach to validity have been decided in the context of my teaching being my prime concern. The approach to analysis and documenting the enquiry have been taken in the
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The context of my research activity and my desire to conduct a rigorous, relevant and valid enquiry. In this way my discussion of methodology was intended to indicate to the reader the way in which I claim to have addressed Hopkins' criteria for classroom research by teachers (see page 235) in making decisions about how the enquiry should be conducted. The primacy of my teaching role was accepted; the data collection techniques were, in most cases, an integral part of my teaching role and were not excessively demanding in terms of time; my approach allowed me to test out ideas and develop my teaching strategies; the concerns are ones to which I am committed and I have addressed ethical issues.

Two other areas discussed in this chapter have set an agenda that will be addressed later in this thesis. The key issues raised about validity will be looked at in Chapter 11 and as well as considering the extent to which the procedures outlined in Section 7.8 have been used effectively I will also use criteria discussed in Chapter 6 for evaluating action research enquiries. The section concerning the way in which impact in classrooms can be evaluated will be developed further in Chapter 9 (Review 4) and Chapter 10.

The end of this chapter brings the reader to the enquiry itself. The previous chapters have set the scene, contextualised the enquiry and established the basis for decisions taken linked to it. The start of the next chapter will offer some guidance into how the ‘story’ of the enquiry can be approached.
Chapter 8 - The enquiry

8.1 Introduction

This chapter tells the story of my enquiry through three key reviews that were carried out in April 1990 (Review 1), December 1990 (Review 2) and March 1991 (Review 3). Chapter 7 provided a discussion of methodological issues concerning these reviews and the reader is reminded of the flow diagram on page 262, which details the chronology of my enquiry. The following chapter contains the final review (4) and Chapters 10 and 11 are a discussion of the issues arising from the enquiry and a summary of the outcomes.

The reader can approach the account in three distinct ways. Firstly, in order to gain the most detailed and sequential account, the reader should begin with the case studies in Volume 2 - read Case Studies 1 and 2, then Review 1, continue with Case Studies 3 to 7 before reading Review 2 and then read Case Studies 8 and 9 before tackling Review 3. By doing this the reader would follow the chronology of the enquiry and the evidence upon which the reviews are based will be read before the review itself. In the reviews my concerns are dealt with in the order they arose.

A second approach would be to go straight to Review 4 (Chapter 9) which approaches key concerns that have arisen in a more logical order and also draws upon the wealth of data collected, beyond the case study evidence, to evaluate the teaching approach adopted. Reference to other reviews and case studies in Chapter 9 would again enable the reader to track back through the different levels of analysis and data to validate claims and identify the origin of concerns and insights.

The third approach, which I recommend, is for the reader to begin by reading Case Study 1, or at least its analysis (Volume 2, page 28) to orientate her/himself to the nature of the teaching sessions, data collected and the analysis. I then suggest reading the reviews in this chapter and referring to case study analysis and data as appropriate. References in the reviews to case studies allow ideas and concerns to be tracked back to the original data. This
Chapter 8 - The enquiry

approach should enable the reader to use the original case studies in a dynamic and interactive way to inform and validate claims made in the reviews. However, as noted, the reviews are structured in terms of the concerns that arose in the order that they arose and it is not until Chapter 9 that they will be dealt with more logically.

It should be remembered that the case study analyses are in the form that they were originally produced (within a few days of the session). They were word-processed within a couple of weeks of the session. The reviews are based upon detailed written material produced at the time and were word-processed a few weeks later. This use of the original material ensures an authentic account of the enquiry. It means there are some differences of style and some inevitable repetition. I have included some editorial notes at the final stage of writing. The concerns identified are included Volume 2 as Appendix 17 if the reader wishes to refer to them alongside this chapter.

8.2 Review 1 - April 1990

The exploratory stage of this research (October 1989) was intended to help me structure my ideas about my teaching and in particular my use of a constructivist approach. This I did through the detailed collection of data during two teaching sessions with BEd students (Case Studies 1 and 2). Figure 8.1 shows the relationship of this review to the others. The analysis of these case studies helped me identify numerous concerns that I considered deserved attention. These were treated as a series of questions in the analyses. Each of these concerns relate to the key question of this enquiry: How do I improve the quality of my teaching through the use of a constructivist approach? The concerns are themselves articulated as a series of questions which provide a means of unpacking and clarifying my key question. They are grounded in the data I collected and their provisional status was recognised from the outset. They were identified as a series of questions to be addressed through further cycles. The concerns, it will become evident from the later discussion, address both the extent to which the approach I used was improving teachers' scientific
Chapter 8 - The Enquiry

Figure 8.1: Review 1

Exploratory Phase

Review 1
April 1990

Review 2
December 1990

Review 3
March 1991

Interviews

Review 4
January 1993

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knowledge and understanding and the extent to which it was impacting upon their classroom practice.

Over the next few months, I reflected on this data and the concerns that arose. I decided to pursue the extent to which two students from Case Study 1 had retained ideas from the session and were able to use them when working with children. I decided to interview them and observe them working with children using the same content area. This I did in March and April 1990. The data from these sessions is included as part of Case Study 1. I extended my analysis of Case Study 1 at that stage to take account of this new data. It was at this time that I decided that I needed to find a more systematic method of dealing with my concerns and how I might address them.

As I discussed in Chapter 6, some of the literature concerning action research has advocated fairly rigid schema which require the identification of a single focus and adherence to a specific sequence of steps. This single focus in then the attention of subsequent cycles. Although there are limitations to these approaches they have the considerable advantage of making the enquiry manageable. The work I have previously done with teachers adopted this approach. However, I had often been concerned, in my role as an advisory teacher supporting this work, that attention on a single focus, particularly at the early stages of an enquiry, could be restrictive and mean teachers missed opportunities for improving their practice by reflecting on a range of concerns.

This aspect of action research is one that McNiff addressed and led her to suggest 'generative action research' (McNiff, 1988). Her approach encouraged the production of a range of concerns from a systematic examination of existing practice and provided a framework for dealing with several different problems. It was this approach I wished to explore further. I considered it was necessary to analyse the variety of concerns I had identified in a way that reflected a 'real' practitioner approach to developing my practice. As I analysed my data it became increasing clear to me that once I had identified a concern I had already, in some way,
started to address it. The process of increasing my awareness of concerns was making those concerns a part of the experience on which I was drawing in order to plan and implement future learning opportunities. In other words, once the concern had been identified it could not be put aside and ignored, it was contributing to my thinking and influencing my decisions. Consequently, it seemed appropriate to try and find a process of dealing with all the concerns that I identified rather than trying, as I had anticipated at the outset of this research, to focus on a key concern that had priority over all others. I needed a means of dealing with my range of concerns that made the 'messiness' of my real teaching situation manageable and allowed me to analyse these concerns in a way that helped me identify the most appropriate response to each, whilst allowing me to investigate my practice in sufficient depth to make the research I was conducting worth sharing with others through publication. I was also intent on finding a means of analysing my concerns which offered me a means of developing my practice in an holistic way. Previous experience of collaborative work had convinced me it was inevitable that one's practice changes simultaneously in a number of different ways that are inextricably linked and therefore any evaluation of changes needs to take account of the whole teaching and learning context, rather than focus on one specific area, in the belief that it is not influenced by and influencing other aspects of practice.

In summary, at this point, my intention was to devise a means of analysing concerns that arose through analysis of my practice which:

i. allowed me to deal with a range of concerns;
ii. that reflected my holistic approach as a practitioner;
iii. that helped make the 'messiness' of teaching situations manageable in terms of my enquiry.

The nature of concerns identified

It was evident that the concerns I had identified through the analysis of Case Studies 1 and 2
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were of various types. They included some which had short term solutions and others which could only be tackled over a longer term. Another significant aspect of the concerns was to do with the nature of the means of addressing the concern. Addressing some of the identified concerns involved changes in my role as a teacher, some required me to improve my knowledge and understanding of science others suggested a need for a change in session ethos. I therefore decided to attempt to construct a framework for analysing the concerns. Within the framework I intended to identify several sets of categories which could be used to analyse each concern. The nature of these categories evolved over several weeks during which I reflected on the range of concerns I had identified.

The first set of categories were to do with the time scale required to address the concern:

- Short term (next session);
- Medium term (several sessions, over a period of weeks);
- Long term (over a period of months).

The second set were related to the nature of the change required:

- Structure of sessions;
- Tutor's role;
- Tutor's knowledge and understanding of science;
- Tutor's knowledge and understanding of professional issues;
- Ethos of sessions;
- Teaching strategies.

These deserve some amplification. The constructivist approach I was using to develop adults' knowledge and understanding of science and to improve their classroom practice involved various phases: orientation, elicitation/structuring, challenging/restructuring, review and application, as discussed in Chapter 2 (Section 2.9). The timing and relationship between these phases is related to the structure of sessions.
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The role of tutor is varied and includes organiser, questioner, challenger, supporter, assessor, facilitator, expositionist, guide etc. Some of the concerns addressed my skills in adopting these roles and the appropriateness of different roles at different times during a session.

A key intention of using a constructivist approach was to help adults construct their own knowledge and understanding in science. This required me to be confident about my own scientific constructs, my understanding of the nature of science and of scientific processes. My background and recent experience meant that there were gaps and 'weak' areas in my understanding and the careful analysis of sessions enabled me to become aware of how this was affecting my teaching. Indeed, there were instances where my own lack of understanding and alternative constructs were causing students to have their own alternative ideas reinforced, or worse, causing students to restructure for themselves my alternative frameworks in their own terms. Consequently, recognising my own weaknesses in this area and identifying ways of improving my own knowledge and understanding were of considerable importance.

Linked, in some ways, to this category was the need for me to improve my understanding of professional issues. There were aspects of the nature of constructivism and its implementation about which I needed to develop my understanding. For example, the use of concept mapping was a strategy that I recognised as useful but about which I needed to know more in order to implement the successful use of concept maps in my teaching.

The next category was less tangible, but nonetheless important in terms of successfully implementing a constructivist approach. The ethos of the learning environment was significant when working with adults who lacked confidence and brought to the learning situation pre-conceived ideas about the nature of science and learning in science that were influenced by secondary school laboratories of previous decades (as discussed in Chapter 4). The means of addressing concerns in this area was less easily described but within the intention of providing a comprehensive framework for analysing concerns in a way that would help me as a
practitioner, such concerns could not be ignored.

The last category in this set was much more practical and was a means of identifying those concerns that required me to change the strategies I had used or adopt new ones, such as encouraging paired work rather than individual work during a particular phase.

The final set were an indication of the relative difficulty of identifying and making appropriate change:

- Straightforward
- Possible with effort;
- Possible with professional support from others;
- Impossible.

The last member of this set is significant because I was aware of the extent to which practitioner-initiated changes are not always adequate or indeed appropriate. It is important for an action researcher to be aware of the extent to which some factors may be out of her/his control. Action then is not restricted to the pedagogical, cognitive or affective changes - it may require an approach to someone else who has the potential to provide what is needed. An example may be a concern resulting from lack of resources with financial implications or in the case of the B.Ed. sessions, concerns about the length of session which required institutional decisions related to time-tabling.

Using this set of categories I analysed the concerns I identified from Case Study 1 and Case Study 2. I intended that an analysis of concerns using this framework, which would need developing and modifying, would help me make decisions about what action should be taken and track action already taken. As I carried out later case studies I intended to add to my concerns, modifying those already identified if necessary and make decisions about when a concern had been sufficiently well addressed to no longer need attention. That is not to say that I no longer need to remain aware of a ‘concern’ but that sufficient action/change has
been effected to allow it to be dropped as a priority at that particular time.

The following is a list of my concerns (identified in October 1989) followed by a summary of the analysis carried out in April 1990, which is discussed in fuller detail in the next section, based on notes made at that time (April, 1990). Action identified as a result of the analysis of Case Study 1 informed the approach taken to Case Study 2. These two sessions can be seen as two action research cycles of plan, act, observe and reflect. The Case Study 1 concerns addressed during Case Study 2 informed my analysis and it takes account of the changes evident in that session. New concerns from Case Study 2 are included.

Concerns Identified as a result of analysing Case Study 1 and 2

1. To what extent should I ensure an orientation period for adult learners?

2. Should I introduce appropriate 'scientific' words if they do not come from the group?

3. What other strategies can I use to elicit students' existing ideas?

4. Should I implement sessions which are so tightly structured, paced and controlled and should this depend on the particular content involved?

5. How can I collect evidence of students restructuring their ideas?

6. How can I encourage students to apply their restructured ideas in novel situations?

7. What view of science do students take away from sessions like this?

8. How can I emphasise the importance of context for scientific activities with children?

9. When should I use use the word "predict" - do I understand its meaning?

10. To what extent should I encourage individuals to expose their ideas?

11. Should I deal with every 'alternative framework' identified or focus upon common ones?
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12. To what extent did the metaphors I used foster misunderstanding in the students?

13. Do I allow students adequate time for practical exploration and investigation? (CS2)

14. How can I use the relationship between adults' and children's constructs to improve adults' knowledge and understanding of science? (CS2)

Analysis of concerns from Case Study 1

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>TIME</th>
<th>CHANGE</th>
<th>DIFFICULTY</th>
<th>COMMENTS/ACTION</th>
</tr>
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<tr>
<td>Orientation</td>
<td>L</td>
<td>Structure</td>
<td>3</td>
<td>CS2 - not problematic re electricity - ? other areas</td>
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<tr>
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<td>S</td>
<td>Role</td>
<td>1</td>
<td>Addressed in CS2</td>
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<tr>
<td>Eliciting strategies</td>
<td>M</td>
<td>Role /</td>
<td>2</td>
<td>Explore concept maps on DES course Need to find out more</td>
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<td></td>
<td></td>
<td>strategy /</td>
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<td>Prof. K&amp;U</td>
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<tr>
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<td>L</td>
<td>Structure /</td>
<td>3</td>
<td>Talk to team - is this about confidence?</td>
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<tr>
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<td>L</td>
<td>Strategy</td>
<td>3</td>
<td>Interviews helpful Links with big ideas?</td>
</tr>
<tr>
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<td>M</td>
<td>Strategy /</td>
<td>2</td>
<td>Use of follow up materials / directed tasks / IT simul.</td>
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<td></td>
<td></td>
<td>Structure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>View of science</td>
<td>L</td>
<td>Role /</td>
<td>3</td>
<td>Interviews / indiv. discussions - CS2 +ve evidence</td>
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<td></td>
<td></td>
<td>ethos</td>
<td></td>
<td></td>
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<tr>
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<td>S</td>
<td>Strategy /</td>
<td>1</td>
<td>Addressed in CS2 School session +ve</td>
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<td></td>
<td></td>
<td>Role</td>
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<td>Use of predict</td>
<td>S</td>
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<td>1</td>
<td>Addressed in CS2 Avon Ass.Project helpful</td>
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<tr>
<td>Exposing ideas</td>
<td>M</td>
<td>Ethos /</td>
<td>2</td>
<td>Try paired work key concern?</td>
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<td></td>
<td></td>
<td>Role</td>
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<tr>
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<td>3</td>
<td>Identify common ideas.</td>
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<tr>
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<td>Sc. K&amp;U</td>
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Analysis of concerns from Case Study 2

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<th>COMMENTS/ACTION</th>
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</thead>
<tbody>
<tr>
<td>13. Time for exploration</td>
<td>M</td>
<td>Structure / strategy</td>
<td>2</td>
</tr>
</tbody>
</table>

8.2.1 Discussion of analysis of concerns

1. To what extent should I ensure an orientation period for adult learners?

This concern arose partly because of the time constraint imposed by the timetable on B.Ed. sessions. Orientation is an important phase of a constructivist approach when working with young learners. With adults, it seemed reasonable to assume that the life experience they brought to sessions would help them come to terms relatively quickly with their own existing ideas about, in this case, electricity. However, it was also recognised as possible that the time offered at the beginning of a session for orientation might help, in particular, those adults who had not given thought to questions such as 'How does a torch work?'. I also considered it likely that some content areas required orientation activities more than others. An area of content such as forces, to which some adults might have not given any previous thought, may have required more time for 'setting the scene'. The part of the analysis which led to this concern also dealt with the lack of unstructured exploration, which raised a different but equally important concern dealt with later (Concern 3). The timescale involved in addressing this concern was predicted to be long since, although it might have proved less significant for the particular content of electricity, it needed to be considered in terms of different content areas and there were a variety of orientation strategies that could be explored such as the use of video sequences (using Modular Investigations in Science and Technology - MIST).
change required was related to the structure of the sessions (although as just noted new strategies could be involved). The concern appeared to be relatively minor, but I was already aware, through discussion with colleagues in planning meetings, that some considered this to be significant to successful work with adults and consequently it was a concern that would need to be addressed as a result of professional discussions and sharing professional experiences with others, especially colleagues who were working in a similar way.

Analysis of Case Study 2 confirmed that a lengthy orientation period did not seem necessary with electricity but as suggested this concern would be reconsidered when other content areas had been explored.

2. Should I introduce appropriate ‘scientific’ words if they do not come from the group?

This concern reflected the general issue of the extent to which adults should be given accepted scientific terminology, facts and ideas during such workshops or whether they should be encouraged to come to a better understanding using ideas and vocabulary they bring to the sessions. The latter approach is more in sympathy with a constructivist view of learning. I recognised a problem about the use of ‘scientific’ words with both adults and children. It was easy for both to use the correct words and sound quite convincing without an acceptable understanding of what those words mean. This could be off-putting for others in the group who had a more limited scientific vocabulary and less confidence. I considered it preferable to encourage the use of adults' own terms rather than requiring them to use the correct scientific term. Equally, if a scientific word was used then they were required to explain in everyday language what they mean by the term. This was the approach I hoped they would also use with young learners and one which I made explicit to the students in Case Study 1 and 2. The particular concern arose since I 'accidentally' used a scientific term during the session. The response needed was clearly related to my role and could be addressed in the short term very easily.
Analysis of Case Study 2 provided evidence that this relatively trivial concern had been addressed, but its identification and clarification helped me to come to a clearer view of the approach and why the use of language is important. Reflection upon the issue and discussion with colleagues helped me to clarify the extent to which I am able to implement my commitment to such an approach. A more significant question for future reflection was the extent to and the way in which I gave 'scientific' information to adults during their practical work. Did I let them restructure ideas as a result of their practical investigations or was there a risk that was I more likely to offer a scientifically acceptable explanation before they are ready to use it to restructure their own ideas? This was clearly an example of where I was aware of the values I held concerning autonomous learning but recognised the extent to which that value could be denied in action as a result perhaps of egotistical reasons of demonstrating my own scientific knowledge.

3. What other strategies can I use to elicit students' existing ideas?

The constructivist approach depends on encouraging adults and children to explore and share existing ideas. It is only when these ideas are exposed that they can be challenged and consequently developed through tutor intervention. There were numerous strategies that I intended to explore over the subsequent case studies including tutor prepared proformas, floorbooks, think books, concept maps, word spurs etc. These strategies resulted from discussions with colleagues and ideas I had gained from my background reading. I recognised this concern would cause me to change my role (in terms of the nature of my questions, the way I handled whole group discussions, the way I recorded utterances etc.) and the strategies I used (eg concept mapping). These would involve me in developing my professional understanding in areas such as the nature of concept mapping. These changes would occur in the short and medium term and I anticipated they would be possible with some effort on my part.
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Specifically, I intended to try out an elicitation proforma with groups (CS3), read about concept mapping, try it myself and with colleagues and explore its use with the DES course participants.

4. Should I implement sessions which are so tightly structured, paced and controlled and should this depend on the particular content involved?

This concern is related to the first and questioned fundamentally my previous approach to working with adults to develop their knowledge and understanding. Case Study 1 describes a session that was structured and fully under my control, although because of familiarity with the likely student response I think I gave the students a feeling of control over the direction the workshop took. However, in this respect electricity was a content area that had a fairly clearly described and documented progression. In other words, students and children could follow a series of steps, or perhaps more appropriately challenges, to develop a better understanding of simple circuits. This provided me with a workable structure for a session. However, other content areas, such as materials, had no such clearly described progression and consequently the approach had inevitably to be different. The importance of an exploratory phase in which learners raise questions which they can subsequently investigate was becoming more evident to me as I read more and discussed teaching strategies with colleagues, who questioned the control I was maintaining over sessions. This was one of the key areas of discussion about these case studies. It is also an area where again what I believe to be important, in terms of student autonomy and control of learning is evidently denied in the way I teach. The adoption of a more open approach required considerable constraint from a tutor since it could take some time for adults to raise appropriate questions for investigation. Consequently, this concern was a key one for the future and was regarded as a long term goal that would be difficult to address. The extent to which this was addressed would be evidence of the extent to which the enquiry did have an impact upon my practice. The implications concerned both my role as a teacher and the structure of sessions. In the short term, it was not addressed in Case Study 2 since that involved similar content to Case Study 1. It was a
concern that would be very relevant during the planning and implementation of the DES course. Discussions with colleagues base upon data collected in their sessions and sessions I had run collaboratively, with Chris Ollerenshaw, on a similar course (CAPSE 14 at Bristol Polytechnic) had provided some indication of possible ways in which my approach could change. In some respects it was a matter of confidence and a recognition that adults would raise appropriate questions as a result of their exploratory work.

5. How can I collect evidence of students restructuring their ideas?

This concern needed addressing if I was to provide evidence that my use of a constructivist strategy had been successful in improving adults’ knowledge and understanding of scientific concepts. This would need to be an important aspect of future analysis of sessions and I intended to explore the use of different strategies for this. Immediately after my first analysis of Case Studies 1 & 2 (October, 1989), interviewing individual students was regarded as an obvious means of confirming restructured ideas and I did this with specific students (identified because of the alternative ideas they exposed during the session) several months after the session. I had also realised that evidence of restructured ideas would ideally be identified in the use of those ideas when working with children and so I had also planned to observe the selected individuals working with children. The evidence of these interviews and the work with children is discussed in the case study analyses. Future cycles would involve the use of other assessment strategies such as concept maps. The links between this concern and Concern 3 regarding the elicitation of ideas was obvious, since restructured ideas became the existing ideas a learner brought to a future learning experience. Again, this was a long term concern that was regarded as difficult to address and would require the professional support of colleagues with experience in this area. The work done on ‘big ideas’ with the Assessment in Primary Science Project (see Ollerenshaw et al., 1991) was seen as providing a helpful framework for identifying the extent to which adults had restructured their ideas.
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6. How can I encourage students to apply their restructured ideas in novel situations?

Another crucial phase of a constructivist approach to teaching concerns opportunities for applying ideas. In the context of the short sessions under discussion at the present time it had been difficult to suggest how this area could be developed further without resorting to directed tasks, follow-up materials and perhaps IT simulations. I noted that the context of the DES course would provide much better opportunities and Day 4 of each cycle would allow me to encourage adults to apply ideas developed earlier in the cycle to new problems. The latter point indicated this was a medium term goal, that would require me to consider the structure of sessions and suitable strategies. This would be possible with effort since much of my previous work as an advisory teacher had involved identifying practical opportunities for problem solving work in science. I anticipated that it was these kinds of opportunities that I would need to identify for adult learners.

7. What view of science do students take away from sessions like this?

My understanding of the nature of science was developing and indeed I anticipated it would inevitably change as the research progressed. At this stage my priorities were to establish the tentative nature of scientific ideas, the humanistic nature of science, stressing the place of the social construction of ideas alongside individual constructivism, and the crucial and inextricable links between developing scientific ideas and the process of behaving scientifically. The means by which I was able to assess the view of science held by adults as a result of my teaching was problematic. It was expected that the evaluative comments written after sessions, such as those in Case Study 1, would provide some useful evidence and interviews could provide further evidence. However, in future cycles I intended to continue to include the nature of science as a key aspect of my analysis of sessions and to explore the extent to which adults' view of science became apparent from their utterances during discussions etc. The view of science internalised by students and other adults would be
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influenced by my role and the ethos of the working environment. A teacher constantly offering 'right' answers and suggesting the best way of carrying out tests would not encourage an understanding of science as tentative knowledge obtained through the use of scientific processes. This made this another long term goal which would be difficult to address and required action on my part to clarify my own perspective. I was already aware of the difficulties of describing the process of science in a way that meaningfully described real science but anticipated future reading and discussions would help me clarify my own ideas in this area. The philosophy of science is a complex area and any attempt to simplify it was likely to mislead. However, I was also aware that the majority of students I worked with were unlikely to make a commitment to background reading that would be necessary to gain an insight into the complexity of the issues involved. Therefore a simplified view, focusing upon what I considered to be key features (as described in Chapter 1) was my goal.

Case Study 2 provided encouraging evidence that the view of science I hoped to foster was indeed being accepted by students as a result of sessions.

8. How can I emphasise the importance of context for scientific activities with children?

This concern was particularly important when working with students since much of their own science education was divorced from relevant contexts and the concern arose from the fact that I omitted to make the point explicitly during Case Study 1. When working with practicing teachers I considered this concern to be less significant. The length of time available for student sessions made it difficult to contextualise the content and consequently I could often only talk about the importance rather than demonstrating it through the medium of my teaching. This was yet another example of what I considered important - contextualising scientific activities to make them relevant to learners, which was not evident in my practice. I was, however, confident that from my own experience as a teacher and my work as an advisory teacher that I had access to sufficient examples to share with students. This...
concern could easily be addressed at one level, in the short term, without any difficulty and indeed there was evidence in Case Study 2 that I did make the context of the work much more explicit. I also intended to look for evidence of students planning work for children in context when I subsequently observed some from Case Study 1. This evidence was clearly available in the case of one student, Zandra.

9. When should I use the word "predict" - do I understand its meaning?

This specific concern was another short term and easily addressed issue that arose as a result of me not clarifying my own thinking about a significant process skill. However, it is sometimes only when probed by a learner that one's own lack of understanding becomes apparent. This was indeed one of the justifications for the model of the DES course proposed. The school-based work was to provide teachers with an opportunity to test out their own ideas against those of children and explore the extent to which they could deal with children's questions. In the particular case of the use of 'predict' a discussion with colleagues on the *Assessment in Primary Science Project* helped clarify my ideas and evidence from Case Study 2 indicates my application of restructured understanding! This was an example of a concern 'addressed' and therefore needing no further attention apart from the usual professional awareness given to my use of language.

10. To what extent should I encourage individuals to expose their ideas?

Many adult learners feel threatened by science and asking them to expose existing tentative ideas that are in the early stages of being structured can add to the unease individuals experience. My strategy at that time of selecting individuals, based on my previous contact with them, in the belief that they would confidently share ideas during whole group discussions, would be of limited use when I worked with teacher groups with whom I had had less contact. In those situations it seemed more appropriate to encourage individuals to share existing ideas with a partner or to write the ideas down anonymously. This would expose them
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to challenge but provide no evidence that could be used to confirm restructured understanding. There were ways in which changes in my role and the ethos of sessions could support less confident individuals in sharing ideas. They would however, only do that if they felt secure in the learning environment. With students, creating a relaxed environment through the use of humour was one strategy I had explored, but more significant changes that will be relatively difficult to implement were my medium term aim. The success of my use of constructivism was again dependent on my skills in encouraging and supporting individuals in expressing ideas. There was a tension evident between wanting learners to expose their existing ideas but wanting, at the same time, learners to feel unthreatened and comfortable in the learning situation.

11. Should I deal with every alternative framework identified or focus upon common ones?

This highlighted another dilemma I needed to face. The approach I was exploring required students' existing ideas to be challenged. However, there was evidence in this first Case Study of a diverse range of alternative constructs. It was apparent that not all could be challenged within the constraints of sessions. However, the identification of these ideas meant that those which are not acceptable in a scientific sense could be tackled in an appropriate way if practical. Some could be tackled through sharing accepted scientific ideas or in some cases (the contents of a bulb) by giving factual answers. The more significant alternative ideas, especially those found to be commonly held, needed be challenged and I intended that the analysis of sessions would help me identify these common constructs. In the first case studies, common alternative ideas about 'clashing currents' were evident and I planned to explore these in more depth in later cycles on the DES course. The strategies that could be used to challenge existing ideas, the means by which individual's alternative ideas might be fed back to them and the difficulties of grouping alternative ideas were all aspects to be explored in the long term and I anticipated this being problematic.
12. To what extent did the metaphors I used foster misunderstanding in the students?

This concern arose due to my use of metaphors during the first session. It is a concern that was related to my own understanding about electricity and could be addressed in the short term quite easily through background reading. However, it raised a wider question about the use of metaphors in developing knowledge and understanding which I consider in a later review.

Evidence from Case Study 2 indicated that my reading helped me address this concern appropriately.

Two further concerns resulted from my analysis of Case Study 2 and subsequent reflection.

13. Do I allow students adequate time for practical exploration and investigation?

This concern was closely related to Concern 4 discussed above. However, my work during Case Study 2 highlighted the significance of time for exploratory activities during which adults can raise their own questions and gain some 'ownership' of subsequent investigations. At that stage I noted it as a key concern for consideration during the DES course. It was a medium term goal that would be relatively difficult to address.

14. How can I use the relationship between adults' and children's constructs to improve adults' knowledge and understanding of science?

At this time (April 1990), I was involved in planning the DES course and this concern was one which I anticipated needing attention. The course proposal (see Appendix 4) was
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underpinned by the premise that teachers' knowledge and understanding of science could be improved by encouraging them to elicit children's existing ideas and to reflect on those ideas, their origins and their relationship to the teachers' accepted scientific ideas. I recognised that my analysis of DES sessions would need to consider the evidence that this was happening and was helping teachers restructure their scientific ideas. I anticipated needing to explore different strategies to encourage this and that I would need to clarify my own scientific ideas in specific areas and be aware of the common alternative ideas that children, and adults, were likely to hold. This concern was regarded as one which would be difficult to address although it was intended to address it within a medium time scale.

In summary, several of these concerns (2, 8, 9 and 12) were concerns that I could deal with immediately. The others required further attention over a longer timescale and would be reviewed after 3 further research cycles.

The framework had proved useful in helping me begin a systematic examination of the range of concerns I had identified. The analysis of these initial concerns using the sets of chosen categories had required me to clarify the nature of each concern and anticipate possible ways to address them. It had led to significant reflection on each and enabled me to appreciate the overlap and links between them. The analysis had indicated a number of areas of my practice where what I considered to be good practice was not evident in what I did in the real teaching context. My 'espoused theories' and my 'theories in action' were not congruent. There were also dilemmas that I had identified which needed resolving. At this stage of my research (April, 1990) I decided to carry out the next review of concerns using the framework in December 1990 after several action research cycles based on the DES course.
At this stage of my research I had collected data from seven case studies. Three of these (CS1, 2 & 3) had been work with student groups and the last four had been cycles of the DES 20-day Course. Each of these latter case studies had involved evidence from four full days of the course. I was treating each case study as an action research ‘cycle’. Consequently, during and after the collection of data for each case study (since there was overlap) my analysis of data was providing me with evidence of the extent to which I was addressing particular concerns and indicating some new concerns. It should be noted that the initial analysis was a set of written notes which were produced within days of the session. The word-processed version was usually produced over the next couple of weeks and included some additional editing and new points based on the additional time for reflection. After each analysis I produced a ‘future action list’ as a reminder of issues raised and these informed the collaborative planning meetings during the autumn term. Two of these involved meetings with tutors from both institutions and two others were formal meetings of tutors on the BCHE courses. Informal meetings were usually held before Day 1 and 4 of each cycle and tutors evaluated each day after the students had left. Figure 8.2 illustrates the scope of Review 2, indicating it involved revisiting case study data and analyses as well as the first review.
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Figure 8.2: Review 2

Investigative Phase

Review 2
December 1990

Review 1
April 1990

Review 3
March 1991

Review 4
January 1993

Interviews

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At the stage of Review 1 I recognised that my approach to analysis was providing me with a relatively unsystematic way of examining the whole range of concerns that I had identified and the framework for analysing concerns was my attempt to deal with this. By December 1990, I considered that I had carried out sufficient analysis of my practice to justify a further more systematic review of concerns, based on the framework I had constructed after the first two case studies. I also intended to examine the usefulness of the framework, in terms of my original intentions for it. This discussion of that review (word-processed in January 1991) is based on material written at the time of the review (December 1990).

My first task was to revisit the concerns identified after Case Studies 1 and 2 and decide whether any needed modification or were no longer concerns since they had been addressed. I noted at the end of my first review (carried out in April 1990) that there were four concerns (2, 8, 9 & 12) identified that could be addressed in the short term. Some of these were indeed noted immediately after Case Study 1 and addressed in Case Study 2. In the intervening months, my work with students (not documented) provided me with opportunities to apply my new insights and understanding of my practice, particularly in respect of concerns 2 and 8. This was confirmed by Case Study 3 evidence collected in October 1990.

In terms of Concern 2, about the introduction of scientific terms, I felt more confident that I could work with the vocabulary students brought to sessions and when 'scientific' terms were used by students it became common practice for me to explore, in everyday language, the meanings held by individuals of those terms. Indeed, there were frequently occasions when students in informal discussions challenged each others' use of scientific terms. There was also evidence in the later Case Studies (3, 4, 5, 6 & 7) that reassured me that Concern 2 had been adequately addressed and could be removed from my list.

Concern 8, related to 'stressing the context of scientific work in the classroom', had also been addressed in my work with students. As noted earlier, I recognised this was less of an issue
when working with practicing teachers. However, the handbooks I produced for the DES 20-day Course stressed the importance of context and each one had a section in which contexts for the particular content were identified. I did this at three levels, specific science topics which covered the content area, general topics which could have a scientific theme in the content area and ongoing classroom activities during which the content could be covered. For example, in the Materials handbook examples at the three levels included, a science topic on 'Water', a science theme of dissolving as part of a general topic on 'Food' and a discussion about waterproofness on a rainy day.

The informal discussions, evidence from school-based days, reports of work from course members' own classrooms and assignment 1 (submitted in December 1989) all provided evidence that the importance of context was appreciated. In every case of classroom activity reported by teachers or included in their assignments the scientific activity was contextualised in some way to make it relevant to the children's experience. Often these were in terms of everyday experiences but most commonly linked into topic work that was going on in the classroom. I therefore felt justified in deleting concern 8 from my list. Primary teachers on the DES 20-day Course recognised this aspect of primary science without it being constantly reiterated by the tutor. However, ensuring that the science the teachers meet is in a relevant context will continue to be a feature of course planning. This is the unanimous view of the planning team.

Concern 9, related to my understanding and use of 'prediction' was also no longer a concern. Having clarified my own ideas about this I was again confident that I could apply this new understanding to my practice. One particular episode, discussed in the analysis but not documented, occurred on day 3 of Case Study 5. During a plenary discussion, reviewing the work they had been doing with children, this issue arose and we looked in detail at several examples, from the detailed data course members had collected, of children predicting. This allowed me to explore with course members their understanding of the term and we explored the differences between guesses, predictions and hypotheses.
Concern 12, which arose as a result of the use of specific metaphors related to electricity, was addressed during Case Studies 2 and 3. During Case Studies 4 and 5, the use of a computer simulation to demonstrate the particulate nature of matter raised a similar issue. However, the evaluations and informal discussions provided evidence that course members had found it useful in terms of helping them understand particulate theory. I recognised however, that this concern deserved more thought since I intended to explore the use of an analogy during the electricity cycles of the DES course. Consequently, I decided to leave Concern 12 on the list. I realised that I needed to be clearer in my own mind about the differences between the terms 'analogy' and 'metaphor'. The dictionary tells me that 'analogy' is a process of reasoning from parallel cases where there is resemblance of form or function between phenomena that are essentially different. Therefore the use of a water system or rail networks to illustrate simple electric circuits is an analogy. A 'metaphor' is the application of a name or descriptive term to an object to which it is not literally applicable. Therefore my description of electricity as 'lazy' (CS 1) is a metaphor, although not necessarily a useful one!

I decided to number concerns consecutively and not renumber when concerns were addressed and therefore deleted from my list. The revised list of concerns, including those identified during Case Studies 4, 5, 6 & 7 was now:

**Concerns Identified as a result of analysing Case Study 1**

1. To what extent should I ensure an orientation period for adult learners?

2. N/A

3. What strategies can I use to elicit students' existing ideas?

4. Should I implement sessions which are so tightly structured, paced and controlled and should this depend on the particular content involved?
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5. How can I collect evidence of students restructuring their ideas?

6. How can I encourage students to apply their restructured ideas in novel situations?

7. What view of science do students take away from sessions like this?

8. N/A

9. N/A

10. To what extent should I encourage individuals to expose their ideas?

11. Should I deal with every ‘alternative framework’ identified or focus upon common ones?

12. To what extent did the metaphors I used foster misunderstanding in the students?

Concerns identified as a result of analysing Case Study 2

13. Do I allow students adequate time for practical exploration and investigation? (CS2)

14. How can I use the relationship between adults’ and children’s constructs to improve adults’ knowledge and understanding of science? (CS2)

Concerns identified as a result of analysing Case Study 4

15. How can I give students/course members more ‘ownership’ of their investigations?

16. At what stage of a DES course cycle is exposition most appropriate?

17. How can I encourage students/course members to raise scientific questions?

18. How can I meet ‘individual’ needs within the DES course structure?

Concerns identified as a result of analysing Case Study 5

19. What are the implications of exposition by an expert in terms of the students’/course
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members' views on their role as teachers?

20. How can I make constructivism less threatening to students/ course members?

Concerns identified as a result of analysing Case Study 7

21. To what extent should I encourage students/course members to use quantitative approaches during investigations?

The following table indicates a summary of my use of my analysis framework carried out at that stage (December 1990). I revised my decisions in certain categories to take account of my analysis of Case Studies 3, 4, 5, 6 and 7. The section after the summary table discusses these decisions in more depth and is again based on notes written at the time of the analysis.

Analysis of concerns carried out in December 1990:

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>TIME</th>
<th>CHANGE</th>
<th>DIFFICULT</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Orientation</td>
<td>S</td>
<td>Structure</td>
<td>1</td>
<td>Combine orientation/elicit.</td>
</tr>
<tr>
<td>2. Eliciting Prof. k&amp;u</td>
<td>M</td>
<td>Role/strat.</td>
<td>2</td>
<td>Use think books more Use concept maps</td>
</tr>
<tr>
<td>3. Structure M</td>
<td>M</td>
<td>Structure/role</td>
<td>2</td>
<td>Needs further team discussion</td>
</tr>
<tr>
<td>5. Application M</td>
<td>M</td>
<td>Strategy/Struct.</td>
<td>3</td>
<td>Rethink day 4 - difficult!</td>
</tr>
<tr>
<td>6. View of sc. L</td>
<td>L</td>
<td>Role/ethos</td>
<td>3</td>
<td>Clarify my own ideas Avoid aim for generalisations</td>
</tr>
<tr>
<td>7. Exposing ideas</td>
<td>M</td>
<td>Ethos/role</td>
<td>2</td>
<td>Further strategies - think books</td>
</tr>
<tr>
<td>8. Challenging L</td>
<td>L</td>
<td>Strategy</td>
<td>3</td>
<td>Common constructs difficult to identify - read more</td>
</tr>
<tr>
<td>9. Metaphors M</td>
<td>M</td>
<td>Sc. k&amp;u</td>
<td>1</td>
<td>Check egs. for electricity</td>
</tr>
</tbody>
</table>
8.3.1 Discussion of review of concerns

1. To what extent should I ensure an orientation period for adult learners?

I remained confident after the case studies under consideration that orientation opportunities existed during the first sessions of each cycle for those course members who needed time to structure their ideas and, as with the B.Ed. sessions, the course members had been given
notice of the conceptual area to be covered during the cycle and this enabled some prior thinking to be done, which was evident from comments made on the first morning of a cycle (such as references to conversations with spouses). At the start of the sessions the ‘orientation’ opportunities were in the context of activities set up to elicit their existing ideas through informal pair or small group work. Although I found this unproblematic and discussions with course members indicated they were comfortable with the way cycles began, I was concerned that it may been seen by the course members as implying orientation was unnecessary with children. Evidence was found of some course members (evident in feedback sessions and in assignment 1) providing orientation time and activities for their children but this was not always the case. The attempt to make explicit to course members decisions about the structure of sessions helped make them aware of the differences between the approach used with them and that suggested with children.

Another aspect of this concern related to evidence I collected suggesting that the less confident course members were the ones needing and apparently benefiting from time to talk informally about a content area before being asked to make their ideas more public. In this respect there are links between this concern and Concerns 10 and 20. This was confirmed through discussions with colleagues running the other course at Bristol Polytechnic.

I also explored the use of video sequences (MIST) as another approach to orientation/elicitation and it proved successful in terms of generating discussion which offered me insights into course members’ existing ideas.

At the stage of this review I decided that this concern need no longer be regarded as a long term consideration and was confident that it was being addressed with less difficulty than originally anticipated.
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3. What strategies can I use to elicit students' / course members' existing ideas?

My evaluation of progress made addressing this concern was also positive. I had begun to appreciate that elicitation was ongoing throughout the whole constructivist cycle and was providing me with insights into course members' learning at each stage. I had explored a number of different strategies for doing this in the case studies collected. It was also becoming apparent that course members were recognising that what they were doing with children when eliciting ideas was essentially assessing and this growing awareness was timely in terms of the concerns in school during this period about teacher assessment. The approach to assessment we had hoped to support through the course model was based on the premise that assessment was inextricably linked with teaching and not something that was done for summative purposes at the end of an activity. The approach evident to course members during sessions, in which I was constantly collecting evidence of their ideas, reinforced this view of assessment.

The strategies I explored included floorbooks, which in Case Study 4 and 5 were completed by tutors. In Case Studies 6 and 7 course members were responsible for maintaining a floorbook for their group and these provided excellent evidence of existing ideas and how those ideas changed during investigations (particularly during Case Study 7). The purpose and value of floorbooks was immediately recognised and accepted by nearly all course members and there was considerable evidence from school-based days, reviews of work from their classrooms and assignments that floorbooks were being commonly used as a practical tool for eliciting and recording children's ideas at the outset of an activity, as an ongoing record of progress through the activity and at the end to record new or changed ideas. It should be noted that some of the Cohort 1 (Case Study 4 and 6) had met floorbooks on previous inservice and were already using them.

I also considered better use had been made of elicitation sheets on the DES course based
upon my experience during Case Study 3 a few weeks before. The sheets used during the materials cycle were based on CLIS (CLIS, 1984-91) teaching material (Case Studies 4 and 5) and elicitation cards based on Kruger and Summers 'interviews about instances' work (Kruger and Summers, 1989) were used during Case Studies 6 and 7. These were used before and after tutor input of accepted ideas (during Case Study 5, 6 and 7) and so provided evidence related to Concern 5.

Concept maps were introduced, as I had planned during my last review, during Case Studies 4 and 5. However, few course members responded to the request, perhaps because it was rather half-hearted, to complete one as a directed task at the end of day 1. After further reading and discussion with colleagues about the response, I introduced the idea more purposefully during Case Study 6, making reference to the previous response, and the results were encouraging. They completed them on day 4 and unfortunately I had nothing to compare them with. Consequently, during Case Study 7 I used them immediately after the tutor input of accepted scientific ideas and on day 4. This provided much more useful evidence of the extent to which ideas had been retained. What I had still not done was used concept maps as a means of eliciting existing ideas at the start of a cycle. However, as an assessment strategy they had considerable potential.

4. Should sessions be so tightly structured, paced and controlled and should this depend on the particular content involved?

The collaborative planning carried out prior to the DES course had been helpful in encouraging me to adopt a less tightly structured approach to sessions, especially on day 1 of each cycle, and I was satisfied that the structure of the sessions in Case Studies 4 to 7 were generally appropriate. Reflection on this concern helped me appreciate that my original question was in fact related to the time I was providing for exploratory work and so Concern 13 provided a more accurate description of what I needed to address.
5. How can I collect evidence of students/course members restructuring their ideas?

I was encouraged by the extent to which I was able during Case Studies 4 to 7 to collect evidence of restructured ideas. It had proved easier than I had anticipated and consequently I reduced the difficulty rating at this stage and recognised it was a concern that was being addressed in the medium term.

During Case Study 4, the data collected on day 4 related to course members' explanations of a candle burning provided evidence that ideas about the particulate nature had been retained and used to explain this phenomenon. Case Study 5 provided further evidence, through the analysis of elicitation sheets completed before and after the tutor's input, of new ideas being used. However, the problems of assessing the extent to which adults are able to use ideas in new situations is probably more significant and this evidence of ideas being used soon after an input needed treating with caution.

Another feature of Case Study 5 was the extent to which I had encouraged course members to assess their own responses to 'how a candle burns' in terms of key ideas I subsequently identified. This was not without its problems but indicated another strategy that could in itself aid the restructuring of individuals’ ideas.

The extent to which individual course members' ideas were socially constructed is another interesting aspect of the analysis of all the case studies. Case Study 6 provided evidence that course members were increasing their awareness of this in their work with children and their reports of work from their own classrooms included examples of individuals whose ideas were explicitly developed through discussion between peers, illustrating the influence of group
members on an individual. Assignments included transcribed data of group discussions from their own classrooms which were analysed in terms of the effect the social context had upon the ideas developed (Andrea (Cohort 2) provided a particularly good example).

My reflection at this time (December, 1990) on the extent to which course members were restructuring their ideas raised another issue in my mind concerning the differences between children’s alternative constructs and those of adults. This was raised by another DES 20-day course tutor from Reading, David Malvern (see Chapter 5, Section 5.7) who suggested apparent alternative frameworks maybe due to ‘a lack of focus in their scientific frameworks which causes them to apply perfectly correct notions based on (say) energy incorrectly to an analysis of forces’. The evidence I collected during Case Study 6 and 7 seems to offer some support to this view and deserves further consideration. Related to this, I was also concerned at that time to clarify my thinking about the extent to which apparent alternative frameworks are simply due to an inaccurate use of a scientific term.

My concern about evidence of restructuring led me to look for evidence of restructured ideas about the nature of science teaching and this can be found in all case studies in terms of the extent to which all course members were implementing constructivist approaches, to some extent, with the children in their classes. Every single course member who submitted an assignment in December (1990) provided evidence of the existing ideas they had elicited from children, and all made reference to ‘valuing’ children’s ideas. This aspect of the course, ie the importance of learners’ existing ideas, had undoubtedly been internalised and part of the practice of the teachers. They did, however, seem to find it less easy to decide upon activities to challenge alternative ideas that they elicited and this was an area that needed more attention. The SPACE material (1990-92) with numerous examples of intervention strategies had recently been published and would, I considered, be helpful to use with them.
6. How can I encourage students/course members to apply their restructured ideas in novel situations?

This concern proved more difficult to address than I anticipated and lack of evidence of teachers encouraging their children to do this (only 2 examples were identified in first assignments) is a worry. There was a specific attempt during Case Study 5 to assess the extent to which course members could apply particulate theory ideas to explain 'conduction in metals and wood'. This provided clear evidence of application of restructured ideas during the last day of the *materials* cycle.

During the *forces* cycles, course members engaged in a consolidation exercise straight after the 'expert' view had been given and were required to apply the ideas in the context of a 'plane in level flight'. The evidence indicated all course members were able to do this at that stage. However, more significant evidence of applying scientific ideas to novel situations needs to be collected perhaps sometime after the cycle.

The application of restructured understanding of the nature of science and of the processes of science can be seen (as noted in the previous section) from the reports of work tackled in the course members' classrooms, especially during Case Studies 6 and 7 when many course members were confidently describing the ways in which they had implemented constructivist approaches using the content areas covered by the first two cycles of the course.

The potential for problem solving work with their own children as a strategy for addressing this in the classroom was discussed in the tutor meetings. Most of us had experience of encouraging teachers to use open-ended problem solving challenges as a strategy for developing more independent learners. The same strategy would seem to provide the best opportunities to assess children's capabilities to apply learning in new situations.
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7. What view of science do students/course members take away from sessions like this?

This concern required me to clarify my own views about science before I felt confident that it was fully addressed. As noted in my first review, my teaching was providing evidence of students/course members who were clearly recognising the tentative nature of science knowledge, were increasingly aware of the links between the process and content of science and were gaining an increased understanding of the human aspects of science and the extent to which ideas are socially as well as individually constructed. The link between process and developing knowledge and understanding was the focus of the first assignment and all who submitted (over 90%) provided evidence of children in their classes developing scientific knowledge and understanding as a result of engaging in the processes of science. This was also the case in the assignments submitted at Bristol Polytechnic, according to tutors there. One aspect of the evidence in assignments was the extent to which teachers were finding it difficult to get children to raise their own questions as the basis for investigations. This seemed to be related to the lack of scientific experience of many of the children.

I was finding considerable evidence, especially during the last two case studies, of course members' restructured ideas about the importance of the processes of science being a route to their own improved understanding of scientific ideas. However, doubts were being raised in my own mind about the nature of science - were course members being encouraged to adopt a rather narrow inductivist view (see Chapter, Section 1.9) as a result of my focus of working towards generalised statements? I recognised the place of generalisations in science but need to clarify the most appropriate manner in which to introduce this to course members. The suggestion that teachers can make generalisation based upon limited and often inaccurate data is worrying. Did I need to make aspects of the philosophy of science more explicit to them and articulate the purpose of practical investigations differently?
10. To what extent should I encourage individuals to expose their Ideas?

During my review of this concern I recognised considerable progress had been made in addressing this area, as discussed below, and considered it appropriate to revise my evaluation of the difficulty and timescale involved with a view to deleting it from the list.

Work during the case studies being discussed indicated successful use of paired work during Case Study 4 which had been positively evaluated by course members. However, evidence from Case Study 5 was not as positive and suggested there was still a problem for some of Cohort 1 with regard to sharing ideas and I was aware of the need for information about individual constructs which I needed to assess and if necessary challenge. Paired and group work made this difficult.

I tackled this concern during Case Study 6 by encouraging individuals to articulate and note their existing ideas and then share them with a partner. This proved relatively successful but needed to be explored further. Course members were apparently happy with the use of floorbooks and these were proving a useful source of evidence.

However, as noted in my discussion of Concern 3, I was becoming more aware through my reading and discussions with colleagues of the potential value of concept maps. These were used during Case Studies 6 and 7. The latter proved the most successful but still threatening to some course members. The use of concept maps illustrated a significant development from my reliance on group discussion as the means of eliciting ideas during the first case studies. It also provided evidence of the value of collaborative work with other tutors since the idea arose from colleagues who had explored it in other contexts. Addressing this concern had encouraged me to explore a variety of strategies for exposing an individual's ideas so that they became available for challenging. Reflection on this concern led me to a recognition that successful use of a constructivist approach required me to maximise the extent to which existing and developing ideas were articulated. In that sense the question under
consideration had a simple answer and on examination the concern was, in effect, now subsumed by Concern 3 and in terms of my teaching was addressed by how I achieved this, not the extent to which it was necessary.

At this stage, I had decided to explore the use of individual 'think books' during the next cycles which would be used to record ideas at each stage of the cycle. They would essentially be private records shared only with me, as tutor, and others with whom the course members chose to share their ideas.

11. Should I deal with every alternative framework identified or focus upon common ones?

The analysis of each case study detailed the alternative constructs I was identifying. The time spent doing this was proving beneficial for me in terms of increasing my understanding of the range of ideas held by adults about specific content areas and this was helping me anticipate the likely ideas of the subsequent group and consider appropriate ways of challenging those ideas. In other words, my analysis of Case Study 4 helped me with my planning of work covered in Case Study 5 and the analysis of 6 helped with the planning of 7. The analysis of each case study confirmed that many of the alternative ideas I (or other tutors) were exposing were indeed being challenged. However, the act of encouraging the individuals involved to consider and explore their own ideas was perhaps as, if not more, important than having them challenged by me or another tutor. The process of exploring and challenging their own ideas is one which I hoped they would recognise as a vital aspect of their learning and one in which they would constantly engage. It was indeed, the process I was attempting to use in developing my own ideas about teaching and learning.

Returning to the theme of alternative ideas, I was finding it difficult to identify common constructs in the same way as other projects such as CLIS, SPACE and PSTS (see Chapter 2, Section 2.7 and Chapter 4, Section 4.4.1), because in a teaching, rather than research,
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context such a range of diverse alternative views were expressed. These projects were, however, providing me with valuable source material for comparative purposes. In the case studies under consideration I had noted common alternative ideas about *materials* such as:

- solids and liquids burn;
- particles in solids are static;
- particles change in size and mass when heated;
- particles have air in between them.

and about *forces*:

- when things move there is a force acting in the direction of movement;
- the amount of motion is proportional to the amount of force;
- if a body is stationary there is no force on it;
- constant motion requires constant force;
- gravity pushes objects towards Earth;
- mass affects acceleration due to gravity.

In terms of *electricity* they were:

- electricity comes from both sides of the battery (dry cell) and clashes in the bulb (lamp);
- batteries and lamps do not require two connections;
- bulbs contain a 'vacuum';
- current gets used up in a bulb and becomes weaker around a circuit.

These alternative ideas were similar to those identified in secondary pupils (Arnold and Millar, 1988, Gauld, 1989; Osborne and Freyberg, 1985) and that others have identified in primary teachers (Kruger, Palacio and Summers, 1988-91; Kruger and Summers, 1989).

It was evident that I needed to spend more time considering the nature of these alternative ideas and considering, as noted above, the nature of adults' apparent alternative ideas
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compared to those of children.

12. To what extent do my metaphors foster misunderstanding in the students/course members?

As discussed at the beginning of this review this concern is one which I intended to revisit after further background reading about the use of analogies, particularly the work of Clement (1987) and the PSTS Inservice packs (Kruger, Palacio and Summers, 1991 a and b).

Concerns Identified as a result of analysing Case Study 2

13. Do I allow students/course members adequate time for practical exploration and investigation?

This concern, which at this time I considered to also address Concern 4, had consumed a lot of my thinking during Case Studies 4 to 7 and featured in several tutor discussions. Reflection on Case Study 4, at the time of this review, indicated that lack of tutor confidence had meant that inadequate time had been provided for exploration and this was confirmed by the fact that on day 3 during school-based work few course members allowed children sufficient exploration time to raise their own questions and gain some ownership of the activity. This was in part addressed on day 4 of the same Case Study through the 'sherbert lemon' activity which very explicitly addressed the issue of approaches to science in the classroom. This activity was relatively successful in terms of the issues it raised and there is some evidence from the feedback of work in their own classrooms that this influenced approach of some of the course members with their own classes. Case Study 5 provides more evidence of this in terms of work with children and this may have been directly related to a more confident tutor approach to the exploratory phase on day 1.

During Case Study 6 the importance and purposes of exploration was made more explicit
during day 1, and they were supported through a specific exercise to take more ownership of the work (see Concern 15). The fact that some pairs spent over an hour at this stage, whilst difficult for me, seems to have had the desired effect in helping them appreciate the significance of exploration when working with children. However, as noted in the analysis there were some course members who found this phase of the cycle frustrating. My own reflections at the point of the December review indicated that I was clarifying my own role during the unstructured exploratory work and recognising the need for a non-interventionist approach. Case Study 7 also provided me with positive evidence related to this concern and the school-based day of this case study included several examples demonstrating the importance course members were now attaching to unstructured exploration, even when, as on these atypical occasions, time is short. There was also an excellent example (related to the use of a collection of balls) of the comparison between two different approaches, during which evidence indicated the more unstructured approach was most successful in leading to improved understanding of the processes of science and ideas related to forces.

This case study also included evidence during the feedback of work from the course members' own classrooms that they were providing time for exploration working with children in school. Assignments provided further evidence of this happening during the sessions reported. It was referred to directly in 2/3 of the reports.

I decided that this concern should in future subsume Concern 4, but that since my role had a significant part to play in addressing this concern it should be added to the factors affecting change in this case. It was also linked with Concerns 15 and 17 as discussed below.

14. How can I use the relationship between adults' and children's constructs to improve adults' knowledge and understanding of science?

As I had noted during the first review (April, 1990), this concern was particularly relevant in the context of the DES course. My analyses of Case Studies 4 to 7 had provided me with some
insights into the difficulty of addressing this concern. There was limited evidence in Case Studies 4 & 5 of this but perhaps the most encouraging evidence at the point of review concerned those examples where course members provided evidence of using the same specific content area on day 1 of the cycle, with children on day 3 and during the follow up work in their own classes. Where this happened, as in the example of floating and sinking (Case Study 6) I began to appreciate how encouraging individuals to reflect the relationship between their own ideas compared to those of children could improve their own understanding of science - as indeed reflection on course members' ideas was in turn influencing my own understanding of scientific ideas. An example of the latter point was evident in Case Study 3. At the point of this review however, it was clear to me that this was a concern that should remain a high priority in the analysis of future case studies and I should make this aspect more explicit to course members.

Concerns Identified as a result of analysing Case Study 4

15. How can I give students/course members more 'ownership' of investigations?

This relatively straightforward concern arose due to restricted time for exploration during Case Study 4 and was addressed through a specific strategy (a prioritising exercise) during Case Studies 6 & 7 which proved successful for most course members. Reflection at the point of review suggested that 'ownership' of activities was important but could be achieved relatively easily. The strategy used during the forces cycles (Case Studies 6 & 7) was not appropriate for all content but worked well in the specific situation. The relationship between this concern and Concern 13 in discussed above. It is also linked, perhaps less obviously, with Concern 17 since the successful raising of appropriate questions for investigation is likely to lead to course members feeling they have 'ownership' of the investigations. Ownership was considered to lead to greater purpose for the practical work and consequently improved motivations and desire to find out. In the light of the links between Concerns 13, 15 and 17 it
was considered unnecessary at this stage to pursue Concern 15 any further but to recognise
that it was covered by the other two.

16. At what stage of a DES course cycle is exposition most appropriate?

I had always recognised that the place and nature of exposition within a constructivist
approach was problematic. During Case Studies 4 to 7 the main exposition had been during
the morning of day 2. This was based on the premise that day 1's opportunities for structuring
and restructuring of ideas through practical work would prepare individuals to cope with the
accepted scientific ideas, or 'expert' view. During Case Study 4, when this particular concern
was identified, I was questioning whether the 'expert' view might be offered earlier in the cycle
so that the practical could build on these ideas. This suggestion came from a student.
However, further reflection confirmed my view that it was appropriately placed after student
practical work. The premise, used in the course proposal, that knowledge and understanding
developed through practical investigation was as noted before an explicit attempt to reinforce
the inextricable links between the content and processes of science. Consequently, I
considered these links required the prioritising of practical exploration and investigation as the
route to understanding. The 'expert' view was one to be considered alongside the students' as one worth considering and testing. This was an area where there was some disagreement
within the tutor team. Some tutors were more committed to 'giving' students the accepted
scientific view earlier in the cycle than others, although all saw the need for exposition to be
based upon learners' existing ideas and made relevant to their experience. The style of
different tutors giving inputs to the groups provided me with the valuable opportunity to
observe and use that reflection to inform my own inputs. I sometimes drew upon the content
and structure of these directly, sometimes modified and learnt from the response of course
members to these inputs.

At the point of the review, I regarded it as relatively straightforward to address and anticipated
reviewing it over the medium term. Linked to this concern was the structure of the course in
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terms of whether the first two days should be consecutive or have a week's gap between. Most cycles were based on consecutive days and this seemed successful. Case Study 5 involved a week between days 1 and 2 and this, according to student evaluations, caused concerns for some students about retaining questions and ideas from day 1 through to day 2. However, discussion with colleagues at Bristol Polytechnic, where the same course was running, caused me to question this further since they were finding a gap between the two days desirable since it encouraged 'thinking time' before an accepted view of science was offered. In the light of this, I resolved to reconsider this concern at the next review.

17. How can I encourage students/course members to raise scientific questions?

The first case studies related to the DES 20-day Course (Case Studies 4 and 5) indicated that raising scientific questions was going to prove more difficult for teachers in the context of the course than anticipated. There was little evidence that teachers came to the course with an understanding of the nature of scientific questions and after Case Study 4 it was decided, by the tutor team, to draw attention to the importance of a scientific question being one that could be answered by investigation (or experimentation). This was addressed in Case Study 5. There was evidence from the student evaluations of these case studies that there was a changed awareness in some students and analysis of Case Studies 6 and 7 provided further evidence that, during day 1 work, the questions being raised were becoming more 'scientific' and that the students' questions were used as a starting point for their practical investigations. During these two cycles, the importance of question raising being seen as an objective of exploratory work was stressed. This links this concern with Concerns 13 and 15 as discussed above. I had identified this as a medium term concern which would require some effort to address. As is apparent from the discussion, it was related to my role and strategies used. At the review stage, I intended to explore other strategies, such as brainstorming and classifying questions but was unsure whether electricity was going to be suitable content to pursue this concern further. There was also evidence, referred to in an earlier section, that the teachers
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were finding it difficult to get their children to raise questions

18. How can I meet individual students'/course members' needs within DES course structure?

From the beginning of the DES 20-day Course it was apparent that the two groups were very mixed in terms of background experience of and confidence in dealing with scientific ideas. This was highlighted during Case Studies 4 and 5 when the explanations provided by some course members, for example about the candle burning, were much more sophisticated in scientific terms, than others. This concern was also raised by an HMI as a result of his visits to both cohorts. It had been intended to address the issue of individual needs through a constructivist approach, by allowing individuals to pursue their own investigations based on their existing ideas. This indeed happened in most cases, although some problems occurred as a result of pairing, where one partner held acceptable scientific ideas, and ended up working with their colleagues' more naive ideas rather than developing their own. Reviewing work on these case studies suggested that further differentiation may have been desirable and this will be explored during the electricity cycle where informal comments had indicated levels of confidence and understanding were particularly varied.

Another aspect of differentiation concerned the differences in terms of understanding about the nature of teaching and learning in science. In some cases those who came to the course with most scientific knowledge were those who most lacked an understanding of learning in science and the implications for teaching. This was regarded as significant in ensuring course members were made to feel that what they brought to the course was valued and worth sharing with others, since during discussions those who 'knew the science' could learn about teaching strategies from others who had perhaps found it easier to adopt a constructivist way of working in their own classrooms. I intended to ensure that both aspects of this differentiation were made explicit during future cycles.
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Concerns identified as a result of analysing Case Study 5

19. What are the implications of exposition by an expert in terms of the students'/course members' views on their role as teachers?

This concern is linked to Concern 16 but was related to the more specific point about the nature of the exposition rather than when it was offered. I did not provide the 'expert view' during Case Studies 4, 5 and 6 but found the examples offered and the course members' responses to them interesting. The inputs on particulate theory had impressed me as apparently very effective inputs which built upon course members' questions and involved them in developing a particular line of thought. However, the comment in a student evaluation about 'teacher implanted' knowledge caused me to raise this concern explicitly. It reminded me of the difficulty of avoiding a situation in which a 'transmissionist' approach to teaching is seen as being advocated, particularly by those who might already be in sympathy with such views. A different, but related, concern about the 'expert' view was raised by the input in Case Study 6 which was dealing with even more difficult ideas and caused several course members to comment in evaluations that they felt they had been offered ideas that were too difficult and which they were unable to make use of in terms of restructuring their existing ideas. At the time, I thought this was perhaps more due to the fact that few of them had been challenged to think at this level scientifically before, in a quantitative way, and they undoubtedly found it difficult. I anticipated comparing their reaction to similar quantitative aspects in the input about electricity (Case Study 8 or 9). In terms of my thinking at that time, I resolved to attempt to ensure my input during Case Study 7, based on notes made during Case Study 6, would cover identical ground although place less emphasis on the quantitative aspects and also be based on the dialogue approach I had witnessed in Case Studies 4 and 5. The evidence from Case Study 7 suggests I was reasonably successful in achieving my aims and no evaluations, or informal comments, suggested that the course members had found it too problematic.
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I particularly looked for evidence in course members assignments of any evidence of 'transmissionist' views persisting, but found none evident, although it is obvious that the practice documented for assignments does not reflect the teachers' approach to all science work. Indeed contradictory evidence was apparent during discussions with a course member's headteacher who reported changes in practice to more learner-centred teaching but suggested 'didactic' teaching was still regularly used during science work. In another case an advisory teacher described a whole-class approach to science work observed, in contrast to an assignment based upon a group activity. Of course, a good teacher will use a range of different strategies but it does serve as a reminder of the need to be sceptical of self-reported accounts. This concern needed reconsideration after the electricity cycles.

20. How can I make constructivism less threatening to students/ course members?

This concern was identified during Case Study 5 and also arose during Case Study 3. Analysis of Case Study 5 suggested that comments during the introduction to this cycle by a co-tutor like 'you will not find this work threatening' may have aggravated the problem with this cohort. It was regarded as a short term concern that could be addressed fairly easily by a change of role and ethos. It was undoubtedly a mistake to start a course that many course members were concerned about by saying it would not be threatening, particularly when this was supported by the comment that 'the other group didn't find it threatening'. At one level, the nature of the approach was always going to be threatening until an individual appreciated that their ideas would not be ridiculed or trivialised. In retrospect, it would have been preferable to have emphasised the need to create a 'secure' social environment in which sharing ideas could be achieved comfortably. In fact, my attempts to do this during Case Studies 1, 2 and 3, with student groups, were probably more successful than the approach used at the start of Case Study 5.

However, there were other aspects of this concern that deserved thought. The extent to
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which course members felt threatened by the approach was also related to the nature of the exposition of accepted scientific ideas offered and this was of concern in Case Study 6 (as noted above). The same case study, and to a lesser extent others, also highlighted the 'threat' some course members felt because they were expected to tackle scientific investigations at their own level. There continued to be a problem for several course members about 'working at their own level'. This was evidently a result, for some, of previous inservice education during which they had never been asked to work at their own level, in a particular curriculum area. They found it easier to talk about how children would, or would not, do activities than to do things themselves and reflect on their achievements.

On reflection, at the point of review, it seems whilst this concern is related to Concerns 10 and 19, it deserves to remain on my agenda and be reconsidered at the next review. It is clearly an aspect of constructivism where a tutor faces a dilemma - wishing to expose learners' naive ideas but not wishing to make the experience threatening or 'uncomfortable' for the learner. I recognised that whilst some degree of discomfort with existing explanations was necessary to motivate a learner to consider new explanations, it required careful and sensitive treatment.

Concerns identified as a result of analysing Case Study 7

21. To what extent should I encourage students/course members to use quantitative approaches during investigations?

The last concern considered at this review arose as a result of my analysis of the second forces cycle. Compared to the earlier case studies, Case Studies 6 and 7 involved much more quantitative work and the 'expert' view, as discussed above, was also based on a more quantitative approach. In some ways this was inevitable due to the content (and the way the National Curriculum describes it). However, it raised a significant question about, more generally, the extent to which I should encourage a qualitative or quantitative approach. I was aware at the time of the review that others working in the same field (particularly Kruger and
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Summers at Westminster College and Malvern at Reading University) were advocating a purely qualitative approach. Consequently, I considered this issue deserved to be addressed in the context of the research I was doing. I had used a qualitative approach with electricity during Case Studies 1, 2 and 3 and considered it would be interesting to explore a more quantitative approach during the DES course for comparative purposes, although I was determined not to introduce the quantitative aspects too early, unless individuals were ready to deal with the ideas involved.

8.3.2 Evaluation of the framework after the second review.

At this stage, the framework had proved useful in focusing my thinking about the extent to which each of the wide range of concerns I had identified was being addressed. It also encouraged me to review the extent to which my original perception of each concern had been appropriate. It had caused me to revisit and reconsider the original evidence in the light of the ongoing discussions with other tutors. The use of the framework, and the resulting summary of concerns in table form, had provided me with a dynamic agenda to inform my practice and changes to it. It had enabled me to retain a perspective on all those concerns and in one sense acted as a reminder of those concerns and my intentions related to them. As I had gone through each action research cycle I had, as a result of my analysis, identified future changes to my practice. However, those analyses had developed from the nature of the particular case study evidence and had not been structured to look at each of my identified concerns individually. The framework provided a way of structuring my review of concerns which required me to view each from a new perspective, taking account of the holistic nature of my practice. In this way I gained an appreciation of how the apparently distinct concerns inter-related and informed or were informed by others. I recognised, as a result of the review, that Concern 13 subsumed Concerns 4, 15 (which I intended to delete from the list) and 17, that 10, 11 and 14 were closely interlinked as were 10, 19, 20 and to a lesser extent 16. In this sense the framework was leading me to identify major concerns, and perhaps was leading me towards identifying a main concern that would provide a more specific focus for later action.
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research cycles.

The review also highlighted that none of my concerns addressed classroom implementation of the ideas and approaches being offered on the course even though this was being covered fairly thoroughly in each analysis and was undoubtedly important to me as a tutor in evaluating the success of my teaching and the approach I was using. At this stage I considered that there was sufficient evidence that the implementation was taking place to mean that it did not need to be identified as a concern. The evidence of impact upon practice would be drawn together at a later stage by way of an evaluation of the approach. The current review was focused upon my understanding of my practice and changes to it.

I also reflected at this stage on the limited number of concerns identified during the later case studies. It seemed that during my exploratory work on Case Studies 1 and 2, I had identified most of the concerns that I subsequently considered worth addressing and only added a few as a result of later case studies. I recognised that this was, in part, due to the fact that I had been thinking about constructivism and exploring its use in my teaching for some considerable time before tackling Case Studies 1 and 2. Consequently analysis of these case studies was informed by a lot which had gone before and effectively the exploration period of my research had started sometime before I began systematic data collection and analysis.

I ended my second review considering the framework to have supported my reflection upon my practice. It had, at this stage, met the purposes I had identified and in particular it had made the 'messiness' of my real practice manageable. The three categories I had chosen all seemed to be appropriate and useful and I therefore considered it unnecessary to make changes. I intended to carry out my next review in April 1991.

My journal entries show that in July 1990 I began to think about my research in terms of 'constructivist' phases. The exploratory phase, before Review 1, I recognised as my own orientation and structuring period during which I clarified ideas I had about my practice. The
cycles between the two reviews were the investigative phase during which further structuring and restructuring of my understanding occurred. The application phase would come later. I intended to reflect further upon this before the next review.

8.4 Review 3 - April 1991

At this stage of my research (April 1991) I had collected data from nine case studies. Three of these (Case Studies 1, 2 & 3) had been work with student groups and the other six had been cycles of the DES20-day Course. The last two of these case studies (Case Studies 8 & 9), concerning electricity, had been implemented since the last review. As I noted at the stage of my December review, each of the DES course case studies had involved evidence from several full days of the course. I was treating each Case Study as an action research cycle. Consequently, during and after the collection of data for each case study (since there was overlap) my analysis of data was providing me with evidence of the extent to which I was addressing particular concerns and indicating some new concerns. After each analysis I had again produced a 'future action' list as a reminder of issues raised. I had planned, after my last review, to carry out a further systematic review of concerns, based on my framework for analysis, during April. This review is based on notes produced at that time. Figure 8.3 illustrates the scope of this review.
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Figure 8.3: Review 3

Review 1
April 1990

Review 2
December 1990

Review 3
March 1991

Interviews

CS 1
Analysis 1

CS 2

CS 4

CS 5

CS 3

CS 6

CS 7

CS 8

CS 9

Investigative Phase

Review 4
January 1993

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8.4.1 Discussion of concerns (Review 3)

1. To what extent should I ensure an orientation period for adult learners?

This concern has been reassessed as one that could be addressed in the short term at the last review (December 1990). I had also reduced its level of difficulty since there had been evidence that orientation opportunities were being provided for those course members who required time to start thinking about the particular content area. The issue which was emerging at the last review, through consideration of this concern, was the relationship, when working with adult learners, between the orientation and elicitation phases of a constructivist approach. There was a related aspect which concerned the extent to which the teachers with whom I was working were providing adequate orientation time for children. The most recent case studies provided evidence to confirm my view that adult learners can orientate themselves to the particular content area through activities that also begin to elicit their existing ideas. It was evident that some course members, during Case Studies 8 and 9, felt it was necessary to spend some time focusing their thoughts on electricity and the activities planned, although fairly tightly structured in terms of timing and outcome, provided opportunities for those who chose to use the time for orientating themselves.

During the DES 20-day course I had explored a variety of different approaches to the start of a cycle and the electricity cycle was more structured than that used for materials or forces, both of which provided opportunities for handling materials and artefacts. The forces cycle also included the use of video sequences. The electricity cycle involved course members in writing sentences including the word ‘electricity’ at the start of the session before moving on to other elicitation questions. This provided me with immediate evidence of their existing ideas but, because it was an individual activity, it had been regarded as too threatening (see Concern 20) to use on earlier cycles in the course, based upon evidence from Case Study 3. However, although individuals were asked to write down their own ideas they were encouraged, if they wished, to talk with a partner about their ideas. This informal discussion
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provided the orientation time for those who needed it.

The initial elicitation questions were related to the uses of electricity and its generation and did not lend themselves to the handling of materials or artefacts. After answering these they were asked to start thinking about simple circuits through the context of a torch. They were asked to draw a torch showing how it worked, a strategy used successfully during Case Studies 1 and 2. At this stage it may have been appropriate to have provided more opportunities for handling and dismantling a torch.

An approach that I had not used was the setting of precycle tasks, or readings, as orientation activities. This had been used on courses at other institutions according to anecdotal evidence from the DES Invitation Conference (see Chapter 5, Section 5.7). My reasons for not setting activities prior to the cycles were that the time between cycles was most appropriately spent following up the previous cycle. This included classroom work and background reading. The timing of the cycles also meant that the gap between day 4 of one cycle and day 1 of the next was short. I was also concerned that precycle activities would lead some course members to look up 'right answers' which would be repeated, perhaps without understanding, during the elicitation discussions and pose difficulties for those trying to express their own ideas in their own terms.

I decided at that time that there was a compromise approach which could involve simple practical activities that required a limited amount of time. For example, the task for the electricity cycle could have involved course members collecting a variety of batteries and torches and noting down key questions they had about them. This approach would, I considered, set the scene for the cycle more effectively and efficiently than I had done during Case Studies 8 and 9.

In terms of orientation time and activities for children, there had been adequate evidence during recent cycles from review discussions, school-based days and assignments that
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course members were valuing and implementing this phase of a constructivist approach. However, there was some evidence that this was more likely to be the case with teachers of Key Stage 1 children. Those working with older children tended to minimise the time for orientation, perhaps as a result of the approach used with them. I had attempted to overcome this through explicitly raising the need for and purpose of orientation activities/time. In retrospect, it would have been appropriate to get the course members to analyse a particular learning episode from the classroom in terms of different phases of a constructivist approach. This could have led to more informed discussions about the purpose and strategies available for orienting learners. The course had tended to focus on the need for and ways of eliciting and challenging existing ideas and therefore less emphasis had been placed on the orientation and application phases.

Action

I intended to plan more precycle activities for the next course and encourage analysis of specific teaching episodes in terms of constructivist phases. The latter exercise could, I decided, be included as an aspect of the second assignment.

Conclusion

Reflection on my practice related to this concern had enabled me to regard it as addressed in terms of my own perception at this point in my research. Discussion with co-tutors confirmed this, although the planning of future sessions will obviously take account of the need for orientation-type activities.
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3. What strategies can I use to elicit students' / course members' existing ideas?

At the last review I had identified the links between this concern and Concern 10 (To what extent should the tutor encourage individuals to expose their ideas?). I had resolved that the latter was subsumed by Concern 3 and my intention to explore individual record books or journals (think books) was another elicitation strategy to explore. My exploration of Concern 3 had involved me in consideration of a range of strategies that involved individual, pair, small group and whole group activities. As well as using individual journals I had also intended to explore the use of concept maps further. However, this required further professional knowledge and understanding which I did not have time to develop prior to the cycles under discussion. This developing understanding about the nature of and potential uses for concept maps will be discussed further in the final review.

During my collection of data (see Chapter 7, Section 7.6) I had explored the following strategies for eliciting existing ideas: brainstorming (whole group); discussion (whole group, small group and pair); floorbooks (maintained by tutor and course members); elicitation cards (pair and individual); concept maps (group, pair and individual); drawings (pair and individual); sentences (pair and individual); Questions cards (pair and individual); think books (pair and individual). The latter four strategies were used during Case Studies 8 and 9. At this stage I noted that the think books, which I had previously explored with student groups (outside the data collection for this research) had proved a successful strategy for eliciting and recording ideas during Case Studies 8 and 9. They were relatively easy to organise, unthreatening to individuals and provided valuable evidence for me into the ideas individuals held at the start, during and end of experiences. They were similar to floorbooks in being a record of firsthand data but had the advantage over floorbooks of documenting the development of an individual's ideas. They did not, however, provide any evidence of the relationship between the ideas of members of a pair or group and in that sense gave no insight into the social aspects of restructured ideas.
Think books had, I recognised, limited use in the classroom when working with Key Stage 1 children, but did have potential with older children. Some course members already had experience of using journals with older children, as recommended by the National Writing Project, and the use of a similar log for recording scientific ideas was received enthusiastically by the Key Stage 2 teachers, some of whom explored their use in the classroom between day 3 and day 4 of the electricity cycles and reported that their attempts to use think books had been successful and had provided useful evidence of children’s learning in science.

**Action**

I intended to develop my understanding of concept maps and extend my use of them in my teaching as a tool for eliciting and recording learners ideas.

**Conclusion**

At this stage of my exploration of different means of eliciting and recording learners ideas I considered that it was appropriate to use a variety of strategies rather than using one strategy exclusively. Each strategy that I had implemented has proved useful in particular circumstances and social contexts. Whatever approach was chosen however, required sensitive use by the tutor to ensure that it was not threatening to course members. In that sense the tutor’s role was significant in addressing this concern.

I was satisfied that I had found a number of successful ways of addressing this concern and had identified, in concept mapping, a strategy with considerable potential which required further attention.
4. Should I implement sessions which are so tightly structured, paced and controlled and should this depend on the particular content involved?

During the last review (December 1990) I concluded that this concern was now subsumed by Concern 13 (Is adequate time available for practical explorations and investigation?). Consequently I will discuss the structure of sessions during Case Studies 8 and 9 later in this review. These case studies are particularly significant in terms of the structure of sessions since the concern arose during Case Study 1 covering similar content (electricity) and the issue of whether the particular content was relevant was raised as part of the concern. The earlier cycles during the DES 20-day Course (Case Studies 4 to 7) provided, as I noted during the Review 2, opportunities for me to adopt a less tightly structured approach, particularly in respect of the exploratory and investigative practical work in which course members engaged. I considered that my approach during Case Studies 8 and 9 was more tutor-led and controlled than the materials and forces work, as a result of the progression involved in circuit work that I had identified with colleagues through previous work. However, comparison between my approach to these sessions and that used during Case Studies 1, 2 and 3 indicated many more opportunities for student-directed explorations and investigations, inevitably helped by the increased time available (during the DES cycles) to cover the same content area.

Consequently, the content area is relevant and a narrowly defined content area such as simple electric circuits, focusing upon specific scientific concepts, allows a degree of tutor predication of likely questions and potential areas of development not as easily achieved in more broadly defined content areas.

5. How can I collect evidence of students/course members restructuring their ideas?

The use of think books throughout the cycle provided some evidence of restructuring of ideas. Tutor assessment of these concentrated on the first day (Case Study 8) and first two
days (Case Study 9). In retrospect I considered it would have been appropriate to have encouraged more systematic use of the logs during work in their own classrooms between day 3 and day 4 and during day 4. However, the cancellation of day 2 (Case Study 8) and the involvement of course members’ Headteachers on the afternoon of day 4 meant that the opportunities for exploiting this strategy for collecting evidence of restructuring on day 4 were limited. The analysis of both case studies provides evidence of restructured ideas at the end of the first and second days. This evidence has been collected as an integral part of the teaching approach and used formatively to inform my plans for the next phase of the work. It would have been desirable to have had more evidence of a comparative nature to indicate the extent to which ideas about simple circuits, particularly related to the workings of a torch, had been restructured to more closely match accepted scientific ideas. For example, had time been available it would have been appropriate to ask course members to try drawing another torch showing, how it worked using annotations. Obviously the use of concept maps, at the start and at this stage could also have provided useful evidence to inform my reflections on this concern.

I noted that the extent to which restructured ideas have been retained would become more apparent when I analysed the interviews I intended to carry out at a later date (July - December 1991). I also appreciated, at the stage of the this review (April 1991), the links between this concern and the next (Concern 6 - How can I encourage students/course members to apply their restructured ideas in novel situations?). The challenges I offered on day 4 of Case Study 9 provided evidence of the extent to which course members had restructured ideas and had been able to use them in novel situations. In particular the challenge related to constructing an alarm provided evidence of the extent to which course members understood simple circuits and switches.

The materials cycle (Case Study 5) had involved a limited attempt at encouraging self-assessment of the extent to which an individual had restructured their ideas. This had not been explored in later cycles and I noted that it was an area worth further consideration.
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Action

Develop the use of concept mapping and consider ways of analysing these outcomes to ascertain the extent to which ideas have been restructured. Consider the nature of restructuring - to what extent should learners be able to apply new ideas before it can be assumed that those ideas have become accepted (assimilated).

Explore ways in which adults can be encouraged to self-assess their own restructuring of ideas.

Conclusion

The constant elicitation of learners' ideas throughout learning experiences that is an essential aspect of a constructivist approach ensured that evidence of the restructuring of learners' ideas was collected. Certain strategies had facilitated the collection and analysis of this evidence more effectively than others and in this context think books and concept mapping offered the most potential.

6. How can I encourage students/course members to apply their restructured ideas in novel situations?

As a result of this concern the planning for the electricity cycles included a problem solving task on day 4 which required the application of ideas about simple circuits and switches. Unfortunately, as noted earlier, the cancellation of day 2 (Case Study 8) meant that only the Cohort 2 (Case Study 9) tackled this activity. The analysis of the session indicated that the task set was appropriate and evidence was found of course members applying understanding that they had been developed during the earlier parts of the cycle. The context for the task was motivating and the task had been sufficiently open-ended to allow individuals and pairs to
devise a variety of unique solutions. The use of kind of task, which has a considerable design and technology element, was noted as an excellent way of tackling this concern and the final phase of a constructivist approach.

Case Study 8 also provided evidence of how a computer simulation (discussed in the analysis of Case Study 3) could be used successfully with adults to encourage them to apply ideas.

During the last review I had raised the need to look for evidence of application of ideas sometime after the cycle. During the electricity cycle I individually asked 3 teachers from each cohort (Andrea, Mary B and Ann from Cohort 1; Kay, Ann and Caroline from Cohort 2) to try and explain what happens in the filament of a bulb as it gives out light when electricity flows, based upon any ideas they met during the materials cycle. All gave explanations including the idea of particles in the wire moving more quickly causing the filament to get hotter (confirming retention of restructured ideas from cycle 1 (see Case Study 5, p117). This provided tentative evidence of restructuring lasting over a period of months. I intended to use a selection of these course members for later interviews.

Further consideration of this concern at this stage led me to the use of post-cycle written and practical tasks which could be done between cycles. To date, I had not encouraged course members to carry out practical tasks, at their own level, between cycles. Some had done this and produced evidence of their work (for example Andrea - ‘dissolving’ during Cases Study 4 and Neil - ‘electromagnetism’ during Case Study 9). The difficulty of addressing this concern within the limited time available during course sessions meant that the use of post-cycle tasks seemed to offer one strategy worth trying.

Another area that I had not fully explored was the involvement of the course members themselves in self-assessing the extent to which they had restructured ideas and could apply them. A check list could have been offered after they completed the problem solving task that would have allowed them to note the ideas about circuits which they considered had been
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used during the task. This area could also be developed to support course members in analysing their own concept maps against key ideas that might be included.

Action

Ensure interviews with course members held after the course include questions related to application of ideas. Use more problem solving activities on day 4 of each cycle and set tasks on day 4 that course members can try in their own time which require the application of ideas in novel situations.

Consider ways of encouraging self-assessment of the extent to which restructured ideas have been applied.

Conclusion

This concern continued to require my attention although this review indicated that I had made some progress and there was evidence that course members, especially during Case Study 9, were being required to apply restructured ideas to solve the problem posed.

7. What view of science do students/course members take away from sessions?

My last reflections on this concern had raised the issue of my own understanding of the nature of science and the significance of generalised statements. I had been satisfied that course members were recognising certain aspects of scientific understanding and how it is reached. The most recent case studies provided no evidence to cause me to doubt that the tentative nature of scientific ideas, the inextricable links between process and content and the importance of social context is recognised by course members. With regard to the extent to which course members had developed and were able to articulate a more sophisticated view
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of the nature of science I had more concerns. There had not been time during the electricity cycles to make aspects of the philosophy of science more explicit to them.

However, the approach to these cycles had not placed the same emphasis as earlier cycles on moving from limited observations and investigations towards generalised statements. In that sense the concern raised in December had been avoided. Consideration of this issue at the stage of the April review led me to noting that it may have been overambitious to have anticipated that I could raise with course members, in the time available on the course, such fundamental questions about the nature of science in terms of inductive, deductive and Popperian ideas (Chapter 1, Section 1.9).

Conclusion

There was evidence that course members had, during the course, constructed a view of science which recognised three key features noted above, which I had prioritised in my initial planning. The concern had therefore been addressed successfully in terms of my intentions for the course. However, my own understanding of the nature of science had been restructured as a result of my reflections on this concern and this had resulted in the need for further consideration to be given to this aspect of my work with teachers and students.

10. To what extent should I encourage individuals to expose their ideas?

As noted at the last review and above this concern was now subsumed within Concern 3, What strategies can I use to expose individuals' ideas? Consequently I decided at this stage to delete it from the list.
11. Should I deal with every 'alternative framework' identified or focus upon the common ones?

My use of a constructivist approach, with its emphasis on eliciting existing ideas, was ensuring that individuals' alternative ideas were being exposed. However, reflection at this stage on this concern led to the appreciation that only a limited sub-set of an individual's alternative ideas in a specific content area were likely to be revealed and consequently challenged within the course sessions. The importance of encouraging adults to challenge their own ideas and look for evidence to support or refute them, highlighted during Review 2 (December 1990), was therefore of paramount importance and this was prioritised during Case Studies 8 & 9. Course members were aware, by this stage of the course, that they had existing ideas in most areas of science which did not correspond to accepted scientific ideas. They were therefore prepared to explore their own ideas critically. My role in helping them structure those existing ideas in a way that enabled them to be challenged was crucial and I was satisfied that I was developing my skills in doing this. I was also satisfied that I was able to challenge course members' ideas when necessary and through appropriate questioning encourage them to challenge their own ideas.

My own understanding of the range of common alternative constructs was improving through my work with the groups and through my own background reading. This understanding was also developing in the course members themselves and was being enhanced by their work with children, both on day 3 of the cycle and in their own classes. The evidence of few alternative ideas about 'clashing currents' and attenuation in these groups during day 1 did not lessen the importance of the groups considering the nature of these alternative constructs and their origins. The school-based sessions provided considerable evidence of these two ideas amongst children. This required the teachers to clarify their own understanding in order to support the development of the children's understanding.

The cycles also provided evidence of the diverse range of alternative ideas that adults hold
and the need to be constantly aware of individual's novel explanations for phenomena which, if not exposed and challenged, will be retained. As with children, adults' alternative ideas can be firmly held despite contradictory evidence unless that evidence is explicitly related to the alternative idea and it often required this link to be articulated explicitly by the tutor.

The consideration given to the origins of children's existing ideas and the influences of informal experiences outside and inside school was intended to help course members reflect on the nature of their own ideas and expose further alternative ideas that they may hold but not have previously articulated. For example, a child's comment about the speed at which electricity travels raised questions in the teachers which led to them articulating there own ideas about this. Consequently, the links between this concern and Concern 14, 'How can I use the relationship between adults' and children's constructs to improve adult's knowledge and understanding of science?' were becoming more evident.

It was also noted, at this stage, that this concern is directly related to Concern 3, since it is through elicitation strategies that alternative ideas are exposed and can be identified. Therefore it seemed appropriate to recognise that this concern need no longer be retained as it is being addressed through the other two.

Conclusion

The elicitation strategies adopted on the course were enabling me to identify alternative ideas held by course members, although it was unrealistic to think all alternative ideas in a particular concept area were being exposed. Those ideas exposed to challenge were being explored by the individual concerned often as a result of tutor support or discussion with a partner or group. This usually involved practical exploration and investigations. However, discussion often led to course members' own ideas being clarified and restructured through consideration of the relationship between their ideas and similar ones evident in children.
12. To what extent did the metaphors I used foster misunderstanding in students/course members?

Consideration of this concern was particularly relevant at this stage since it had arisen as a result of my initial case studies based on the same content area (electricity) during which I used metaphors and analogies. There was evidence that analogies were being used extensively on other similar courses and in secondary science work (Osborne and Freeman, 1989). I was therefore interested to explore their use. Electricity was a content where the use of a water analogy was commonly used and I was fortunate to have a colleague working with me on Case Study 9 who had regularly used a 'water analogy' before. I was therefore able to observe his use, discuss its implications and clarify my own understanding before using it with the Cohort 1 (Case Study 8). I was also able to raise issues related to the use of analogies with that group and highlight the advantages and disadvantages of their use. Indeed the discussion at that stage of the cycle was particularly helpful for some course members in clarifying their ideas about electricity and simple circuits. I attempted to identify possible alternative ideas that could be fostered through the use of the particular analogy in an attempt to avoid the concern I identified and I specifically avoided using terms like "lazy" to describe what was happening.

Conclusion

Consequently, I considered these cycles provided evidence of progress in terms of my use of analogy (which seems more appropriate than the use of metaphors). I had still to explore the use of other analogies in different content areas. However, in comparison to other concerns and in particular at this stage when I was recognising the significance of certain key concerns, such as Concern 3, I decided this particular area would no longer be retained as one of high priority.
13. Do I allow students/course members adequate time for exploration and investigation?

This concern was emerging, through my review, as a key concern that subsumed Concern 4, Should sessions be so tightly structured? I noted that at the beginning of my research, as is evident from the early Case Studies (1 - 3), I was offering students limited opportunities to carry out their own explorations and investigations. At the point of the last review I noted that this was still evident in Case Study 4 and I identified my lack of confidence as an explanation for this. My concern about being able to deal with the diverse range of outcomes and the unpredictability of the questions that were likely to be raised were the reasons for this lack of confidence. This was having an adverse effect on course members in terms of their own practice since there was evidence that they were not all providing opportunities for their children to carry out explorations.

However, reflection on Case Studies 5 to 7 provided a more optimistic view since as there was clear evidence that the structure of sessions was becoming more flexible and student-led explorations were being given a greater priority.

My role had been identified as a significant factor in addressing this concern. As a result of analysing Case Studies 8 and 9 and comparing the extent to which these teachers had opportunities to pursue their own enquiries, compared to the students working on the same content during Case Studies 1 to 3, I was able to identify the progress made in relation to this concern. This is particularly significant since I had recognised during Review 2 (December 1990) that a limited number of key concerns were emerging from my analysis and this area covered a number of the concerns discussed in December. As already noted above, Concern 4 was regarded as one subsumed in this one. However, there are aspects of Concern 15, related to student ownership of activities, Concern 17, related to raising questions and Concern 18, related to individual needs which are closely related.
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My developing confidence to allow course members to pursue their own lines of enquiry during the electricity cycle meant that, as I had concluded in December, the issue of ownership of the activity and the motivation that gives ceased to be a concern.

The time available for exploration may have contributed to the variety of questions which were raised and noted in their think books. During my immediate analysis of the Case Study I also raised the significance the structured elicitation activities may have had in contributing to the raising of questions.

The flexibility I offered during day 1 of the electricity cycles allowed me to ensure those with particular needs could be supported. As noted in the analysis of these case studies a number of course members already had some experience of electricity as a result of previous INSET activities and therefore needed to be challenged at a different level to those tackling work on simple circuits for the first time. The use of the relatively unstructured sessions during the latter part of the day for student-led activities enabled me to differentiate the support offered in terms of the individual needs of the course members. There was also opportunities for exploration and investigation on day 4 (for example during the problem solving activity in Case Study 9 and through the use of the computer simulation in Case Study 8). Therefore, my attempts to address Concern 13 had enabled me to address Concern 18.

Conclusion

This concern had emerged as a key concern during the review and my thoughts on the links between 13, 4, 15, 17 and 18, noted during the December review, had been confirmed. I was satisfied that further progress towards addressing the need for adequate time for practical explorations and investigations had been made. In doing this I had clarified my understanding of a appropriate structure for the cycles, allowed course members to retain 'ownership' of activities, encouraged them to raise scientific questions and provided opportunities for their individual needs to be met. I was also aware that there was a need for me to give this area
Chapter 8 - The enquiry

further attention in order to apply the understanding I had gained to my work with students. The sessions with students are shorter and therefore the opportunities for exploration are more limited.

14. How can I use the relationship between adults' and children's constructs to improve adults' knowledge and understanding of science?

As noted above, this concern is closely linked with Concern 11. The electricity cycles had been specifically planned to encourage course members to compare children's ideas with their own. The same elicitation questions were used with course members on day 1 and children in school on day 3. The evidence of children's ideas was collected together by course members and initially analysed by them. I had then typed up the evidence and added my own analysis. The ideas of children of different ages were grouped to enable some insight into the progression there might be in the ideas. This evidence and the analysis was given to course members on day 4 for them to consider, together with evidence of ideas from their own classrooms collected between days 3 and 4. In this way it was intended that course members would be encouraged to relate their own ideas, noted in their think books during day 1 and 2, to those of children. Unfortunately, there was limited time available for discussion and course members were asked to give this material further attention in their own time. Evidence was not available of the extent to which this activity was effective in helping course members to clarify their own ideas. This remained an area of concern which during the research cycles had not be adequately addressed.

Conclusion

This was developing as another key concern for me but one that I had been least able to collect evidence about and it therefore remained one which I intended to explore further during the next DES 20-day Course which would be outside the scope of this research. Further discussion about this will however be included in the final review.
16. At what stage of a DES cycle is exposition most appropriate?

This concern had been regarded as fairly unproblematic at the last review. Evidence during Case Studies 8 and 9 supported my views at that stage. Exposition of the 'scientist's view' had been offered on day 2 of Case Study 9 and day 4 of Case Study 8. The latter was due to the postponement of day 2. This meant that Cohort 1 were offered the input after the school-based day and this was less satisfactory that the usual pattern since the discussions on that day could not be based on or refer to the conventional scientist's view. Cohort 2 responded positively to the input (based on a 'water analogy' as discussed above) and made reference to it during the school-based day in terms of discussing the children's ideas.

During these cycles, as the immediate analysis of case studies noted, I also offered informal input of the 'scientist's' view of electricity during the afternoon of day 1 as questions arose which could not be answered by exploration or investigation or to confirm developing ideas expressed by course members.

The role offered during this activity was intended to provide a model of how accepted scientific ideas could be offered to children during their investigative work as worth testing alongside their own ideas. In this context, I noted that the approach and the positive response of course members to it was also addressing Concern 19. I had made my role during the cycle explicit to course members and a specific attempt made to identify the differences between the kind of exposition offered on day 2 and that being discussed. I noted that this was not the first time on the course that accepted scientific ideas had been offered by tutors during day 1 but during the electricity cycle, in response to Concerns 16 and 19 the nature of this input had been made more explicit.

The timing of cycles raised in my last review and the benefits of consecutive days 1 and 2 was still a matter of discussion between the teaching team. The three key tutors running cohorts at
Chapter 8 - The enquiry

Bristol Polytechnic and Bath College all held differing views about this and the pattern initially adopted seemed the one an individual preferred. This is similar to evidence provided by HMI (at the Invitation Conference in April 1991) that course members claimed to have a preference for the particular attendance pattern they had been offered.

Conclusion

The stage for exposition within the DES cycles was, I concluded, appropriately timed during day 2. This concern related to the structure of the course no longer needed to be addressed.

17. How can I encourage students/course members to raise scientific questions?

This concern has been discussed in this review linked with Concern 13 since it is during the exploration phase that those questions were generally raised. My intentions during the last review to encourage course members to brainstorm questions and classify them according to how they could be answered were not met during the electricity cycle. However, as noted earlier, I was satisfied that question raising was occurring. I also had evidence at the review point of the living things cycle, in which I was not involved, during which emphasis on day 1 was placed on question raising and the resulting questions were classified, with tutor support, according to their nature and the way they could be answered. The tutors involved reported that course members responded positively to the activity and most were confidently classifying those listed.

18. How can I meet individual students' needs within the DES course structure?

At the point of the last review (December 1990) I had resolved to ensure individuals' needs, in terms of their own scientific understanding and in terms of their understanding of teaching
science, were addressed. The *electricity* cycles highlighted the different background knowledge and understanding the students brought to the course. With both cohorts I made explicit the differentiation issue by identifying those, during the orientation and elicitation phase, who already had a sound understanding of simple circuits and providing differentiated tasks for them. This involved one pair in Case Study 8 and was unproblematic in terms of their own selection of questions and activities to pursue. At the start of the cycle described in Case Study 9, three course members identified themselves as having a sound understanding of circuits. However, when I probed their understanding I realised that there were some problem areas and I was able to identify activities to address those areas. My approach to differentiation ensured the group was organised in a way that allowed me to interact with pairs according to their needs. This structured approach to differentiation did not inhibit the extent to which all pairs were able to work at their own rate and level on activities they chose. In this way the concern was linked with Concern 13 related to the time available for exploration and investigations.

In Case Study 9 the use of a computer simulation was found successful as a way of setting up differentiated tasks.

The use of a collaborative approach on day 3 meant that differentiation was also facilitated in terms of individuals' understanding of teaching science. This had been the approach successfully used on all cycles. There was further evidence during these cycles that pairs were demonstrating different levels of understanding of a constructivist approach and how to implement it with children. The pairings were self-selected and tended to involve teachers who had similar confidence and skills in implementing constructivism. Therefore, the analysis of sessions carried out collaboratively allowed individuals to work at their own level. Plenary discussions of analyses of the school-based work allowed a broadening of individual's perspectives and understanding through the sharing of ideas and evidence that occurred.

An approach to differentiation that I had not explored at this stage involved the use of
Chapter 8 - The enquiry

differentiated follow up tasks after a cycle. Distance-learning materials also have potential for this.

Action

Consider ways in which differentiated follow up tasks can be used on future courses, especially in terms of the use of distance-learning materials (from the Open University or NCC (1992 a and b)).

Conclusion

Differentiation was facilitated by a constructivist approach since the existing ideas of individuals were the starting point for further work. In some scientific content areas, such as electricity, the different levels in understanding were substantial and it was necessary to structure the group in a way that allowed those differences to be accommodated. This involved identifying those who were capable of dealing with more complex concepts and providing appropriate activities matched to those individuals' needs. This approach offered a model of differentiation that is necessary in the primary classroom.

My reflections at this stage suggested that progress had been made in addressing this concern.

19. What are the implications of exposition by an expert in terms of the students' views on their role as teachers?

This concern was discussed above, linked to Concern 16. It had been identified as a short term concern that could be easily addressed and there is evidence that I made the approach to exposition more explicit during these cycles and offered an approach to sharing the 'scientist's view' which was based on discourse rather than exposition. There was no evidence
in student assignments, in their performance on school-based days or in their discussions of classroom-based activities that any used a transmissionist approach or considered it an appropriate way of teaching scientific knowledge and understanding.

The input on electricity did involve a quantitative dimension and I found no evidence that this was too difficult for students although many found it challenging.

Conclusion

My understanding of the way accepted scientific ideas could be communicated had improved and I was developing my own skills in sharing the 'scientist's view' through discourse. A constructivist approach can accommodate a variety of teaching techniques and forms of organisation. I therefore concluded that this concern had been addressed within the context of the DES 20-day Course.

20. How can I make constructivism less threatening to students?

There was no evidence in the last two case studies to indicate that any course member still felt 'threatened' by the approach and it had now become the accepted way of working for all in terms of participation of the sessions and for most in their own classrooms. No comments had been made that children felt 'threatened' by the approach. The conclusion I came to at the point of this review was that teachers needed to have considerable experience of this approach on a course in order to feel secure in sharing existing ideas and proposing tentative hypotheses and suggestions about activities (at their own level and with children). The DES 20-day Course model ensured a consistent approach had been used for each cycle and therefore the pattern, expectations and ground rules had become established. The two groups had become extremely cohesive over the period of the course and supportive of individuals who felt concerned about particular ideas or approaches.
Chapter 8 - The enquiry

Conclusion

This concern had been identified at the last review as a short term one which could easily be addressed. My reflections at this stage allowed me to feel confident that it had been and should no longer be considered, although the implications for the start of a new course need to be remembered.

21. To what extent should I encourage students/course members to use quantitative approaches during investigations?

The electricity cycles involved a number of course members in work of a quantitative nature, although for most this resulted from considerable exploratory work of a qualitative type. Those, discussed above, who felt confident about simple circuits almost immediately started using meters and measuring current and potential differences. During the first day of both cohorts most pairs met ideas about the relationship between current and resistance in circuits and some were happy to explore this relationship quantitatively. This arose for several pairs when a bulb (lamp) and buzzer were connected in a series circuit and only the buzzer operated. This puzzling phenomena stimulated numerous questions and discussions which led to ideas about resistance and current. For some pairs the use of the computer simulation allowed them to explore their ideas in various ways whilst for most the use of digital meters was adequate.

The input on day 2 (Case Study 9) also had a quantitative aspect which elicited no adverse evaluative comments. However, I indicated to both groups that the quantitative approach to circuits was inappropriate for primary-aged children and it was being used with them to enable them to develop their own understanding in order to support children's work at a less sophisticated level.
Chapter 8 - The enquiry

Conclusion

I found no evidence to suggest that course members were unable to deal with quantitative ideas about electricity as long as it was related to their practical explorations and investigations. I also found no evidence that course members were unhappy about this approach. In terms of certain concepts, such as the relationship between resistance and current, a quantitative approach seems appropriate.

8.4.2 Evaluation of the framework after the third review

The analysis of concerns through the framework I had produced had again proved to be successful in allowing me to deal with a variety of different concerns. Perhaps more importantly it had helped me to appreciate that the wide range of concerns I had could be reduced to a more limited number of key concerns. This process of reducing multiple concerns to key ones is of considerable importance to a practitioner who wishes to deal effectively with the complexity of real teaching situations in an holistic manner.

It was enabling me to clarify the concerns which I had successfully addressed, although as noted earlier, the notion of ‘addressed’ does not imply they are no longer in need of attention when planning work. In some respects it was becoming clearer to me that when I considered a concern ‘addressed’ what I meant was that my understanding was such that I now considered that the personal understanding I had constructed was ‘embedded’ in my practice. The process of identifying the concern as a question, focusing my reflections upon that concern and evaluating new strategies had helped me to ensure that ‘new’ insights became part of my practice and in that way were evident as ‘knowledge in action’. In other ways, the notion of ‘addressed’ meant that specific dilemmas I had identified in the context of my work were resolved in a manner that no longer required them to be an explicit focus of further reflection, at least at the particular time that conclusion was drawn.
The following summary had resulted from this review. The 'key' concerns are emboldened.

### Analysis of concerns carried out in April 1991

<table>
<thead>
<tr>
<th>QUESTION</th>
<th>TIME</th>
<th>CHANGE</th>
<th>DIFFICULTY</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td></td>
<td></td>
<td></td>
<td>Addressed</td>
</tr>
<tr>
<td>Eliciting Role/strategy Prof. k&amp;u</td>
<td>M</td>
<td>Role/strategy</td>
<td>2</td>
<td>Addressed but more use of concept maps</td>
</tr>
<tr>
<td>Structure</td>
<td></td>
<td></td>
<td></td>
<td>Subsumed by 13</td>
</tr>
<tr>
<td>Restructuring</td>
<td></td>
<td></td>
<td></td>
<td>Linked to 3</td>
</tr>
<tr>
<td>Application Strategy/Struct.</td>
<td>M</td>
<td>Strategy/Struct.</td>
<td>3</td>
<td>Some progress Action post-cycle tasks</td>
</tr>
<tr>
<td>View of sc. Sc. k&amp;u</td>
<td>L</td>
<td>Sc. k&amp;u</td>
<td>3</td>
<td>Progress</td>
</tr>
<tr>
<td>Exposing ideas</td>
<td></td>
<td></td>
<td></td>
<td>Subsumed by 3</td>
</tr>
<tr>
<td>Challenging</td>
<td></td>
<td></td>
<td></td>
<td>Linked to 3/14</td>
</tr>
<tr>
<td>Metaphors</td>
<td></td>
<td></td>
<td></td>
<td>Addressed</td>
</tr>
<tr>
<td>Exploration Structure Strategy/role</td>
<td>M</td>
<td>Structure</td>
<td>2</td>
<td>Key concern</td>
</tr>
<tr>
<td>Adult/child ideas Strategy/sc. k&amp;u</td>
<td></td>
<td>Strategy</td>
<td>3</td>
<td>Key concern</td>
</tr>
<tr>
<td>Ownership</td>
<td></td>
<td></td>
<td></td>
<td>Addressed</td>
</tr>
<tr>
<td>Exposition</td>
<td></td>
<td></td>
<td></td>
<td>Addressed / Linked to 19/20</td>
</tr>
<tr>
<td>Raising questions Role/strategy</td>
<td>M</td>
<td>Role/strategy</td>
<td>2</td>
<td>Progress / Linked to 13</td>
</tr>
<tr>
<td>Indiv. needs Strategy</td>
<td>M</td>
<td>Strategy</td>
<td>2</td>
<td>Progress / Linked to 13</td>
</tr>
<tr>
<td>Expert view</td>
<td></td>
<td></td>
<td></td>
<td>Addressed</td>
</tr>
<tr>
<td>Threat of const.</td>
<td></td>
<td></td>
<td></td>
<td>Addressed / Linked to 10</td>
</tr>
<tr>
<td>Quantitative app. Strategy/role</td>
<td>L</td>
<td>Strategy/role</td>
<td>2</td>
<td>Progress</td>
</tr>
</tbody>
</table>
Consequently, the ‘key concerns’ for further reflection are:

1. How do I provide adequate time for exploration and investigation?

2. How can I use the relationship between adult and children’s constructs to improve adults’ knowledge and understanding of scientific concepts?

These key concerns will be revisited in Review 4, in the light of interview data and other evaluative data available.
Chapter 9 - Review 4

9.1 Introduction

This chapter is the fourth and final review of my enquiry (see Figure 9.1). The earlier enquiry reviews (Chapter 8) focused upon my practice and my understanding of it and in doing this included evidence and some discussion of the strengths and weaknesses of the approach being used on the DES 20-day courses and, consequently, of the course itself. In that sense they have provided a self-evaluation and a more general evaluation of an approach and the course during which it was used. This review begins with a different focus and the evidence relating to the success of the course and the approach used will be examined before revisiting the concerns raised about my practice. In this way I hope the evaluation of the course and the approach used will inform my understanding of my practice in the way that previously I consider the reflection upon my practice and the detailed examination of it have informed an evaluation of the approach and the course. This will address one of the key criticisms of INSET evaluation, cited by Kinder and Harland (1991, p2), that evaluations sometimes “involve a wholesale swing towards documenting outcomes with insufficient complementary attention to process factors”.

The chapter begins with a consideration of data that was not available at the time of the earlier reviews discussed in the last chapter. This includes interview data collected from a sample of DES 20-day Course participants several months after the teaching sessions involved in the enquiry. My reasons for the choice of sample were discussed in Chapter 7, Section, 7.4. This analysis includes references to the original data, contained in the Case Study Volume of this thesis. The teachers involved in this sample are then profiled, drawing upon other data collected during and after the course to examine: the nature of the INSET outcomes, analysed in terms of the NFER typology (see Chapter 5, Section 5.8) and the teachers’ responses to the course analysed in terms of the PSTS typology of teacher types (see Chapter 4, Section 4.4.1).
Chapter 9 - Review 4

Figure 9.1: Review 4

Review 1
April 1990

Review 2
December 1990

Review 3
March 1991

Application Phase
Interviews

Review 4
January 1993
Chapter 9 - Review 4

After this section, which focuses upon individual responses and outcomes, other evaluative data will be considered to look for more general indicators of course outcomes and impact upon practice. This will involve analysis of evaluation pro formas completed at the end of the course, questionnaires of teachers’ perceptions of their own scientific knowledge and teaching competence (completed before and after the course), evidence from course participants’ written assignments and other evaluative data collected. Evidence from outside evaluators (HMI and an External examiner) will be considered.

After this discussion of evaluative data, I will revisit the key concerns identified in Chapter 8 in the light of the earlier evidence. In doing so I intend that the evaluative evidence discussed will illuminate and substantiate some of the claims and insights gained during the enquiry, raise further questions and further develop my own understanding of my professional practice.

9.2 Analysis of Interview data

The chapter discussing methodological considerations (Chapter 7, Section 7.6.6) outlined the reasons for using semi-structured interviews of DES 20-day Course participants as part of this enquiry. This section provides an analysis of the outcomes of those interviews. The interviews were intended to provide data related to the impact of the course in terms of the teachers’ own scientific knowledge and understanding and to provide data indicating impact upon the teachers’ professional practice resulting from the course. This analysis is therefore also in two sections. The first deals with scientific knowledge and understanding; the second deals with professional concerns.

I carried out five interviews between July and December 1991.
Chapter 9 - Review 4

Figure 9.2: Information about interviewees

<table>
<thead>
<tr>
<th>Name</th>
<th>Cohort</th>
<th>Date of Interview</th>
<th>School</th>
<th>Age taught</th>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caroline</td>
<td>2</td>
<td>15.7.91</td>
<td>Urban primary</td>
<td>Y3/4</td>
<td>2 years</td>
</tr>
<tr>
<td>Frances</td>
<td>2</td>
<td>18.11.91</td>
<td>Rural primary</td>
<td>Y6</td>
<td>10+ years</td>
</tr>
<tr>
<td>Ann</td>
<td>1</td>
<td>19.11.91</td>
<td>Suburban primary</td>
<td>Y2</td>
<td>5+ years</td>
</tr>
<tr>
<td>Kay</td>
<td>2</td>
<td>6.12.91</td>
<td>Suburban infants</td>
<td>R</td>
<td>4 years</td>
</tr>
<tr>
<td>Anne</td>
<td>2</td>
<td>6.12.91</td>
<td>Urban infants</td>
<td>R</td>
<td>5+ years</td>
</tr>
</tbody>
</table>

All of the interviews were carried out in the interviewees’ schools.

The interviews were structured to elicit the teachers’ scientific knowledge and understanding in the three areas; materials, forces and electricity that were covered in the case studies. The key concepts that the sessions covered (in terms of the language used during the sessions and that in the National Curriculum for Science (DES, 1988c)) and of which I hoped to find evidence were:

**Materials**

Mi. Solids, liquids and gases are made up of particles which are constantly moving;

Mii. heating causes the particles to move more quickly;

Miii. a change of state occurs as a result of the particles moving more quickly;

Miv. some solids (such as wax) and liquids (such as paraffin) change to a vapour before they burn.
Chapter 9 - Review 4

Forces

Fi. gravity is a force which pulls objects towards the Earth;
Fii. a force is needed to start something moving, to speed it up, to slow it down and to stop it;
Fiii. when an object is moving at a steady speed there is no force acting in the direction of movement;
Fiv. friction is a force which slows things down;
Fv. mass is the amount of ‘stuff’ in something and is constant;
Fvi. weight is the force due to gravity acting on an object and can vary.

Electricity

Ei. A complete circuit is need before electricity can flow;
Eii. the correct connections to a bulb and battery are needed to complete a circuit;
Eiii. electricity causes a heating effect in a bulb which produces light;
Eiv. current is a measure of the flow of electricity and is the same in each part of a simple circuit;
Ev. a switch is a device for breaking a circuit.

The following analysis indicates which of these concepts is evident in the data for each interviewee. The references are to lines in the Case Study data (Volume 2, Case Study 10, pages 201-236). A gap indicates no evidence was obtained. An ‘X’ indicates evidence of an explanation or idea which does not match accepted scientific thinking was given. Some of these are discussed below.
This analysis provides evidence that these teachers were still able to provide scientifically acceptable explanations for phenomena some considerable time after the teaching sessions. The evidence concerning the explanations of the *particulate nature of matter* and the use of this to explain changes of state is particularly encouraging since analysis of Case Studies 4 and 5 indicates that none of the interviewees provided any evidence of being aware of the
particulate nature of matter, apart from Kay, who provided evidence of alternative ideas in this area: “when heated the particles are broken down .. when it cools particles harden and join together” (CS5: 615). The others stated they had not met the idea before the course on their end of course evaluation sheets and consequently they had ‘restructured’ their understanding of the nature of solids, liquids and gases. This is an area of science tackled on the course which was not intended to be used directly in the classroom and none, evidenced by feedback during day 4 of Case Studies 4 and 5, had attempted to introduce these ideas to children. Therefore this was not an area where the restructuring of understanding was reinforced by work with children in the same way as, for example simple circuit ideas might have been. Some alternative ideas were also evident. For example, Ann suggested that there was air in the gaps between particles (CS10: 303). This was a question raised by someone else in her group during the teaching session which did not get addressed (S4: 323). This highlights the importance of a tutor being alert to all questions and attempting to identify alternative ideas that might arise as a result of the question or subsequent discussions. The alternative ideas about burning evident were Kay’s idea that the wax doesn’t burn but the wick does (CS10: 490) and Frances’ explanation that “solid wax burns” (CS10: 208). Case Study 4 and 5 data indicates prior to the teaching session none of the participants understood that wax turned to vapour before burning. This explanation goes against intuitive ideas and everyday experience of burning and therefore it is not surprising that some of the teachers retained original ideas that they held.

The area of forces indicates less ‘retention’ of accepted scientific ideas. Frances described gravity in terms of a “force from above” (CS10: 214), implying it is a push rather than a pull. However, the more problematic area concerns the intuitive ‘impetus’ notions still held by three of the five. Caroline said of the ball was going over the net, “(there is still) the force from the person or it wouldn’t still be moving, would it?” (CS10: 85). Ann says of the same episode “There is a force from the movement of the racquet, the initial thrust, otherwise it wouldn’t go over the net” (CS10: 326) and Kay describes the rolling ball as “exerting its own force ... the
force inside it turning (it)” (CS10: 507). During the teaching sessions nearly all held this view (Ann (CS6: 294); Anne (CS7: 294); Caroline (CS7: 275); Kay was absent). The teaching sessions attempted to challenge an ‘impetus’ explanations (which is a common alternative idea held by children (SPACE, 1990-92) and adults (Kruger et al., 1990b)). However the interviews would suggest restructuring did not occur for over half those interviewed. Similarly accepted scientific ideas about mass and weight were not evident. This cycle was one found the most difficult by both cohorts (see appendix 16) and the interview evidence would indicate that it some ways, at least in terms of restructuring the teachers scientific understanding, it was the least successful.

The evidence relating to electricity was generally encouraging although Ann, despite having done similar work with children quite recently, found this very difficult. During the electricity cycle she was unable, at the beginning, to draw a circuit (CS8: 166), although her later work on a bulb was better (CS8: 188) and her practical activities were successful (CS10: 235, 412). It should also be noted that the electricity cycle for Cohort 1 was disrupted by bad weather which led to the cancellation of day 2. The Cohort 2 interviewees provided sound evidence of acceptable scientific ideas apart from Kay’s idea that “there is less coming back because it has been used” (CS10: 445). Her comments on day 1 of the electricity cycle are interesting: “I have learnt about the workings of a bulb .... This morning I had no concept of - or never thought about before ‘how a torch works’ and this afternoon I made one! I am beginning to understand the difference between current and resistance - although I doubt I could explain my understanding in a coherent manner. I fully understand switches - we’ve had a good day” (CS9: 108).
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It is also interesting to look at the teachers' own perceptions of their scientific knowledge and understanding in these areas before (first number) and after (second number) the course (see Appendix 14).

Figure 9.4: Interviewees' perception of their own scientific knowledge and understanding.

The ratings given (from 1 (good) to 5 (poor)) were:

<table>
<thead>
<tr>
<th>AREA</th>
<th>CAROLINE</th>
<th>FRANCES</th>
<th>ANN</th>
<th>KAY</th>
<th>ANNE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>1/2</td>
<td>3/2</td>
<td>2/2</td>
<td>2/1</td>
<td>3/2</td>
</tr>
<tr>
<td>Forces</td>
<td>2/2</td>
<td>4/2</td>
<td>4/2</td>
<td>2/4</td>
<td>4/2</td>
</tr>
<tr>
<td>Electricity</td>
<td>1/1</td>
<td>2/2</td>
<td>5/3</td>
<td>3/2</td>
<td>5/2</td>
</tr>
</tbody>
</table>

From this Caroline seems to be the teacher rating herself most highly before and after the course. Ann and Anne are the two who in terms of the own view have made most progress. Kay's perception of her understanding of forces may well have resulted from her absence for a key part of the cycle.

The following evidence from the end of course evaluation form indicated the teachers' response to each cycle. Ratings are again from 1 (good/relevant) to 5 (poor/not relevant).

Caroline

**Materials (2)** The explanation of particle theory helped my understanding and I became more confident. However, I found it hard to think at my own level and
get to grips with it, but it got easier.

**Forces (1)** I found it very hard to get to grips with the ideas at an adult level but feel I've gained some knowledge.

**Electricity (1)** I really enjoyed this cycle and felt confident to enter discussions. The explanations given helped my understanding.

**Frances**

**Materials (1)** Very good - especially on how to use collections and particle theory - input was helpful and informative. Made me think of things in a new way.

**Forces (1)** Good cycle with lots of ideas for the types of activities that could be carried out.

**Electricity (1)** Most of the activities were enlightening. Made me realise that there is much more to bulbs and batteries than I first thought. I've gained a lot of personal knowledge that I was blissfully unaware of before!! I feel more confident in helping the rest of the staff.

**Kay**

**Materials (2)** Did not really understand what was expected of me - felt threatened.

**Forces (2)** The most difficult cycle as far as understanding went - being absent did not help.

**Electricity (1)** Fairly easy to get on with this cycle and took ideas into school.

**Anne**

**Materials (2)** Found input on particle theory very interesting - it was really new to me. Fresh learning - hard to grasp but very worthwhile.

**Forces (1)** Dealing with this at an adult level was extremely difficult for me - however it was worthwhile.

**Electricity (1)** The area I was least comfortable with.

This provides evidence of teachers' general level of satisfaction with the cycles, but more significantly indicates how difficult some of them found particular cycles. They did find aspects of the course threatening as terms like 'least comfortable' suggest and the aspect of working 'at an adult level' is commonly mentioned perhaps indicating that this INSET was novel in
making that demand of them. Caroline’s comment was not untypical when she reported on her evaluation form “I thought at the beginning it would be really hard and I felt like dropping out. But I’m glad I stayed, I feel a lot more confident”.

Kruger and Summers (1989) identified four types of primary teacher during their research (see Chapter 4, Section 4.4.1). Analysis of the teachers interviewed in terms of the data from earlier case studies would suggest Caroline, Frances and Kay fit into their third category - teachers who have been exposed to formal models and theories during schooling but who are unable to use them appropriately to offer explanations and who often opt for ‘life-world’ explanations. Ann and Anne were clearly in their first category of teachers whose understanding of concepts was necessarily based upon ‘life-world’ beliefs since they have had little formal science education. In this they represent the most common group in Kruger and Summers’ (1989) sample and in terms of the cohorts on the courses involved in the BCHE DES 20-day courses. I identified no examples of the fourth category (teachers who were able to give explanations which were almost congruent with accepted scientific understanding) on the two cohorts. One or two examples of the second group (teachers who had been exposed to formal models and theories but were unable to use them appropriately and provided evidence of incorrectly understood ‘symbolic-world’ knowledge from school) were identified. Mark and Dave (Cohort 2) and Andrea and James (Cohort 1) are examples.

However, the interviews would suggest that the impact of the course was similar for both ‘types’ of teacher interviewed. Those without formal science education gained as much, if perhaps not more in terms of their starting point, and their own perceived gains, than those with some formal science education.

The next section will consider the extent to which there is evidence that the course had an impact upon the interviewees’ classroom practice.
Analysis of the teachers' responses in terms of the impact of the course upon teaching practice involved looking for evidence of the following:

i. Awareness of the importance of context/relevance for children's scientific work;
ii. Valuing children's existing ideas;
iii. Use of elicitation strategies;
iv. Valuing talk/discussion as a part of scientific work;
v. Encouraging children to test out their own ideas;
vi. Intervening to challenge children's ideas;
vii. Examples of use of scientific areas covered in the course (*materials* - *mat.*, *electricity* - *el.*).

**Figure 9.5: Evidence of Interviewees' classroom practice in science**

The references are to lines in Case Study 10 (Case Study Volume pages 219-235).

<table>
<thead>
<tr>
<th>AREA</th>
<th>CAROLINE</th>
<th>FRANCES</th>
<th>ANN</th>
<th>KAY</th>
<th>ANNE</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. (context)</td>
<td>15</td>
<td>173</td>
<td>268</td>
<td>389/416</td>
<td>560</td>
</tr>
<tr>
<td>ii. (valuing ideas)</td>
<td>10</td>
<td>172</td>
<td>278</td>
<td>402</td>
<td>571</td>
</tr>
<tr>
<td>iii. (elicitation)</td>
<td>8</td>
<td>183</td>
<td>267</td>
<td>402</td>
<td>567/599</td>
</tr>
<tr>
<td>iv. (talk/discussion)</td>
<td>20</td>
<td></td>
<td>287</td>
<td></td>
<td>601</td>
</tr>
<tr>
<td>v. (test own ideas)</td>
<td>19</td>
<td>180</td>
<td>282</td>
<td>393</td>
<td>570</td>
</tr>
<tr>
<td>vi. (challenging)</td>
<td></td>
<td></td>
<td></td>
<td>392</td>
<td>570</td>
</tr>
<tr>
<td>vii. (content)</td>
<td>(mat.) 17</td>
<td>(el.) 174</td>
<td>(mat./el.) 270/343</td>
<td>(el.) 387</td>
<td>(mat./el.) 564/590</td>
</tr>
</tbody>
</table>
This analysis provides evidence that the course had some impact upon the practice of all those interviewed. I deliberately gave the interviewees very little notice of my visit, and prior to a few days before the interview had no idea that there would be any follow up to the course of this type. They would not have been able to set up work or displays simply for my visit and it was clear that some of the floorbooks and children's work predated my request to interview. In all cases, an enthusiasm for the work and a confidence to implement it was also evident, perhaps most explicitly in the case of Anne (CS10: 551). Ongoing contact with Anne a year after the course, in the context of supporting her later work on an Inservice B.Ed. long study, provided further evidence of similar work ongoing in her classroom and encouragingly, evidence that she was influencing colleagues throughout the school.

There is little doubt from these visits and interviews that all the teachers were contextualising children's scientific work and ensuring it was made relevant to the children's everyday experiences. This reinforces evidence obtained during the course from feedback during sessions and in 'assignment' accounts of school-based work. All were recognising the importance of practical activity and using the processes of science to lead to a better understanding. This point, implicit in the evidence from the visits to classrooms and the interviews was dealt with explicitly in the first assignments each teacher produced. For example, Frances analysed an incident when her 11 year old children were exploring floating and sinking. She wrote (including references to her observation data which have been removed):

The hypothesis that wood was lighter than water and would therefore float was tested (by the children) by weighing the wood blocks and then weighing the same volume of water. Lignum vitae (a wood that sinks) was also used. The children had no previous experience of this wood and were amazed when it sank. Mark was very confused at this occurrence and tried to explain it in a variety of ways. After comparing the weight of this block to the weight of the same volume of water, however, it was found to be slightly heavier. His understanding of the properties of wood in water had been modified and hopefully extended and he was pleased to have found the solution to the
puzzle!

unpublished assignment p3

This account is interesting since it is also evidence of Frances working with children in the same area that she herself worked on the course (see Case Study 7 lines 155-210) and applying her own restructured understanding of the factors which effect floating and sinking.

The extent to which all of the interviewees were eliciting and valuing children's ideas is also evident and further substantiates evidence from assignments and feedback during course sessions. This aspect of a constructivist approach seems to have been that which had most impact upon teachers' practice and the area they found most easy to implement. A variety of strategies were in use including floorbooks in every class and novel ideas such as a 'How Does it Work?' book (CS10: 599) and journals (CS10: 183) in some. Kay was the only teacher to express difficulties with implementation, claiming "I don't use it (the constructivist approach) totally because I (find) I haven't got the time to deal with all the children in this way" (CS10:396). This reiterates a comment on her end of course evaluation form: "Have specifically used the constructivist approach in sessions on materials and electricity, but only really in small groups".

Although the social context of learning was not referred to explicitly in all cases during the interviews, the nature of data collected from assignments again indicates that all teachers were valuing the place of discussion in science activity. No accounts indicated that the teachers were implementing science as an 'individual' activity, in the way for example some were structuring mathematics learning on an individual basis. Evidence of class and small group discussion of existing ideas, ways of testing those ideas and how those ideas had changed were commonly documented in assignments. Similarly in all cases it was evident that the teachers were encouraging children to test out their own ideas rather than imposing specific activities upon them. Teacher support in helping them devise investigations was evident although there were fewer examples of teacher intervention being used to challenge
children’s alternative ideas. This area appears to have been more problematic to implement.

All interviewees had covered similar conceptual areas of science with the children to those covered during the course in the immediate period before I visited. Materials and/or electricity work was evident in each class although no evidence of forces work was seen. Analysis of assignments indicated that this reflected the general take up of area of science to use with children during the course. Work on materials and electricity was more enthusiastically approached and reported during feedback sessions than that on forces and featured far more often in case studies used for assignments. This may reflect teachers’ lack of confidence in an area of science they found most difficult or the difficult they perceived in providing contexts and appropriate activities for children in the area of forces. When examples were given, the use of toys as a starting point was most common.

Overall the interviews provided a positive indication of the impact of the course. Frances’ comment on her evaluation form was typical: “It (the course) helped me to radically review the way I teach science”.

The outcomes gained from the course by these participants will now be analysed using the typology of INSET outcomes provided by Kinder and Harland (1991) which was discussed in Chapter 5, Section 5.8. They identified three 3rd order outcomes (which on their own are least likely, according to Kinder and Harland, to have an impact in terms of classroom practice): provisionary, information and new awareness.

All interviewees, either during their interviews or on their evaluation forms, indicate they have gained a new awareness of science teaching, perhaps most obviously in terms of valuing children’s existing ideas. The provisionary aspects were cited in terms of ideas for use in the classroom (eg Frances’ comments about the Forces cycle) and the value of the handbooks (Anne described these on her evaluation form as “an excellent resource”). The number of
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additional handbooks sold during the course, to be used with colleagues back in school, was also evidence of this provisionary outcome. The recent introduction of the National Curriculum and the changes proposed to this during the course period ensured an 'information' outcome for participants. In particular the use of 'big ideas' as a means of dealing with planning science (see Case Study 4: 139) was cited as useful. Consequently, each third order outcome was apparent for all five teachers.

Kinder and Harland's second order outcomes were: motivation, affective and institutional, which were identified as more likely to lead to an impact upon practice, although again only if achieved in combination with the highest (1st) order outcomes. The first two have already been discussed above, for example Anne's enthusiasm and Caroline's statement about overcoming her initial fears and not dropping out. The reviews indicate I recognised the role of affective outcomes (Concern 20) but whether I attached sufficient importance to it is discussed in Chapter 10. The increase in confidence resulting from the course, and relevant to this 'affective' outcome, is discussed again later in this chapter. The 'institutional' outcome has not been discussed in this enquiry in any depth since the focus has been upon the impact upon individuals. However, in the light of HMI general comments about the courses (Chapter 5, Section 5.6), Kinder and Harland's (1991, p150) and Halpin et al.'s (1990) recognition that the institutional dimension does significantly affect the impact of the course upon individuals this is an important consideration which was taken seriously by course providers. The involvement of headteachers during the course and the focus of the last cycle upon work with colleagues were examples of this. Several of the interviewees claimed, on their evaluation forms, that they now felt more confident to work with less-confident colleagues. The third assignments provided evidence of all the teachers involved on the course, apart from two who were unable to work with colleagues for reasons outside their control, had planned, implemented and evaluated some form of inservice activity which involved colleagues. The success of these varied, but crucially the institutional context was considered in terms of course planning and did feature in terms of INSET outcomes.
Particular impact of this nature was cited by teachers whose schools were used for day 3 of the cycles (including Caroline and Frances). The rest of the staff were keen to find out what was going on and to follow up the day collaboratively. Anne also provided evidence that she immediately used the model of the school-based day with the rest of her colleagues on an inservice day during the first term of the course. The evaluation data and interviews indicates that two second order outcomes (motivation and affective) were evident for nearly all participants to some extent and three second order outcomes were achieved by many.

In terms of the highest, first order outcomes: value congruence and knowledge and skills, the latter area has been addressed in terms of the earlier analysis. Kinder and Harland found these first order outcomes must be present for impact upon classroom practice to be effective. All interviewees gained new knowledge and skills as a result of the course in both the professional and scientific domains. Value congruence is a term referring to the "personalised versions of curriculum and classroom management which inform a primary practitioner’s teaching and how far these coincide with INSET messages". There are several possible responses of teachers: they may find the values made explicit during an INSET activity do not match their own and reject those offered; they may find the values are similar to their own and this leads to their existing philosophy and practice being ‘validated’ and reinforced or they may be genuinely inspired or motivated to adapt current practice to accommodate the new message. There is, of course, a danger that the values held by course providers are misinterpreted by course participants who use their own interpretation to ‘validate’ practice which is not congruent with the course providers’ intentions. Evidence from the teachers interviewed would suggest that the course was effective in terms of introducing the participants to new values related to teaching and that these values were accepted by participants and informed changes to their practice. For example, course providers recognised the importance of eliciting and recording children’s existing ideas. This value has been accepted by course participants and used to inform their decisions about classroom practice such as using floorbooks. In some cases, for example Kay, and to some extent
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Frances, this value congruence is less evident from their responses although changes to practice had occurred. Some values made explicit on the course, such as the importance of group work; the significance of children's practical work and the importance of context and relevance for children's science were not new to all participants and therefore can be seen as reinforcing previously held values. This can be important in terms of work with colleagues, who perhaps do not have the same values related to teaching science. There was no evidence of teachers misinterpreting ‘messages’ and using them to endorse practice which was not congruent with the values underpinning the course.

Therefore, the teachers profiled in this section show how the course has led to a variety of outcomes and that for each teacher analysed outcomes of Kinder and Harland's first, second and third order are identifiable. This combination of outcomes of different orders, according to their research, is necessary for impact upon classroom practice to result and be long-lasting. Kinder and Harland also looked for evidence of this impact as an outcome. In my enquiry the evidence of this has been less direct but nonetheless convincing. The typology Kinder and Harland proposed was useful for analysing outcomes and, at this stage of my consideration of the data, did not lead me to identify any other outcomes not included, although this view changed later as I will indicate in Chapter 10. Nor did I find any evidence to counter their claims about the nature and significance of the different order outcomes and their inter-relationship. Their framework, dealing as it does with affective and institutional outcomes has more use for INSET evaluation than that devised by Joyce and Showers (1980) and discussed in Chapter 5 (Section 5.8).

9.3 Other evaluation data from DES 20-day Courses

The sample of participants used for the profiles discussed above was used to illustrate aspects of the course outcomes and other data would suggest that their response to the course and what they got from it is not untypical of other participants. This is clear from the
case study data which shows their participation in course sessions to be similar to others. Their assignments were also similar to others and as noted above the assignments provided course providers with evidence that there had been some degree of impact upon the practice of every teacher involved. For some, like Anne, this had caused a fairly radical change, for others like Frances and Kay, the changes were less significant. The other evaluation data collected allows these profiled teachers’ outcomes to be seen in a wider context.

Course participants were asked to complete a proforma at the beginning and end of the course indicating their perceptions of their own scientific knowledge and understanding and the difficulty they considered different areas of science were for them to teach. The latter provided an indicator of their perceived confidence to teach science. The proformas (Appendix 11) were analysed and the results included as Appendices 14 and 15.

The results at the beginning of the course were predictable and in line with others who had carried out similar exercises (Smith and Peacock, 1992; Wragg et al., 1989a). Information technology, genetics, forces and Earth in Space were rated most difficult to teach by both cohorts. The information technology area, which in the National Curriculum (DES, 1989a), was concerned specifically with the scientific aspects of information technology seemed, after discussion with teachers, to be confused with using IT and the concerns they had about the use of computers. Genetics and Earth in Space were rated as difficult to teach because of the problem of providing practical activities. A surprise in both lists was the position of electricity (10th and 11th) which makes it a lower concern for these teachers than those surveyed elsewhere. This may be the result of previous INSET activities which have focused upon electricity in both LEAs in the period prior to the course. Living things and processes of life were predictably low in both lists. There seemed to be little difference in the response of Key Stage 1 and Key Stage 2 teachers.

Comparison between these lists and those resulting from the post-course proformas is
interesting and requires the two cohorts to be considered separately. Cohort 1 showed little overall increase in confidence if the number of 3/4/5 ratings is taken as an indicator (73 before, 69 after). It is also evident that materials is the only area covered by cycles used for data collection that they felt more confident to teach after the course. Their responses for forces and electricity are similar before and after the course. Cohort 2 showed a more marked increase in confidence using the same indicator (96 before and 54 after) and this was particularly shown by their responses to materials and forces. This may indicate Cohort 2 began as a less confident group of teachers, but this would not account for the differences in the cohorts' different responses to forces.

An analysis of the teachers' perceptions of their own knowledge and understanding reveals a different pattern. For Cohort 1, there is again less overall change in terms of their scientific knowledge (82 (total 4/4/5 ratings, indicating reasonable to poor knowledge and understanding) before to 73 after). However, there were claimed improvements in their knowledge and understanding in the areas of material, forces and electricity, although this was least in the case of forces. Genetics, which had not been a concern before the course had become a major area of concern by the end and in all the areas of biological science this cohort claimed to be less 'knowledgeable' after the course than before. This could be taken as an encouraging indicator that they were now more aware of gaps in their knowledge that they did not know they had at the beginning. Cohort 2 claim a much greater increase in their own knowledge, using this rather crude indicator (109 before to 35 after) and analysis of their responses show dramatic changes in perceived knowledge in the areas of forces, materials, and electricity. As with the rating concerning 'difficulty of teaching' these figures indicate that overall this cohort rated their own knowledge lower than the first cohort and therefore at the start did not seem to overestimate. By the end however, they did seem to be the more confident group in terms of self-perceived knowledge. This could be because they remained less aware of the gaps in their knowledge than Cohort 1, but there is no evidence of this. In particular their rating for biological sciences, including genetics, reduced dramatically and
although not covered by this enquiry it should be noted that the two cohorts had different teaching staff involved in the living things cycles and genetics was addressed on Day 4 of that cycle for Cohort 2.

Obviously this evidence should be treated with caution since the numerical analysis is not based upon recognised statistical procedures and therefore its validity is suspect. My claims related to it are intended to be illustrative rather than generalisations to apply to other contexts.

I will now look at the teachers' responses to particular cycles. This was taken from the end of course evaluation sheets (Appendix 7) and an analysis is included as Appendix 16. Firstly, the ratings of both cohorts to the perceived difficulty of dealing with ideas on each cycle is very similar. Forces was clearly the cycle found most difficult by both cohorts as the following shows:

Figure 9.6: Course participants' responses to particular cycles

The rank order is based on a calculated mean value for each cycle with each cohort. The ratings were 1 hard to 5 easy.

<table>
<thead>
<tr>
<th>Cohort 1</th>
<th>Mean rating</th>
<th>Cohort 2</th>
<th>Mean rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forces</td>
<td>2.19</td>
<td>Forces</td>
<td>2.0</td>
</tr>
<tr>
<td>Electricity</td>
<td>3.34</td>
<td>Electricity</td>
<td>2.97</td>
</tr>
<tr>
<td>Materials</td>
<td>3.5</td>
<td>Light</td>
<td>3.5</td>
</tr>
<tr>
<td>Light</td>
<td>3.88</td>
<td>Materials</td>
<td>3.69</td>
</tr>
<tr>
<td>Living things</td>
<td>4.23</td>
<td>Living things</td>
<td>4.46</td>
</tr>
</tbody>
</table>

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These responses can now be compared to the rating given to cycles in terms of how good/relevant to poor/not relevant they were considered. This varied more between the cohorts. The first two days of the forces cycle rated most relevant/good for Cohort 2 and much lower for Cohort 1. Day 4 of the living things cycle was also much higher in the list for Cohort 2. The ratings also suggest that Cohort 2 rated the parts of cycles more consistently than Cohort 1, for example all of the electricity sessions got similar ratings.

The reasons for these differences and the apparently different responses between the cohorts may be accounted for by the fact that Cohort 1 always had sessions before Cohort 2 and therefore as a result of the collection and analysis of data from the first sessions the second run was improved. This, it might be argued, was most significant on the forces cycles when Cohort 1 expressed concern about the content presented on day 2 (see Case Study 6 analysis, page 146). Therefore the different responses and degree of outcome may be evidence of the enquiry having a more beneficial result for Cohort 2. However, let me reiterate the point that this tentative conclusion is based upon evaluative evidence which needs treating with caution. The 'feel good' factor may have had a stronger effect upon the ratings of the second cohort as a result of other causes. For example, I did more teaching with Cohort 2 and there was more continuity of experience for that group; I felt more confident with that group having worked with the other cohort previously; Cohort 2 came from the LEA in which I had worked and knew most about in terms of other LEA initiatives and approaches to primary science; I had had direct contact on previous INSET with several course participants on Cohort 2. Despite these reservations, and the limitations of the crude indicators used there is, overall, evidence of the course having successfully improved the perceived confidence and scientific knowledge and understanding of those involved, even if this was different between the two groups. This is reinforced by more detailed reading of individual comments made on the forms which have also informed the discussion above.
9.4 Evaluation data from external sources

The courses were visited by an HMI who was part of the team evaluating a sample of courses (see Chapter 5, Section 5.6). He spent a full day with each cohort (Materials Day 2 for Cohort 2 and Forces Day 4 for Cohort 1) and provided an informal feedback to course providers and the then Inservice Course Director at the College. This section is based upon a written report by the Inservice Course Director, Stephen Ward, produced at the time of this feedback session (20th December, 1990) for circulation amongst teaching staff. The comments made included:

i. the courses benefited from joint planning with colleagues from another institution;

ii. the internal coherence of the course structure was “extremely attractive”. The main feature of this was the use of an open exploratory approach to teachers’ learning which was designed to model children’s learning. This was well-supported by school-based elements;

iii. the teachers did not found the approach easy to take on;

iv. the course faced up well to the task of developing teachers’ own knowledge of science;

v. course assignments were relevant and reinforced the course rationale;

vi. teachers’ individual needs were identified at the outset and this allowed for strengths and weaknesses to be addressed;

vii. the school-based work was highly successful and brought into focus many of the
viii. National Curriculum issues were well handled and links between processes (AT1) and content (ATs 2-16) were clear. The implicit teaching and learning methodology in the NC were made explicit throughout the course. There was emphasis on Programmes of Study rather than Attainment Targets;

ix. the selection of specific areas for study in depth rather than attempting to cover all was effective;

x. excellent liaison with LEAs was evident;

xi. the role of the science coordinator was well-handled and the assignment on this topic was particularly helpful;

xii. a good selection of materials was available to teachers and the handbooks were very useful and of good quality;

xiii. assessment and recording of children's progress benefited from being handled throughout the course;

xiv. cross-curricular links were well brought out, especially in language although mathematics could have been addressed in some more depth;

xv. course evaluations from participants were very positive and many commented that they were radically re-examining their practice.

The feedback also provided evidence of the similar provision in the two institutions, indicating
that the collaborative aspects of the course were leading to a similar experience for teachers regardless of the particular course they selected. As a consequence of the HMI's evaluation I was invited to write a paper for the HMI Invitation Conference for DES Designated Course Providers in April 1991 (see Appendix 13), outlining the course model and its implementation. This paper was circulated to all participants and used to inform discussions during group sessions. This was further endorsement of the success of the course model and approach.

The other external comments that were recorded came from the external examiner who read a sample of scripts from each cohort for each assignment. His comments are included in Appendix 8 but his concluding comment is indicative of his written and informal feedback:

There was no doubt in my mind that the work under present scrutiny provided ample evidence of the course having sharpened students' awareness of children's learning, of classroom processes, of issues connected with assessment, of certain curriculum developments to their own professional and personal satisfaction.

External Examiner's comments from BCHE Inservice Education Monitoring and Evaluation Report, October 1991

Having considered a range of evaluation evidence concerning the course the next section will revisit the concerns identified in the last review.

### 9.5 Revisiting concerns discussed in Review 3

This section considers the range of concerns addressed during the enquiry, in the light of the evaluation evidence discussed above, to see whether the conclusions drawn in Review 3 (Chapter 8) need to be revised and focuses upon the key concerns identified. The order will be more logical than that in the earlier reviews in Chapter 8 which was based upon the order in which concerns were identified. In this review the approach will be considered in the order of the phases of: orientation; elicitation; intervention and application. The reader is referred to
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Appendix 17 (Volume 2, page 288) for the specific wording of each concern.

9.5.1 Orientation.

The additional evidence discussed does not challenge the claims in Chapter 9, related to Concern 1, that orientation and elicitation phases are inextricably linked for adult learners and that those that need orientation time can be offered opportunities through exploratory and semi-structured elicitation activities. However, in areas of study that teachers find particularly difficult, such as forces, it is likely that more teachers will take the opportunity to orientate themselves to the area of study and will spend more time doing so. Encouraging them to do this in a relaxed atmosphere may make the sessions 'less threatening'.

9.5.2 Elicitation

Numerous concerns were raised and tackled related to this phase of a constructivist approach. A variety of strategies were implemented (Concern 3) and evidence from interviews and evaluation exercises indicate that all participants recognised the value of some of these and explored them with their own children. Floorbooks were most commonly used with children, but evidence of concept-mapping was also found (for example, in Frances' second assignment). This phase was found threatening by some participants (Concern 10 and 20) according to the later evaluative data, confirming my initial evidence, and it was therefore appropriate to look for strategies to reduce this. This area was one where consideration of the 'ethos' of the sessions was of significance. It would seem that I was more successful with Cohort 2 in addressing this and the apparent effect of an input that participants found particularly challenging (Case Study 6) does seem to have had repercussions in terms of the participants' confidence and feelings about the course. The importance of ethos and the atmosphere established at the beginning of a course are crucial. This was more successfully achieved with Cohort 2 based upon evaluative comments made.
Elicitation is the phase when learners structure their existing ideas and it has two purposes. For the teacher/tutor it is the time when those existing ideas are revealed and made explicit. The strategies explored and developed during the enquiry have addressed this purpose with some success. However, the other purpose of elicitation as a phase when the learners clarify and organise their own existing ideas, whilst in some ways supported by these strategies, is also facilitated by exploratory activities. It is this aspect of my practice that has evolved as a key concern (Do I allow students adequate time for practical exploration and investigation? - Concern 13). However, in earlier reviews the significance of this to elicitation had not been so clear to me. My view of elicitation had focused upon its value to the tutor rather than to the learner. Discussions with colleagues, further work with children and more recently on a recent book (Ollerenshaw and Ritchie, 1993) have clarified my understanding of this and Chapter 3 of that publication provides a more extensive discussion of the nature of elicitation as I understand it. Returning to the key concern, reflection confirms the interdependence of Concerns 4, 7, 15, 17,18 and to some extent 21. Fundamental to this phase being of value to the learner is the need to ensure that she/he takes responsibility for her/his learning. This can take time and sensitive support from the tutor. A degree of unstructured activity is necessary to enable learners to select, through their exploratory activity, an area of interest in which to develop further knowledge and understanding. It is during this exploratory activity that the importance of raising scientific questions can be highlighted (Concern 17). Although some progress in terms of course participants raising scientific questions is evident in tracking back through the case studies, there is less evidence from assignments that they have been successful in encouraging their children to raise questions. The accounts provided of classroom activity indicate that children in their classes were not ‘naturally’ raising scientific questions. My own understanding of the difficulty of this and possible strategies to encourage scientific question raising was developed through some classroom work which is reported elsewhere (Ritchie, 1991b). The strategies
used in that case study of helping children to raise and analyse questions proved successful and have been used with adult learners with the DES 20-day 1991-92 cohorts. There are other aspects to raising questions which, on reflection, were not addressed during the enquiry. My view of scientific question-raising as a ‘technical’ rather than ‘creative’ activity is evident in revisiting the reviews and this perhaps influenced the course members. Strategies to encourage a more open-ended approach to question raising, certainly in the early cycles will be explored. The significance of question-raising in terms of its relationship to the nature of science (Concern 7) was made explicit to course participants and seen in the context of the questions leading to more systematic investigations, which provided the route to an improved but tentative understanding of the world around them, reinforced the relationship between process and knowledge and understanding. No evidence from assignments or evaluations indicated course participants constructing a view of the nature of science which was not congruent with that of course providers and outlined in Chapter 1 (Section 1.9).

Encouraging course participants to raise their own questions during exploratory activity was also, on reflection, a key strategy for encouraging them to take ‘ownership’ of the investigations. More specific attempts to address this concern (Concern 15) used in Case Study 7, although successful, were in retrospect far less important to this issue than the need for course participants to be given time and support to raise appropriate scientific questions for later investigations.

Addressing individual needs was a concern highlighted by HMI (DES, 1992b) and Harland and Kinder (1992). It was evident from very early on in the course that the cohorts were ‘mixed-ability’ in terms of existing scientific knowledge and understanding and, like any class of learners, effective learning would only occur if those individual differences were recognised and dealt with. This was enabled by the approach and the strategies used and highlights one of the strengths of a constructivist approach which requires assessment to be seen as an integral and ongoing aspect of the teaching, not a ‘bolt-on’ at the end.
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Consequently, the elicitation phase, seen as important for both tutor and learner, plays an important part in ensuring individual needs are met. The nature of the questions raised and the 'ownership' given learners of those questions and subsequent investigations ensures that self-identified needs are addressed. Tutor assessment during this phase of learners' existing ideas leads to appropriate interventions to address tutor-identified needs. Reflection during this review suggests this was generally successful and the later evaluative evidence which confirmed the teachers were treating their children as individual learners whose specific needs required attention supports this claim.

The proposal to use follow-up material to address teachers' different learning needs was actioned with the DES 20-day 1991-92 cohorts. Materials from the NCC on *Forces* (NCC, 1992a), available in draft form, proved particularly useful in this respect as did another publication which was also sent free to all schools from the Royal Society for Chemistry (Archer, 1991). Additionally, PSTS Packs on *Forces* and *Energy* (Kruger et al., 1991 a and b) and Open University materials have been used with the 1992-93 cohorts.

Crucial to all these related concerns is the need for the tutor to allow course participants sufficient time for this exploratory phase. As noted previously, this is an area where I consider my own practice has changed considerably during the period of my enquiry. However, even at this stage of reflection I recognise the difficulties for a tutor of allowing this relatively unstructured part of the session to be in the control of the learners. The tension I feel is related to the need to give participants maximum support and perhaps in some ways to 'give them value for money' in a financial climate where inservice activities of this substantive nature were and are so rare. I recognise the need for the tutor to stand back and let the learners pace the activity, but encouragement and support during this, in a way that doesn't direct too much and take control of the learning away from the learner, is an aspect of my role that needs further consideration. The amount of content in the National Curriculum Programmes of Study that needs to be covered also adds to the dilemma I faced as a tutor and the teachers faced in
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their classrooms. The decision taken by the course team was to go for depth and not breadth and use the notion of 'big ideas' to maximise the coverage of content during the course. Teachers face a bigger problem of the statutory requirement to cover Programmes of Study. This provides the major constraint upon teachers in adopting a constructivist approach. Those who recognise its value, who appreciate the need for appropriate orientation and exploratory activity and the time this takes face the dilemma of whether working in this way will allow them to cover the content necessary. The use of the notion of 'big ideas' and recognition that key concepts can be used to plan work covering several areas of the Programmes of Study can help in this respect, but the dilemma remains as one each course participant has to address in their own classrooms in terms of the educational values they hold.

Consequently, reflection upon this key concern for me as a tutor has reinforced the extent to which it encompasses other concerns I have addressed and also helped me to appreciate how the same concern has to be addressed by course participants in their own teaching.

9.5.3 Intervention and review

This phase is that during which learners should be restructuring their existing ideas so that they more closely match accepted scientific thinking. The role of investigative work plays an important part in this as does the role of the tutor. In this phase the tutor will be supporting the investigative activity, challenging the learners and when appropriate offering the 'scientist's view' as one to compare with their own ideas. This phase of the constructivist approach links to several concerns raised during the enquiry and leads to the second key concern identified.

The discussion of practical activity above, during elicitation, focused upon the importance of exploratory activity that leads to more systematic investigations during which learners devise a means of testing out tentative hypotheses in order to find an answer to, or perhaps further clarify, their questions. This approach to practical activity was that emphasised by the course
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team and focused upon during day 1 of Case Studies 4 to 9. However, constraints caused by
the accommodation and the equipment available did cause some frustrations amongst course
members, for example when carrying out investigations related to friction. The time taken for
investigation, and the need to allow learners to pace this activity, also raises issues about the
tutor’s role similar to those raised above. A different approach to practical work was also used,
although in some respects the significance of the difference has only become clear to me
during later reflection. During day 2 (eg Case Study 4, 5, 6 and 7) activities were set up by
tutors and carried out by course participants to illustrate key concepts. These were not directly
related to questions raised during exploratory work, although usually addressed similar
concepts. The different purposes of this kind of practical activity, which I refer to as ‘illustrative’
were not made explicit to course participants and this may have led to confusion about the
nature of practical activity in science work in the classroom. Illustrative in this context indicates
an activity set up by a tutor for students with a specific purpose of illustrating or providing
supportive evidence of a specific scientific concept or concept area. Students may be
required to devise aspects of an investigation linked to the activity but crucially it is not an
investigation that they devised in response to a question they had raised. In this way it is used
differently to the way the NCC use it (NCC, 1991). Analysis of assignments indicated
considerable use of illustrative activity with Key Stage 2 children. Such activities have less
potential for developing scientific skills such as question-raising and hypothesising. Although
they are often used in secondary science lessons, it is my view that they are of less value in
primary science than learner-initiated investigations. Why then, did we use them on the
course? With adult learners, who had been previously encouraged to devise their own
investigations, they provided an efficient means of tackling key areas of scientific
understanding. In this they were successful, however, the disadvantages with younger
learners at a formative stage of developing an understanding of the nature of science did
need to be explored. This has been a feature of subsequent courses. It is also important to
recognise that the nature of both types of activities, within a constructivist approach, should
be regarded not as educational experiences in themselves which will automatically improve
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the scientific understanding of anyone undertaking them but instead as “routes pursued by a learner from a given starting point in the course of answering a question” (Ollerenshaw, 1993).

My intervention during investigative and illustrative activities did not cause me particular concerns, apart from the extent to which my approach to investigations was encouraging an inductive view of science. There is clear evidence during the early cycles of the DES 20-day Course that the course participants were expected to provide generalisations as a result of their limited investigative work. This emphasis changed during the course as the significance of this upon the view of the nature of science it may be generating became clearer. My own view of science, discussed in Chapter 1 (Section 1.9) is now clearer in terms of the role of generalisations and I now feel more confident in articulating this to teachers. On future cohorts I have not encouraged teachers to see the outcomes of their investigations as generalisations and have placed more emphasis upon the investigation leading to a clearer restatement of the original question and/or to the generation of further hypotheses for testing. This reinforces the idea that scientific investigations are dynamic and on-going rather than leading to quick and ‘right’ answers.

Another aspect of tutor intervention - sharing the scientist’s view of the world through exposition, was a focus for several concerns (16, 19 and 20). These were dealt with thoroughly during Review 3 and referred to in the earlier section of this review when the course participants’ reactions to the forces cycle were considered. Analysis of assignments and evaluation forms provided no evidence to suggest that the way the expert view was offered led to teachers adopting a didactic approach to their own work during which ‘telling the children’ was emphasised. That is not to say that sharing with children accepted scientific ideas was regarded as inappropriate, but offering those ideas alongside the children’s own and in the context of a review of children’s own practical investigations seemed to be recognised as more desirable. This modelled the approach we used on the course.
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The use of exposition as a means of dealing with learners' alternative constructs does need revisiting as a result of the data in the earlier section of this chapter. The evidence of course participants retaining the 'impetus' idea of 'a force acting in the direction of any moving object' is of concern. There was a direct attempt to challenge this common alternative construct during both Case Studies 6 (CS6: 310) and Case Study 7 (CS7: 318) and concept maps produced on day 4 of Case Study 7 (CS7: 495) showed no evidence of the alternative idea being retained. However, any restructuring that did occur was not retained by all participants after the course. This raises the question of what is meant by 'restructuring' and this will be considered again in Chapter 10. At this stage of the discussion it is sufficient to recognise that the attempt to get course participants to restructure intuitive ideas such as these, through exposition of accepted scientific ideas, was not successful, even though it was approached through dialogue and related directly to the ideas learners held. This would seem to be an area where the lack of illustrative or investigative activity was significant. It also identifies an area of activity where a quantitative approach may be appropriate (Concern 21) but the earlier point about constraints resulting from the equipment available are relevant. This has been addressed with later cohorts through the use of a computer simulation addressing dynamic forces and 'analogies' through the use of the PSTS material discussed below.

Other concerns pertinent to the intervention stage include the question about whether all alternative ideas should be addressed. Evidence collected after Review 3, for example related to 'air between particles' suggests that alternative ideas offered, or even implied, by other members of a group can easily be taken on by an individual and therefore, whenever possible alternative ideas should be identified and challenged by a tutor. There is a danger that the emphasis placed upon common alternative ideas, by a tutor, can lead some individuals to take on those ideas themselves. Kay (CS10: 435) introduced the idea of 'clashing currents' into her interview explanation of a circuit, as a 'theory'. There is no evidence in Case Study 9 that she held that before the session, and although she rejects it in her final explanation there is a suggestion that she did not internalise it as a 'common alternative
framework’ but as an ‘acceptable theory’. Zandra (Case Study 1) took on the idea of a ‘dead wire’, which was introduced as a common alternative idea held by children, according to her interview several months later (CS1: 561). There is therefore a need to be very explicit about ideas which are ‘common alternative frameworks’. The importance of raising teachers’ awareness of the common alternative ideas children are likely to hold has not been diminished as a result of these new insights, but the way they are introduced and dealt with does need addressing. With later cohorts common alternative ideas have been given to participants in documented form together with the related ‘acceptable scientific idea’. The accepted scientific ideas have also been revisited in later cycles as a ‘review of key ideas’ to reinforce the ‘accepted’ over the ‘alternative’. This is less of a problem for the teachers when working with children since they would not need to raise with young learners the range of ‘common alternative ideas’. With children their responsibility is simply to challenge those alternative ideas they identify.

Another concern related to the intervention and restructuring phase is to do with the use of analogies (Concern 12). Although originally raised in the context of using metaphors, reflection and background reading led to the recognition of analogies as having the most potential for helping adults restructure their ideas. Since Review 3, the PSTS INSET materials on Forces and Energy have been published (Kruger et al., 1991a and b). These are based upon the work of Clement (1987) and for a number of key concepts within each topic they are structured around:

i. A target problem - eg. How can friction be a force? (in the context of trying to move a rock).

ii. Possible causes for the problem - eg. forces are thought to be acting only when there is an obvious effect, such as a rock moving.
iii. Another way of looking at the problem - e.g. for no movement to occur another force must be acting against the pusher.

iv. An anchoring example, which is in agreement with most people's intuitive beliefs and also corresponds to the accepted scientific view - e.g. two brushes with a single bristle each pushing in opposite directions.

v. An analogy, to bridge the gap between disbelief (target problem) and acceptance (anchoring problem) by providing an intermediate bridging analogy which is designed to show the problem and anchoring example are analogous - e.g. two brushes acting against each other, with all their bristles catching.

vi. A conceptual model, as an invented representation which is scientifically accepted - e.g. representation of 'smooth' surfaces as 'rough' when magnified.

This material has proved very helpful in terms of the concern I identified and has been used with later cohorts both during course sessions and as material to be used for differentiated follow-up activities. The use of the material in the context of course participants' own investigations and tutor-initiated illustrative activities has provided another approach to exposition of the accepted scientific view which developed as a result of the enquiry.

The key concern that was identified during Review 3 related to restructuring was: How can I use the relationship between adult and children's constructs to improve the adult's knowledge and understanding of science? (Concern 14) This concern, whilst recognised as key, has in some respects been the most difficult to address and evaluate. There are several stands to my thinking about this concern, which refer back to the notions of 'children's science', 'teachers' science', and 'scientists' science (Gilbert et al., 1982) introduced in Chapter 2. It should be added that 'tutors' science' is a category that might well
be appropriate to this analysis. Consideration of the similarities and differences between ‘children’s science’ and ‘teachers’ science’ were seen as another route for developing the teachers’ scientific knowledge and understanding. It is also appropriate to recognise other reasons why school-based elements were such a necessary and integral part of the course. It was the view of the course developers that no INSET activity for teachers could or should be divorced from their professional concerns about making use of the INSET back in the classroom. Children were seen as a powerful factor in galvanising teachers into action (Ollerenshaw, 1993). In some senses we saw children as the medium for teachers in the way that materials and activities were the medium for the child - whilst a child actively constructs an understanding of phenomena a teacher is actively constructing an understanding of the child’s learning. This view underpinned the school-based elements.

During the centre-based sessions the relationship between ‘teachers’ science’ and ‘scientists’ science’ was under scrutiny, perhaps mediated through ‘tutors’ science’ where the latter two were not congruent. The intention was to enable teachers to identify differences between their own ideas and those accepted by scientists in order for them to restructure their ideas to develop a better ‘match’.

During the school-based days that make up Day 3 of each cycle on the course the focus was upon the relationship between ‘teachers’ science’ and ‘children’s science’. These days provided opportunities for course participants to elicit children’s ideas, reflect upon them in terms of their relationship to their own ideas and plan activities to challenge and develop the children’s ideas. This process was intended to lead to clarification, further questioning of the explanatory power of the teachers’ own ideas and the identification of ‘gaps’ in their current knowledge. There is evidence that this occurred, but in retrospect, I now consider I adopted a relatively passive role and left this to happen rather than being more active in ensuring it happened. During the intensive analysis periods of the school-based days I sat in on the discussion of pairs and made some contributions but these tended to focus upon the
children's ideas and actions and only occasionally did I get the teachers to make the relationship with their own ideas explicit. Similarly, my contribution during plenary sessions on these days focused upon the children's thinking and changes to that were evident rather than the teachers and the gaps that had been exposed in their current understanding.

Another aspect of this relates to the work the teachers did with their own children between days 3 and 4 of each cycle. My role during the reviews of this can be criticised in the same way. The focus of these sessions was directed towards insights gained into 'children's science' rather than the relationship between 'children's science' and 'teachers' science'. The links between the work at an adult level by teachers during the course and work with their own children in schools were a vital part of the course model and, as HMI remarked, contributed significantly to its success. This was made explicit by tutors throughout in terms of the appropriateness of the approaches to learning and teaching with adults and children. This was recognised by the course participants and informed their own practice. However, in other ways there was too distinct a separation between the two aspects of the course and the relationship between the centre-based and school-based activities in terms of teachers' scientific knowledge could have been made more explicit. That is not to say that this was not addressed, and some evidence from assignments shows the way in which some teachers were well aware of how their own understanding of science was being developed and consolidated through their work with children (eg Frances (Cohort2) concerning floating and sinking). However, this could have been reinforced more through tutor intervention. Encouraging teachers to focus upon this during their assignments would be another specific strategy that could be used.

Another aspect of this concern relates to the differences between 'children's science' and 'teachers' science' which again were perhaps not dealt with as explicitly during the enquiry as might have been appropriate. Adults were using abstract models and studying some phenomena at a microscopic level, in a way that is significantly different from science work in
the primary classroom. For example the teachers were meeting explanations of materials based upon particulate models which were not intended nor appropriate for children. This learning could therefore not be related to ‘children’s science’ in the way, that for example, ideas about simple electric circuits could. The teachers were required to interpret children’s questions and ideas about materials in terms of the abstract model. Young children’s ideas are based upon source and effect rather than upon unseen or abstract aspects. This for example, meant that the ‘scientist’s’ Newtonian physics of dynamic bodies was potentially very difficult to relate to children’s explanations of cause and effect and the teachers’ own intuitive ideas of ‘impetus’. These difference and the difficulties involved in comparing them were not dealt with as explicitly as I now consider would have been desirable.

The nature of teachers' scientific knowledge and understanding is effectively 'put to the test' when they attempt to apply their understanding to work in the classroom either planning, implementing or assessing children's learning. Consequently, using the classroom context to consolidate the teachers' learning was appropriate and evidence would suggest it was successful. The importance of the classroom context for the effective development of teachers' professional and academic knowledge and understanding was highlighted by Eraut (1982). This enquiry has provided evidence to endorse his view and further challenge HMI's view that DES Designated-courses should involve a maximum of three school-based days (see Chapter 5, Section 5.8). Ollerenshaw's views of the latter (Ollerenshaw, 1993) have significantly affected my own reflections upon this area during this review and is further evidence of how collaboration and the use of the framework for analysing concerns has enhanced my enquiry and indicated the next stage of my own professional development. As a result of this review I now intend to focus my data collection upon my interactions with teachers during reviews of school-based work to ‘investigate’ the extent to which I am able to make better use the experience teachers have when working with children for extending their own scientific knowledge and understanding.
9.5.4 Application

The interviews have provided me with evidence of the course participants applying learning from the course in their own classrooms and during questioning able to apply their understanding of scientific concepts to novel situations. Both are important outcomes. The concerns identified during the enquiry related to application involved the extent to which application of scientific ideas was being encouraged during course sessions (Concern 5 and 6) and were dealt with during Review 3. Since that review a more concerted attempt has been made to provide opportunities during a following cycle to apply ideas developed in the previous one, similar to the example cited in Review 3, when a small sample were asked to explain the heating effect in the filament of a bulb using particle theory.

9.6 Evaluation of the framework

The framework for analysing the range of concerns I identified during the first review, at the end of my 'exploratory' activity, has been used to revisit these concerns on three subsequent occasions, drawing upon different evidence and analysing the concerns and action taken using different techniques. The third review led me to recognise two key concerns which still warranted attention. This review has provided me with new insights into those two key areas and this in itself seems to indicate the process and the use of the framework has been of value to me. The process of review and analysis has evolved during the enquiry and for example, it was only during preparation for this last review that I recognised the extent to which self-evaluative data and course evaluation data could interact in a dynamic way and inform both aspects of the enquiry, although in retrospect this may seem obvious. As I will consider later, I recognised throughout this enquiry that my own learning was a result of my own active construction of an understanding of both my practice and my use of action research. That was a dynamic process and this review is a part of that process. It was only after I had completed work on the contextualising chapters (2 to 6), revisited the case study data.
(during the stage of producing the Case Study Volume) and the earlier reviews (Chapter 8) that the structure and content of this review was identified. The writing of this Chapter has itself been a 'dialogue with self' and although it is the part of the enquiry that has has least involvement of colleagues, in that at this stage the review has not been discussed with others, it has been a valuable process which leaves me with an enthusiasm and commitment for the 'next' stage of my ongoing professional development. This is unlikely to have occurred without the use of some form of analytical framework for dealing with the diverse concerns I identified, and a format for summarising them.

In the spirit of this thesis, a final evaluation of my use of the framework and the process in which I engaged will be carried out in Chapter 11. The rest of my thesis is in three parts. Chapter 10 will be a discussion of the enquiry in terms of its 'content'. This will consider tentative conclusions I can draw about my use of a constructivist approach with adult learners and discuss the insights which I consider I have gained from the enquiry and how I have used those insights. This discussion will relate to the background provided in Chapters 3, 4 and 5. Chapter 11 will provide a discussion about my use of action research and insights I have gained into practitioner-centred research and my particular variant of it. This will relate back to Chapters 6 and 7 for context. The final chapter will attempt to bring together the different strands to ensure the conclusion reinforces the holistic nature of the overall enquiry.
Chapter 10 - A constructivist approach and adult learning

10.1 Introduction

My enquiry has provided evidence, detailed and discussed in the last two chapters, to allow me to claim tentatively that the constructivist approach I used when working with students during initial teacher education courses and with teachers on inservice education courses was successful in terms of the learning that resulted. This chapter provides a discussion of the enquiry outcomes in terms of the apparent benefits of the approach to students and course participants. The outcomes can be conceptualised in two distinct, but related, areas. The approach I used was intended to have an outcome in terms of changes in the practice of those involved. In other words, my teaching was intended to improve the teaching of those with whom I worked, in order to improve the quality of learning for their pupils. After some general points about the reasons why I consider the approach and the course was a success in this area, I will summarise these outcomes for participants. They will be discussed, drawing upon the insights gained during the enquiry, and related to the nature of the approach I used and the values I hold as a teacher. The other outcomes intended were concerned with improvements in the scientific knowledge and understanding of the adults involved. The next section will address the way in which this increase in knowledge and understanding was facilitated and the nature of the restructuring that resulted from the teaching sessions.

Having discussed the outcomes for those with whom I worked, I will explore my own learning in terms of new insights I gained into my own practice and the constructivist approach I used. This will draw upon the evidence in the reviews (Chapters 8 and 9) of changes in my own understanding during the enquiry and the nature of those changes.

The enquiry was intended to lead to improvements in my professional practice as well as an evaluation of an approach and an evaluation of the DES 20-day Course which was based upon that approach. The third of these aims will be considered in the next section of the chapter and this will discuss the extent to which the BCHE course model and my use of it addressed some of the criticisms made in national evaluations of the DES designated
courses. It will highlight lessons learnt and raise further issues of concern to me and other inservice providers.

The chapter will conclude with a section exploring the application of the insights and the new understanding I gained during the enquiry in other contexts. This indicates the way in which the final phase of a constructivist approach to teaching also provided a way of conceptualising the end of this enquiry, although, as with young learners in the classroom the end of one activity is the beginning of another and this enquiry is not the end of my professional development. Arising from this phase are questions and proposed actions to take me forward, beyond the terms of this thesis.

10.2 The success of a constructivist approach

My first tentative claim in this concluding part of my thesis is that the constructivist approach that I and colleagues have used with students on college courses and teachers on inservice courses has been successful in improving the scientific knowledge base (see 10.4) and professional practice (see 10.3) of the adult learners involved. This has been achieved by adopting an approach to teaching based upon a view of learning which was made explicit and which enabled the adult learners to recognise the nature of their own learning as well as that of children they teach. The constructivist epistemology which emphasises an individual's active construction of their own knowledge can be seen as appropriate at three levels in this enquiry: in explaining my own learning; in explaining the learning of the students and teachers and in explaining the learning of children in science. For the adult learners (including me) the metacognition involved in attempting to understand the nature of one's own learning is a factor in the effectiveness of that learning.

As well as a constructivist epistemology offering an explanation for all levels of learning, it also provides a view of learning to explain learning in science and the development of professional
knowledge and understanding. The development of scientific knowledge and understanding is the area in which the constructivist view was made explicit to teachers and students during the teaching sessions. The extent to which it applied to the development of their professional knowledge and understanding remained implicit during sessions.

Another factor leading to the success of the DES 20-day Course, and to a lesser extent the work with B.Ed. students, was the adoption of a teaching approach which was consistently used by all tutors, which was applicable for the students or teachers to use with young learners and which was made explicit to them throughout the course(s). The constructivist approach with its emphasis upon eliciting learners' existing ideas and challenging those ideas was one which appears to have had an intrinsic appeal for some teachers. I suggest that there may be several reasons for this. Primary teachers have little difficulty accepting the notion of 'starting from where the child is'. This simple statement is one which most primary teachers would endorse and it is implicit, if not explicit, in the literature concerning primary education. It could be claimed to be a common 'value' held by primary teachers. The simplicity of the statement, however, disguises the difficulty of finding out 'where the child is'. A constructivist approach offers one answer and in that way provides an approach which is congruent with the values many primary teachers espouse of treating children as individuals and responding to their individual needs. Primary teachers are also, it might be reasonably claimed, interested in children and the nature of children's ideas. Introducing teachers to the nature of children's common alternative ideas and inviting them to elicit ideas from their own children was appealing and motivating. Consideration of these existing ideas convinced them of the significance of these ideas to future learning. For example, realising children think 'ice melts because of the light' after you have set up a range of activities to show it results from heat is illuminating! Generally, primary teachers also enjoy talking and listening to children. Introducing an approach to teaching science that encourages this and values children's existing ideas again has an appeal to many primary teachers.
Consequently the teaching was based upon an approach which could be relatively easily communicated to teachers both through their own involvement in it and through discussion. It was an approach that is in line with the values many held and it offered a practical way of approaching science teaching.

The nature of the constructivist approach with phases of orientation, elicitation, intervention, review and application lent itself to teaching sessions lasting a relatively short time or those spread over a longer period. It also offered a clear structure for sessions which was one teachers as learners could reflect upon and relate to their own teaching context.

The case study evidence collected during the enquiry illustrates how a constructivist approach to work with adults can be implemented in a practical and, apparently, effective way. It has shown that adult learners do have existing ideas about phenomena and that these ideas can be elicited through a variety of strategies. It has shown that adults' existing ideas do show evidence of common alternative frameworks. The case studies indicate how those existing ideas can be challenged and changed through practical activities during which adult learners obtained evidence that conflicted with what they already thought, or reflected upon their own existing ideas or those of others, during activity or reviewing activities. However, this restructuring was not always effective and the application of restructured ideas in new contexts was an important, if not essential, part of the learning process. The role of the teacher/tutor using a constructivist approach also played an important part in facilitating effective learning. The nature of this role varied at different phases. During elicitation the teacher/tutor was required to be an active listener and responsive questioner, probing existing ideas. During the next phase the teacher/tutor had to make key decisions about the nature of intervention - helping the learners test out their own ideas or offering alternatives including accepted scientific ideas when appropriate. At all stages the teacher/tutor had to be alert to evidence of the nature of the learners' ideas and respond to them in a way that encouraged the learner to construct independently a better understanding and apply that
understanding. The case studies illustrate this in action and offer evidence of the tutor encouraging adult learners to take control of their own learning and benefit from the support of others. The structure of the DES 20-day Course, whilst based upon a constructivist approach, had other aspects, such as the use of school-based days, which were factors in its overall success as I will explore later. However, having made some general claims for the success of the approach and my use of it, I intend to focus upon the outcomes in terms of the impact upon the practice of those involved. This will concentrate upon the teachers involved in the DES 20-day courses, but will also refer to the students involved in ITE. The reader is reminded again that these claims are made tentatively and are based upon the case study and evaluative data discussed in Chapters 8 and 9.

10.3 Outcomes in terms of impact upon practice

The first part of this section will consider the range of these outcomes, referencing them to the typology produced by Kinder and Harland (1991) and introduced in Chapter 5, Section 5.8, and referred to in the profiles of teachers in Chapter 9. As a reminder these are:

<table>
<thead>
<tr>
<th>3rd Order</th>
<th>provisionary</th>
<th>informational</th>
<th>new awareness</th>
</tr>
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<tbody>
<tr>
<td>2nd Order</td>
<td>motivational</td>
<td>affective</td>
<td>institutional</td>
</tr>
<tr>
<td>1st Order</td>
<td>value congruence</td>
<td>knowledge and skills</td>
<td></td>
</tr>
</tbody>
</table>

The order of outcomes in the following discussion is not indicative of the importance attached to them. The evidence upon which these claims are made, drawing upon a variety of sources, is discussed in Chapter 9 (in particular pages 381-388). The issue of measuring impact in classrooms was addressed in Chapter 7, Section 7.9, page 289.
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I. Practical activity

It is evident from almost every example of work with children reported during course sessions (for example, the evidence during Case Study 5 (Volume 2, page 115), reported in assignments (such as the example discussed on page 383) and evident in interviews (see the analysis on page 382 indicating evidence of all the teachers supporting children in testing out their own ideas) that every teacher who participated in the courses recognised the importance of children's practical activity to learning in science. For most this was not a question of gaining new awareness but having their existing values about the importance of practical work endorsed (IPSE, 1988a, page A1) and in that sense it was an outcome concerned with value congruence. The importance of this should not be underestimated in the context of a course that run at the early stages of the implementation of the National Curriculum for Science. The number of knowledge and understanding Attainment Targets (ATs 2-16), compared to the single one for the processes of science (AT1), despite the 50%:50% weighting of the two Profile Components, led to some teachers thinking that science was concerned with a body of knowledge which should be taught in a didactic way, or through book-based study (Ritchie, 1990a). This was leading to some teachers undervaluing the importance of practical activity for children. The course had addressed this and provided an approach to science education for them, and their pupils, which recognised the significance of practical activity. There was also evidence that the teachers recognised, again as a result of their own practical work during sessions, the differences between exploratory activity, as a time for question raising, and more systematic investigative work that can result from those questions. Accounts of work with children indicate evidence of teachers offering children time for exploratory activity before encouraging them to devise their own investigations (see the example in Volume 2, page 219). There is also evidence that the practical activity on the course and in their classrooms was approached in a way that recognised the links between processes and knowledge and understanding. The practical activity was not organised as an end in itself but as a means of the learners gaining a better understanding of the world around them (for
example, in the area of ideas about floating and sinking discussed on page 383). It is not claimed that all of the science in participating teachers' classrooms was practical all of the time. Such a claim would require evidence of a different order. However, there is sufficient evidence to support the claim that such work was seen as an important part of science education by these teachers. The more limited evidence of students’ work with children (Case Study 1, Volume 2, pages 19-27) supports this claim.

II. Valuing children’s existing ideas and skills

This again involved an aspect of value congruence, in terms of the values many teachers on the course held about the importance of ‘starting from where the children are’, discussed above. But perhaps more significantly for most it involved new awareness, particularly in terms of the range of common alternative ideas they elicited from children or were introduced to by tutors. The nature of children’s existing ideas surprised and enthralled some teachers on the courses and in that way this outcome had affective aspects as well. The evidence collected indicated that ‘valuing children’s existing ideas and skills’ was probably the most common outcome for teachers as a result of the DES 20-day Course. Numerous evaluation forms referred to the teachers valuing children’s ideas more than they had done previously. The course tutors emphasised the importance of children’s existing skills and understanding of process in science and this also featured in the teachers’ work with children (particularly on day 3 of the cycles). This outcome was evident in the classrooms of all the teachers visited for interviews (Volume 2, page 219, line 10; page 224, line 181; page 226, line 266) and during post-course get-togethers which usually included sharing ideas the teachers had elicited and the origins and nature of those ideas.

III. The importance of the social context and children’s talk

As indicated in the earlier part of this section, the importance of children’s language and talk in
science involved a new awareness for many teachers, but this was congruent with the values teachers held in terms of the importance of talk in other areas of the primary curriculum (Wells, 1986). Previous primary science INSET and published materials (discussed in Chapter 3) had emphasised the importance of practical activity but placed much less emphasis upon talk. Similarly, the relevance of the social context upon learning in science was not evident in the teachers' comments at the early stages of the course. However, transcripts of small group discussion and analysis of these in terms of the way an individual's ideas are affected by the social context she/he is in were evident by the end of the course. This outcome was not universal, but evident in 85% of assignments and implicit, if not explicit in the evidence from interviewed teachers (see page 384).

iv. The Importance of context and relevance for primary science activities

Like the earlier outcome related to practical activity, this outcome involved a reinforcement and endorsement of the values held by many primary teachers related to the importance of providing activities for young learners that are relevant to their everyday experiences and offered in a context to which they can relate and which is motivating (IPSE, 1988a, page A1). The activities the teachers were offered on the course were designed to meet these criteria and there is evidence that they recognised this and it was reflected in their own work with children. As with the previous outcomes this was evident in the classroom work of the B.Ed. students (Case Study 1, Volume 2, page 23) as well as teachers after the inservice course. Even content areas like electricity were implemented in the context of lights on Christmas cards or 'eyes' for a robot (see Case Study 10, Volume 2, page 229, line 389). This outcome was clearly one related to value congruence and was evident in all of the work of teachers observed and examined from their own classrooms (Case Study 10, page 220, line 10; page 224; page 178; page 233, line 560) although the same claim cannot be made for work in schools on day 3 of each cycle. The time-scale and lack of information about the class often mitigated against activities being contextualised in the same way as they could be in the
v. Importance of Independent Learning

Another example of an outcome involving *value congruence* for many of the teachers since most recognised the importance of learners being given a degree of control over their work (IPSE, 1988a, page A1). This is evident in much primary practice in other areas of the curriculum but allowing children to work independently in science required a degree of confidence and understanding of the nature of science and its processes that some course participants apparently lacked at the beginning. This is one reason why prescriptive workcards are sometimes used for science work (Cronin-Jones, 1991) - they are less threatening for a teacher but offer limited independence to the learner (County of Avon, 1986, p4). The DES 20-day Course reinforced the importance of allowing children control over the direction of the exploratory and investigative work and there is evidence from feedback during course sessions, assignments and interviews that this was accepted and led to children being given more responsibility for their science work. Therefore, for some teachers this endorsed values they already held, for others it introduced them to a new educational value which they accepted. All the interviewees cited examples of children devising their own investigations (page 382). Again this is not to claim that in all the science work of these teachers there was evidence of independent learning but no examples of teachers challenging this value were found, although discussions about the difficulties of implementing it were common, especially during feedback sessions.

vi. Approaches to assessment

The view of assessment adopted by the tutors as an integral aspect of teaching was a view that had been articulated in both LEAs in terms of the general approach to assessment within the National Curriculum (Ollerenshaw et al., 1991, Ollerenshaw and Ritchie, 1993, Chapter 6).
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Therefore the message from the course offered a value congruence outcome for those who had met and accepted the approach before. For others there was evidence of a new awareness of the nature of assessment and the extent to which it was practiced on the course by tutors reinforced its practicality and demonstrated skills that were needed (see below). The issue of assessment was the focus of the second assignment which provided evidence of the teachers' understanding of assessment and evidence of a range of strategies being used to gain insights into children's learning and record that learning. The majority of teachers submitted this assignment and all that did provided case study evidence of formative assessment in action. In no accounts was assessment seen as purely a summative activity involving 'testing'. In most assignments from Key Stage 1 teachers (implementing SATs for the first time) an explicit critique of the Standard Assessment Tasks and their purpose was articulated.

vii. Additional resources

The course members (and students) were provided with resources linked to the sessions and dealing with the content covered and the way in which that content could be tackled with children. The response to these materials was positive and examples of their use with colleagues was cited by several teachers. Teachers were also provided with materials from the Assessment in Primary Science Project (Ollerenshaw et al., 1991) as they became available, including the data collection books. There was evidence that these were used with colleagues (see page 385), on inservice days and during collaborative activities in a less-confident teacher's classroom (during Cycle 5 of the courses). Other materials were provided in the form of hand-outs and the assignments provided evidence of these being used. These outcomes were of a provisionary nature.
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viii. Update on the National Curriculum

The timing of these cohorts meant that considerable changes to the National Curriculum in terms of assessment, recording and reporting and revisions to the Science Orders were occurring during the course (DES, 1991c). Course participants were kept informed of these changes and there is evidence from evaluation forms that this was appreciated by teachers, who in the role of science coordinators could go back with some confidence to explain the implication of changes to the rest of the staff of their school. The approach to ‘big ideas’ (see Ollerenshaw et al., 1991; Ollerenshaw and Ritchie, 1993, Chapter 7) developed during the Assessment in Primary Science Project was used throughout the course and this anticipated the proposed changes to the Science Orders. This made those changes less difficult for teachers to understand and more in line with the approach of the course. This updating aspect of the course provided an information outcome for all participants and was explicitly referred to by 70% on their evaluation forms.

vi. The role of the teacher

There is evidence that at the beginning of the course some teachers saw their role as one which involved them in giving children the answers to questions in science and this led to comments related to their lack of confidence such as 'I'm worried that I'll never be able to answer their questions about circuits' (see Volume 2, Case Study 2, page 52). The course introduced a different, but no less challenging, role for the teacher. This involved a range of different skills which were modelled by the tutors and the teachers were given opportunities to practice in controlled conditions (on day 3 of each cycle) before they applied them in the context of their own classrooms.

In considering this outcome which involved new awareness and knowledge and skills, it is appropriate to return to the ideas of Joyce and Showers (1980) discussed in Chapter 5,
They provided a framework which can be used for considering the impact of INSET upon teachers. The outcomes they identified are evident in the data discussed in Chapter 9. The teachers involved gained an awareness of new skills, which were presented to them by tutors and were based upon the constructivist theory of learning. These skills were 'modelled' by tutors. The teachers 'learnt the principles of those skills' and had the opportunity on day 3 of each cycle to practice the skills in 'simulated and controlled conditions'. They got 'feedback on performance' from other teachers and tutors before being asked to 'apply those skills' in the classroom and 'integrate them into their teaching repertoire'. In this way the structure of the course and the approach used can be seen to parallel the model Joyce and Showers proposed to enable impact of training back in the classroom. This may account for the apparent success of the course.

There were also significant parallels with Kolb's (1984) cycle of experiential learning, discussed briefly in Chapter 2 (Section 2.8). These parallels can be applied to the adults' learning in science and in the development of their professional skills. Opportunities were provided for concrete experience (during practical workshops on day 1 and 2 of each cycle and work with children on day 3), for reflective observation (reviewing scientific work during centre-based sessions and evaluation sessions during school-based days), abstract conceptualisation (further reading, discussion, and writing in both areas) and active experimentation (day 4 work in terms of science and follow-up activities in their own classrooms in terms of professional skills). Although Kolb's experiential model was not discussed in these terms with course members, the significance of preferred learning styles were explored. One course member (on Cohort 2) had particularly strong feelings about this since he preferred 'abstract conceptualisation' to 'concrete experience' and raised this on several occasions during workshop sessions.
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vii. Adoption of a constructivist approach

The extent to which the approach used on the course was adopted by teachers varied from one individual to another. For one or two it was adopted in the form presented and used in science and other areas of the curriculum (eg. Anne - Cohort 2, see Volume 2, page 233, line 557) for others it was used in parts or at times. For example, Kay (Cohort 2, see Volume 2, page 229, line 395) found it worked for her when she could focus on a small group. There does, however, seem to be a pattern in the take up which is interesting in the light of my own concerns. Orientation is a phase that was recognised as important by teachers when they talked about their approach but there is limited evidence of time being provided for this, particularly with older children, in case studies of their work. It was a phase that was not problematic in terms of the teachers' role, resourcing or classroom organisation but in terms of the amount of work to be covered in the context of the National Curriculum it seems some found it hard to justify the time for this and as during some course sessions it became integrated with elicitation. Elicitation was the phase of the cycle that was most commonly evident in teachers' work with children. This links, of course with the outcome above about valuing children's ideas. Teachers were offered strategies to facilitate elicitation, such as floorbooks, which they used, some enthusiastically. There is no indication that any found the use of these strategies particularly problematic and elicitation was a phase that could be organised with a whole class or small group. It therefore did not pose organisational problems. An added motivation for some teachers also appeared to be the potential floorbooks and posters of children's existing ideas offered for display purposes - for the children, their parents and other colleagues to see. Consequently elicitation was valued, practical to implement and was used by all teachers during the course, and at least by some, according to the evidence, after the course had finished. It is also worth noting that the course lasted nine months and therefore use during the course was not a matter of trying something once, but evidence was regularly provided throughout of the extent to which the teachers were eliciting children's ideas. Intervention was found to be more problematic by teachers. Again its
importance was recognised in discussion and the way they talked about their approaches to classroom work, but the evidence indicated less examples of effective intervention, based upon existing ideas that had been elicited. It had proved easy, in some respects, to find out what the children thought, but harder to do anything about it. Most teachers’ own case studies indicated that they were aware of the need to challenge children’s existing ideas and attempts were often made to do this but not always with success. This led to some evident frustration on the part of teachers. Intervention was, apparently, the phase of the constructivist cycle that teachers found most difficult to implement in the classroom. Review was again valued and evident in many examples of teachers’ work. Opportunities were increasingly made to encourage children in small group or whole-class contexts to talk about what they have achieved and learnt. Floorbooks were often used at this stage, to refer children back to their original ideas and to record changes to those ideas. This phase was recognised as particularly important by Key Stage 1 teachers in Cohort 2, where an LEA initiative had encouraged the use of a HighScope approach (Hohmann et al., 1979) which involves stages of Plan, Do, Review. They were already implementing regular ‘review’ sessions with their children. This reinforces the value of coordinated inservice provision where the values and approaches in different areas are congruent and teachers can relate one INSET activity to another and implement changes to their practice in an holistic way. The Key Stage 1 teachers’ experience was drawn upon to inform Key Stage 2 teachers in Cohort 2 who had not had this previous Inservice support. Application was rarely made explicit, at least in assignments and reports of classroom work, and was a phase that, perhaps again due to time constraints, was ‘squeezed out’ in terms of classroom work. That is not to say that children did not have opportunities to apply their ideas and skills in new situations, those opportunities may well have been occurring incidentally. However, the evidence collected would suggest this phase was not addressed in the way course tutors had anticipated. This again reflects my own concerns about the application phase with the teachers in terms of their own learning. The outcomes in terms of the take up of a constructivist approach were evident, but with the reservations discussed above. The outcomes were related to new awareness,
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motivation and new skills.

viii Increased confidence

This affective outcome is more difficult to make claims about since reflection during the enquiry about the nature of confidence related to teaching leads me to ask questions about exactly what it means. Discussions with a colleague about the evaluative data led to her suggesting that a lack of confidence in teaching science may well be better termed a 'lack of willingness to act'. There can be a number of reasons for this which are not necessarily directly to do with confidence. The course, I would claim, has improved teachers' willingness to act in terms of teaching science. Claims to improved confidence are also apparent in the participants' evaluation comments (see Chapter 9, Section 9.3), evidence from interviews (see page 386) and other informal evidence from advisory teachers and others who have talked to course participants or visited their classrooms, which address the issue of confidence in the sense that it has been used by other researchers (Cox and Taylor, 1989; Wragg et al., 1989a; see Chapter 4, Section 4:3). The indicator discussed in Chapter 9 (Section 9.3) resulting from the analysis of pre and post-course questionnaires also supports the other evidence I obtained. On its own such an indicator should be treated very cautiously and the 'feel-good' factor, related to how teachers' emotional state at the time they complete the form, is one which can have unpredictable but significant effect upon the way teachers fill in such questionnaires. For example, Cohort 1 had had a longer gap between their last course day and the previous one and the weather was much better on the last day for Cohort 2. However, in the light of other evidence discussed in Chapter 9, the course does seem to have resulted in primary teachers feeling more 'confident' about the teaching of science.

This discussion of the outcomes of the course and the use of a constructivist approach indicates, as the specific analysis of individual teacher's outcomes in Chapter 9, that the course led to outcomes at all three levels of Kinder and Harland's typology (1991, p163). The
only outcome not addressed in the discussion is the institutional one. Insufficient evidence was collected to allow claims to be made about this. Dissemination of course outcomes to colleagues, which was very relevant to the institutional outcome, was the focus of cycle five and although assignment three was a case study of work with colleagues these assignments have been analysed in less detail than the first two. However, dissemination to colleagues is an important issue in an evaluation of the course and will be returned to in Section 10.5. To return to Kinder and Harland's typology; their claim, discussed in Chapter 9 in the context of the interviewed teachers, that outcomes of first, second and third order in combination are likely to lead to a long-term impact upon practice is again supported by the evidence available and analysed. However, the relative importance of those different outcomes and the way they inter-relate cannot be illuminated from the evidence available.

It is necessary to note that although this section is concerned with impact upon practice and that that impact is intended to lead to improved quality of learning for the pupils the evidence collected does not allow me to make that claim, although the teachers involved have made such claims explicitly and implicitly in their assignments and reports of school-based work. My claims are restricted to the changes that have resulted in teachers' practice which have the potential to improve the quality of their pupils' learning.

In considering the outcomes in terms of changes to practice the reader should also be alert to the tendency for teachers (and students) to select from experiences and ideas offered those which suit their own particular perspectives and values as discussed by Calderhead (1987, p6). This may account for the differential take up of different aspects of a constructivist approach. A longer term and more indepth study of individual teachers would be necessary to allow claims to be made related to the significance of these factors. However, the references to outcomes discussed in terms of value congruence are illuminative in this area.

The changes to teachers' professional knowledge base implicit in these changes in practice
are another area where this enquiry cannot allow me to make claims that are anything other than extremely tentative. As discussed in Chapter 2, Section 2:10, the literature concerning teachers' professional knowledge is extensive and as Calderhead noted the way in which this knowledge is conceptualised varies considerably amongst researchers (1987, p15). However, there is a consensus view that teachers' professional knowledge results, at least in part, from their experience of working with children in a variety of contexts. The experience of participating in the course has added to that experience and therefore, it can be assumed, to the teachers' professional knowledge. However, the nature of the approach and the emphasis placed upon reflection upon that experience will, if Schon's view of professional knowledge (1983) is accepted, have had a greater impact upon the teachers' professional knowledge than that which may have resulted from the experience alone. To draw again upon some lines from T.S.Eliot,

We had the experience, but missed the meaning,
And approach to the meaning restores the experience
In a different form ...

from The Dry Savages, the Four Quartets, 1944

The extent to which a constructivist perspective can be used to explain teachers' development of professional knowledge will be revisited after the next section.

This next section will focus upon one of the first order outcomes in Kinder and Harland's typology, knowledge and skills. This has been touched on above related to professional knowledge and skills. I will discuss the outcomes of the approach and the course in terms of the scientific knowledge and understanding that students and teachers gained during my enquiry.
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10.4 Outcomes in terms of scientific knowledge and understanding

Improving the scientific knowledge and understanding of the students and teachers with whom I worked was a key intention of my use of a constructivist approach, based upon the assumption that a subject knowledge base is necessary to teach effectively (for example as stated by HMI (DES, 1989b)). John (1992) reviews the literature in this area. McDiarmid et al., (1988) cite evidence of teachers’ subject knowledge being critical for asking children questions, selecting appropriate tasks, assessing pupils’ understanding and making curricular decisions. Bennett and Carre (1991) found “teachers need such knowledge adequately to transform programmes of study and attainment targets into worthwhile and appropriate tasks, they need it to frame accurate and high quality explanations, and they need it to diagnose accurately children’s understandings and misconceptions (sic)”. The use of a constructivist approach, as discussed in Chapter 2, has been advocated as an appropriate strategy for developing pupil’s knowledge and understanding of science for some years. However, although initial teacher educators and inservice providers have articulated the potential value of the approach with adult learners there is little evidence in the literature of this approach in action or of the effectiveness of the approach for adult learners. This is a contribution that I hope this enquiry will make. The evidence contained in the case studies and discussed in Chapters 8 and 9 provides the basis for the general points I intend to make in this section. The analysis of each case study covering the DES courses included a section Evidence of restructuring ideas (see Volume 2, pages 104, 123, 145, 164, 217). These sections included limited quantitative data of changes to teachers’ understanding (eg. page 123) and analyses of concept maps constructed at different stages (eg. page 158). However the key data to support the claim of improved scientific knowledge and understanding is that resulting from interviews and this was analysed and discussed on pages 374-378. All of these claims are made tentatively although I hope it will be clear that some are more speculative than others. In particular the section about ‘restructuring’ ventures into some complex issues related to cognitive psychology which are beyond the terms of this practitioner-centred
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enquiry. My intention is to discuss the outcomes for adult learners in this area, in terms their understanding of their own learning of science, of their understanding of the nature of scientific knowledge and of their knowledge and understanding of the concepts that were introduced on the course, in order to look at the strengths and weaknesses of the approach adopted and my use of it.

I. Awareness of gaps in their own scientific knowledge and understanding

There is evidence that a common outcome for students and teachers from the teaching sessions was an increased awareness of gaps in their own scientific knowledge and understanding (see for example, Frances' comments on electricity, page 380). The work of the Primary School Teachers and Science Project (PSTS) provided earlier evidence that teachers were often unaware of the science they did not know, or of the alternative ideas they held in areas of science about which they were confident of their knowledge base. Kruger et al. (1990e) cited this evidence when questioning the findings of the Leverhulme Primary Project (Wragg et al., 1989a) related to teachers' self-perception of their knowledge base. This criticism stands in terms of the data collected during this enquiry. However, my claim that an increased awareness of scientific knowledge is based upon more specific evidence from teachers during sessions. In almost all areas of content the course revealed to teachers the extent to which their existing knowledge base was incomplete or unacceptable in terms of conventional scientific understanding. This was particularly apparent in some of the responses of Cohort 1 to the areas of energy and genetics. It was only during the course that some realised how much they did not know or understand (see Appendix 15). Comments on evaluation forms support this claim. For example, Andrea (Cohort 1) commenting on Materials said, 'The first time reality (sic) was realised in that we found we knew much less than we thought'. She went on to comment about Electricity, "It was appalling how quickly I found I reached the limits of my own knowledge and understanding". This outcome can be
categorised using Kinder and Harland’s typology as *new awareness*.

Self-knowledge of this kind is important for the individuals concerned in terms of their own learning and in terms of their work with colleagues. Kinder and Harland stated, in the light of their evidence:

> Limitations in the capacities for self-knowledge and self-awareness are seen as major obstacles to an accurate diagnosis, hence fulfilment, of individual professional needs and then stimulating an interest in satisfying them in particular curriculum areas (i.e. motivational outcomes). Perhaps many teachers would benefit from inservice provision which focused upon imparting the general skills and techniques in reflexivity and the formulation of valid self-knowledge.

1991, p148

The constructivist approach had increased teachers self-knowledge and hence motivation to improve their subject knowledge. Another factor related to this is discussed in relation to teachers’ knowledge of the nature of their own learning which goes further than Kinder and Harland propose.

II. **Motivation to Increase knowledge base**

*Motivation* is a second order outcome in the typology. The new awareness students and teachers gained concerning their knowledge base led to a motivation to improve the situation. This was evident in the commitment shown in the case study data of teachers to their own learning. The case studies provide a picture of students and teachers enthusiastically attempting to improve their scientific knowledge base, even though they generally recognised how difficult this was (as the evaluation comments at the end of day 2 during Case Studies 4 and 5 indicates). Another encouraging indicator of this motivation came from comments made about activities carried out after sessions (eg Case Study 4, CS4:143), about requests made to others and use of other materials after sessions (eg Case Study 1, CS1:...
610) and in the comments made during interviews about referring to course materials (CS10: 528). Informal comments during course sessions about discussions with spouses and offspring about the ideas they were meeting were also evidence of this increased motivation. This supports Kruger et al.'s evidence (eg. 1990c, p141). In the context of the National Curriculum for Science primary teachers recognise the need to have a firmer scientific knowledge base and the DES 20-day Course, in raising their awareness of their existing knowledge base, contributed to their motivation to do something about it.

III. Insights into the nature of their own learning

The view of learning underpinning the approach was made explicit throughout the sessions and course. Students and teachers were encouraged to reflect upon and think about the nature of their own learning and how it parallels that of the children with whom they work. This use of metacognition led to an increased awareness of their own learning. For example, James (Cohort 2) said early on in the course when referring to his own learning "(I) certainly learnt a good deal about the processes of learning on this day" (CS4: 331). Margaret (Cohort 2) talked about "seeing how far my knowledge has been built upon/changed/reinforced" (CS4: 300). This outcome would seem to be an important one where developing subject knowledge and understanding is concerned. It does not fit into a category proposed by Kinder and Harland (1991) and is the first outcome identified which suggests a gap in their typology. A new category metacognition referring to 'knowing how you know things and the processes by which you think' (Fisher, 1990, p120) is needed. In considering what 'order' outcome it should be it would seem to be equivalent to knowledge and skills and in some ways inextricably linked to that outcome and therefore a first order one. Although inextricably linked, it does warrant a separate category since, as Kinder and Harland found, improvements in knowledge and skills can occur without teachers understanding how those improvements resulted. My claim is that understanding the nature of improvements in their own knowledge can lead to these having greater impact upon their practice.
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iv. Techniques for finding out more

This outcome was not as evident as I had hoped and the range of distance-learning materials which are now available, but were not then, limited the options available to teachers. The use of a ‘book box’ of suitable reference material, including computer software, was available during the course and some teachers purchased their own copies of some of these and made use of what was available. The course handbooks were also intended to provide reference material and there is evidence, referred to above, that suggest these were valued and used. However, a more common strategy for find out more seems to have been to ask someone, usually a spouse, for information. This outcome which is of a provisionary and skills type was identified as one needing further attention on later cohorts. This was implemented in terms of the use of distance-learning materials from the NCC (NCC, 1992 a and b) covering forces and electricity.

v. Recognition of the nature of scientific knowledge

The enquiry provided evidence of students and teachers gaining a new awareness of the nature of scientific knowledge. There was a tendency early on in the course for participants to ask for ‘right answers’ (CS5: 340). However, the emphasis in the case study analyses concerning the view of science students/teachers took from sessions and the discussions about this in Chapters 8 and 9 indicate that for many, if not all course participants, their understanding of scientific knowledge as tentative, dynamic, socially constructed and usually resulting from the use of scientific processes did develop as a result of the teaching approach. However awareness of this is not enough and a more significant aspect of this was the way in which their own learning in science was organised in a way that reinforced this view of science and this led to their work with children being implemented in a similar way. This is not to claim that as a result of the sessions/course that they could articulate an account of the
philosophy of science in Popperian or Kuhnian terms, but there is evidence that science was not seen as a body of fixed factual information that children should be 'told about'.

VI. Awareness of the difference between the 'scientific' ideas of scientists, teachers and children

Another outcome involving new awareness relates to students' and teachers' insights into their own ideas and those of children. The emphasis placed on eliciting their ideas during teaching sessions and using these as the basis of investigative work and then for comparison with accepted scientific ideas, for example on day 2 of each cycle, was intended to help them appreciate that explanations for phenomena vary from one individual to the next, although there are often common features, and that 'accepted' scientific ideas are another set of ideas, usually with more explanatory power, but also subject to change. The school-based days and work in their own classes highlighted the nature of children's ideas, which sometimes had features in common with their own but were often very different. The extent to which the significance of this was appreciated by individuals is less easy to evaluate and the discussion about the relationship between adult and children's ideas in Chapter 9 (in the context of Concern 14) indicated my on-going work in this area.

The extent to which the teachers' ideas can be called 'teachers' science' and the children's ideas, 'children's science' as they were by Gilbert, Osborne and Frencham (1982) is debatable in terms of the evidence available. There is evidence that teachers explanations for phenomena are not always coherent and consistent, particularly when attempting to explain phenomena that are new to them or they had not thought about before. At times unthought through 'first ideas' are apparent which are modified and sometimes rejected during questioning or discussion. My own evidence is more in line with Solomon's views of
alternative ideas as "dynamic, complex, multifaceted, situational and context dependent" (1992, p27), although there is clearly evidence of adults' common alternative ideas supporting the claims of Kruger et al. (1988-91), and children's common alternative ideas similar to those identified by others (eg SPACE, 1990-92). Therefore, whilst I continue to hold the view that teachers' and children's existing ideas are significant in terms of future learning, I am not convinced that such ideas are sufficiently well organised by individuals to warrant the label 'science' in the way Gilbert et al. use it. Although I can be regarded as a pluralist in that I do not consider scientific theories to be 'right' and recognise that alternatives may be equally useful in terms of their explanatory power I do not accept that this pluralist view should be extended to see every alternative explanation as 'science'. There is also a question in my mind about whether the term 'alternative framework' is the most appropriate as I will discuss in the next section. I do however, continue to find 'misconception' an inappropriate term for alternative ideas since there is evidence that these ideas do 'work' for individuals in allowing them to explain phenomena and should not be seen as 'wrong' concepts.

An intention for future work will be to encourage teachers to reflect upon 'scientists' science', 'teachers' ideas about science' and 'children's ideas about science'. This is vital in terms of teachers making decisions about the nature of their interventions. Such decisions require them to know what the children think, know what scientific concepts that they hope to develop in the children and know how their own current understanding may mediate in that process. As noted in the earlier section, intervention is the stage teachers appeared to find most difficult and there is a relationship between the decisions they need to take and the knowledge base that informs those decisions.

vii. Improved knowledge and understanding of scientific concepts

This is the key outcome in this section. Is there evidence that students and teachers had a better scientific knowledge and understanding as a result of the teaching sessions? My claim
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is that evidence (see page 428) from case studies (Volume 2, 104, 123, 145, 164, 217) and
discussed and referenced in Chapters 8 and 9) is indicative of some improvements and that
the interviews provide confirmatory evidence (see pages 374-379) that those improvements
were still evident several months later. There is similar evidence of improvements in the
scientific knowledge and understanding of ITE students who were interviewed five months
after taught sessions (see Volume 2, pages 35-36). However, the nature of those changes
and how they resulted is not straightforward and the discussion that follows is offered
tentatively, more with the intention of raising further questions that to offer definitive answers.

Throughout this enquiry I have used the term 'restructuring' to describe changes in an
individual's understanding. This has disguised a complex process which may vary
considerably from one individual to another and from one conceptual area to another. In
discussing these issues I intend to begin by considering the nature of the existing ideas
evident during elicitation phases of sessions. It is not surprising and hardly profound to claim
that adults, when asked to explain phenomena, offer explanations that do not match
accepted scientific ideas. But what is the nature of those alternative ideas? In Chapter 2 a
concept was defined as 'an element of knowledge or an idea which an individual can know'.
Therefore it seems unproblematic to recognise that some ideas, or concepts held, are
'alternative concepts' when they do not match with accepted scientific thinking. Examples of
these are referred to in all the case study analyses, such as for example 'a bulb containing a
vacuum' (CS1: 557) or 'gravity being a push from above' (CS7: 304). However, the term
'framework' used in the literature (Driver, 1983, p3) and in my analyses, suggests these
concepts are organised in some way by the individual to enable them to be used for
explaining phenomena. A key question is whether the adults whose ideas have been elicited
organised their 'alternative concepts' into an 'alternative framework' before elicitation or
during elicitation. The evidence from case studies illustrates that 'alternative concepts' are
offered during almost every group discussion. However, rarely are examples evident of these
being articulated and defended in a coherent and consistent way. During small group
discussion, as these alternative concepts are exposed and shared, they begin to be organised into frameworks with explanatory power that can be used to explain observations (eg Case Study 2: 216-330). Therefore, it seems likely that the emphasis on elicitation in a constructivist approach can lead to learners constructing more coherent alternative frameworks from the 'alternative concepts' that they held. This suggestion seems disturbing on first impression. Is elicitation leading to alternative frameworks being constructed and in that way leading to learners holding alternative frameworks which may be more resistant to change than 'alternative concepts'? The response to this from a constructivist perspective is that in order to construct frameworks which are acceptable scientifically it may help learners to consider the way in which existing concepts can be organised to explain phenomena, which can then be challenged through tutor or peer intervention. In other words the step of structuring existing ideas (even when they do not match accepted scientific concepts) is a step in the cognitive process which leads to restructuring of frameworks to more closely match accepted scientific frameworks. It should be recognised that some explanations sought during elicitation have indicated adult learners holding alternative frameworks which involve the coherent organisation of a number of acceptable and alternative ideas (see for example CS7: 290). It is also evident that on other occasions the explanations offered are no more than guesses held tentatively with little conviction (Case Study 1 analysis, Volume 2, page 32). Adults use of scientific language can also be used to disguise their inability to offer a coherent explanation. On some occasions explanations involved the selection of 'scientific' words thought to be relevant but used without understanding (see Case Study 6, Volume 2, page 145). An important implication of this for course providers is to ensure 'alternative frameworks', once they have been constructed by learners are challenged (Concern 11). The issue of alternative frameworks or concepts also raises another concern evident from my consideration of the evidence collected as I discussed in Chapter 9. Does the emphasis given to children's common alternative ideas lead to some adults later using those ideas to construct their own understanding of phenomena? There is a risk that ideas introduced as common alternative ideas are retained in preference to the accepted scientific explanations offered by
tutors. For example the alternative framework concerning 'clashing flow' (a framework since it is a way of organising several concepts, some acceptable and some alternative - 'electricity flows', 'materials conduct electricity', 'the flow of electricity makes a bulb light', 'electricity can travel from both sides/ends of a battery', 'electricity can flow both ways in a circuit', 'electricity flows both ways at the same time') is one which may not be held by adult learners, but as in the case of Kay in her interview (Case Study 10), may be remembered and used to explain flow in a circuit. As I noted in Chapter 9, the way in which children's common alternative ideas are introduced and addressed is important. Related to this is the extent to which individuals retain alternative ideas introduced by other students or course participants. The novelty value of these ideas can mean that they are remembered and drawn upon when 'new frameworks' are constructed. This issue, in the context of recognising and valuing the social context of learning, is one that is relevant to work with children as well as adults.

Another set of questions relates to the nature of the restructuring that occurred for adult learners. The evidence suggests that some concepts such as 'the particulate nature of matter used to explain change of state' were easier to retain than others such as 'the forces acting on a moving body'. Is this because the restructuring involved is of a different order? If a concept is not retained does that mean restructuring did not occur?

Vosniadou and Brewer (1987) discussed 'weak' and 'radical' restructuring. The first involves gradual change where the development of knowledge for an individual is continuous and cumulative. This form of restructuring they parallel with Kuhn's 'normal science'. The radical form of restructuring they claim is drastic, dramatic and non-continuous. It is paralleled with Kuhn's 'revolutionary science'. Carey (1989), as we saw in Chapter 2, holds a similar view based on 'weak' and 'strong' restructuring. From her evidence weak restructuring was involved when similar concepts are involved in existing schema and those of scientists. Restructuring is then concerned with changes in the relations between these concepts. Strong restructuring involves conceptual change. Carey cited 'impetus' notions that moving
bodies have a force acting in the direction of movement as an example where 'strong' restructuring is required. Watts (1983a) described this alternative idea as 'motive force'. The existing ideas of the learner, if they hold an 'impetus notion', are similar to Aristolian views of motion. The change required is to a Newtonian view. This indicates the conceptual shift required and evidence from this enquiry would support this view. The teaching was not successful in leading to restructuring for all teachers in this particular conceptual area. The concepts related to the particulate nature of matter, although abstract may not, it can be claimed, require 'strong' restructuring. Even though the students and teachers claimed not to have met these ideas before, the concepts that 'things can made up of smaller parts', 'that there is microscopic dimension to the world', 'that heating causes changes' are held and in some ways it is changes to the relations between these accepted concepts that is required for the restructuring involved in understanding kinetic theory and the particulate nature of matter.

Therefore the suggestions that there are different orders of restructuring is a useful and significant one for teachers. The evidence I have is supportive of these claims. However, the parallels with 'normal science' and 'revolutionary science' need treating with care. As I discussed earlier, I have reservations about seeing children and adults alternative frameworks as 'science' and, therefore, seeing restructuring as parallel to changes in scientists' understanding of the world is problematic. The parallel also risks the implication that learners need to go through some sort of specified developmental stages as scientists might in moving from one paradigm to another. This is not helpful to the teacher. However, the parallel reminds teachers what a radical change is needed for learners to restructure ideas in particular conceptual areas, and this is useful.

Another aspect of restructuring concerns the affective factors. Do learners want or need to restructre their existing ideas? It might be suggested that the particulate nature of matter offers new explanatory power that the learners did not have and their reactions to meeting these ideas in Case Studies 4 and 5 indicate they found the ideas extremely valuable and
interesting. They offered new opportunities for explaining phenomena that hitherto had been accepted but not satisfactorily explained. Therefore Osborne and Freyberg's (1985) criteria for conceptual change are met in that the new ideas are:

i. intelligible;
ii. plausible;
iii. fruitful, in that they are preferable to the old point of view.

By contrast although Newtonian views of motion are intelligible to adults they are possibly less plausible and fruitful. Adults' intuitive view is that 'there must be something making a body move' and the idea that it is a 'force' is plausible and allows them to explain the phenomenon. Therefore, they have less motivation to change their existing ideas.

This area of cognitive psychology is one to which this research enquiry cannot make a significant contribution. However, the questions that I have raised are important ones to teachers and inservice providers and need more detailed treatment. The nature of alternative ideas is now extensively documented and being communicated to teachers in a variety of forms. The next step is for further research into the nature of the conceptual change required to move from 'alternative' to 'accepted' scientific ideas. There are already some examples of this (eg. Carey, 1989; Clough, Driver, and Wood-Robinson, 1987; Strike and Posner, 1982; West and Pines, 1985) but more is needed. The 'alternative frameworks' research may, in some ways, have done teachers a disservice by suggesting that all alternative ideas require a similar kind of restructuring. Carey claims most treatments imply a 'weak' restructuring is needed whereas in fact conceptual change is required and the form of restructuring is more appropriately seen as strong (1989, p114). Analogies, as used by the PSTS team (Kruger et al., 1991a and b) in their INSET materials (discussed in Chapter 9), may be one way of dealing with strong restructuring, in that they offer a bridge from existing concepts to new ones.

Another interesting consideration, again beyond the scope of this enquiry is to consider the
issue of restructuring in terms of teachers' professional knowledge and whether weak or strong restructuring was required. As far as the above discussion is concerned, it would seem most likely that for the experienced teachers on the DES 20-day courses the restructuring was 'weak' in that they already held concepts of a similar nature about pedagogy and curriculum which required changed relations rather than conceptual change. For students in initial teacher education this may not be the case. The nature of teachers' and students' existing ideas about their professional practice was not explored systematically during this enquiry and another area that is not covered by the literature reviewed is the nature of these ideas and the impact of these upon changes in practice and professional knowledge - perhaps this should be the next focus for the 'alternative frameworks' researchers.

In conclusion, to reiterate my earlier claim, which is the most significant in terms of the enquiry and its intentions, there is evidence that the students and teachers with whom I worked did gain an improved knowledge and understanding of some scientific concepts. This outcome was most probably as a result of the experiences they had during sessions when I, or my colleagues, used a constructivist approach.

10.5 The nature of my own learning and insights gained

The insights I have gained as a result of this enquiry have, I hope, been evident throughout Chapters 8, 9 and 10. At this stage I intend to summarise those insights which relate to adult learning. They are evidence of developments in my own professional knowledge and the result of my experiences and reflection upon those experiences as well as being informed by others. They developed, I claim, as a result of me clarifying my existing understanding through a process of structuring what I already thought. These existing frameworks were then tested against my experience and the evidence available and the views of others were used to 'challenge' my existing ideas and led to those ideas being restructured. The different levels of analysis involved in the enquiry (Chapter 7) can be considered as a series of challenges to
my current understanding.

The insights can be grouped as: the nature of a constructivist approach; my role as a teacher/tutor; the nature of adult learning; the nature of my own learning; the nature of children's learning; the nature of science; the nature of inservice education.

1. The constructivist approach

I have come to recognise that a constructivist approach to teaching adults needs to be conceptualised in a more flexible way than the 'model' used in Chapter 2, Section 2.9 suggests. The relationship between orientation and elicitation for adult learners is different to when young learners are involved. Orientation does not need to be seen as a separate phase but opportunities for orientation can be provided during the elicitation phase. With adult learners orientation activities can also be set up prior to a teaching session. Elicitation as a phase is not simply a time for teachers to elicit learners existing ideas. Just as importantly it is a time for learners to become aware of the nature of their own existing ideas and organise them in a coherent manner. From a tutor's point of view it is necessary to recognise that elicitation of learners' ideas goes on throughout a teaching session and an investigation involving the learner in restructuring one set of ideas may involve a range of existing ideas in a related area being structured and made available for scrutiny. Similarly a learner applying restructured ideas and talking about her/his work may provide a tutor with evidence of existing ideas in other areas of scientific knowledge. Intervention/restructuring is also inextricably linked with elicitation. On some occasions the elicitation phase led to investigative work where the challenge to existing ideas came from evidence gathered and the tutor's intervention was to facilitate this investigative work and help the learners interpret the outcomes. On other occasions the elicitation activity led directly into exposition by the tutor based upon elicited ideas. Again a model which conceptualises the stages as discrete and sequential does not provide an adequate description of a complex process.
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I have also recognised the extent to which a constructivist approach can involve a range of teaching techniques and, as noted above, exposition of accepted scientific ideas is a vital part of the approach.

The nature of practical activities has also become clearer. The important distinction between illustrative and investigative activity is one which now informs my work.

II. The nature of my role as a teacher/tutor

I have gained numerous insights into my practice in terms of implementing a constructivist approach. These are detailed in the earlier chapters. Examples include the use of a range different elicitation strategies and an awareness of their advantages and disadvantages. I will not rehearse all of these but briefly cite some examples, and the nature of my insights.

I have explored my use of concept mapping techniques and recognised their potential as a means of probing a learners' understanding. Drawing upon my own experience and that of others (Brodie, 1992; Harlen et al., 1990; Novak and Gowin, 1984; White and Gunstone, 1992). I have explored their potential for assessing development of understanding by using them before and after teaching sessions and now intend to investigate different means of interpreting the maps. Discussions with others have also led me to identify different approaches to and types of concept maps. For example the hierarchical approach (Brodie, 1992; White and Gunstone, 1992, p21); the free form; the centre-outwards model; the everything-to-everything approach; appropriate linking of more than two words. The importance of starting again and redesigning maps has become clear - adults need to be encouraged to see them as 'dynamic' and evolutionary. There are also difficulties concerning primary teachers’ familiarity with ‘topic web’ and limiting themselves to concept maps of a similar structure. Primary teachers also have a tendency to place too much attention on the
appearance of the map rather than its content. Concept maps have potential for self-assessment and in areas other than science. For example, I used them myself when planning Chapters 2 and 6 when I was trying to clarify my own understanding of the topics involved.

The use of ‘think books’ as an adult version of floorbooks was successful and the use of floorbooks with children was unreservedly successful. The only concern I have related to the teachers’ use of these is that they have not been used to their full potential in recording the development of investigative work. They have tended to be used solely for elicitation at the beginning, and perhaps the end of a session.

Elicitation based upon cards illustrating instances or episodes have also been useful and allowed elicitation to be focused on particular concepts. These cards were useful during teaching sessions and interviews and have potential for follow-up work and directed tasks for students.

The different tutor roles during sessions have been clarified through the enquiry. In particular, I have found the analytical frameworks of Harland (1990) and Joyce and Showers (1980) useful in considering my role during teaching sessions. Harland’s framework of different modes: provisionary (I will give you); hortative (I will tell you); role modelling (I will show you) and zetetic (I will ask you) can be identified in each case study and as he found, a combination of these roles is desirable in providing effective inservice that impacts upon teachers’ practice. Joyce and Shower’s framework was discussed in 10.3 above, and contributed to my understanding of the purposes of different tutor roles.

Exploratory and investigative activities make different demands upon a tutor. The difficulty of encouraging adults to raise scientific questions is a specific area where it became evident that a new approach was necessary. The extent to which adults found the approach threatening has led me to recognise the importance of a sensitive and relaxed approach to elicitation and
the review stages of the sessions. Paired work was found less threatening and it is evident that extensive use can be made of this during sessions.

The way in which I approach exposition of accepted scientific ideas has been changed and considerably informed by my observations of others. The need to pace this according to adults’ responses and the use of their responses as a hook for the next idea - using dialogue rather than monologue has been illuminated during my enquiry and I am now more confident and ‘comfortable’ about this. There was always a tension for me related to my concern about not wishing to communicate knowledge in a ‘transmissionist’ mode, since it is not inline with my educational values nor my epistemological view. However, I now understand the need to introduce accepted scientific ideas alongside those of the learners and have gained insights into how this can be done. Linked to this has been an increased understanding of the place of models, metaphors and analogies in adult learning.

The importance of my role in helping adults relate their own ideas to those of children and scientists was discussed in Chapter 9, but is evidence of another significant insight into the nature of my role.

III. The nature of adult learning

The earlier sections are evidence of my improved understanding of the nature of adult learning. The enquiry has provided me with evidence of the kinds of alternative ideas adults have in the areas of science covered. I have also become more aware of the difficulties of supporting them in restructuring those ideas. My own existing idea was naive in terms of thinking this restructuring was relatively straightforward to facilitate. I have an improved understanding of how difficult it is to achieve this outcome. Indeed, this enquiry has caused me to question a number of firmly held beliefs about the nature of learning, for example that all elicted ideas should be regarded as ‘alternative frameworks’.
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I have an increased awareness of the significance of affective factors in adult learning and my reflections upon the responses of the two DES 20-day cohorts has enhanced this understanding. Adult learning cannot simply be viewed as a technical exercise in using the 'right' techniques and you will gain the desired outcome - learning is much more complex and affected by a range of factors, such as the learners desire to learn and the extent to which that learning is considered 'threatening' and perceived as difficult. Like Smith and Peacock (1992), I have come to recognise the "danger of disabling teachers by exposing contradictions and their misconceptions (sic)" (p66). Inservice providers must ensure that work with teachers does not expose gaps in their knowledge and reinforce a view that science is hard. It is all too easy to expose teachers' alternative ideas and make them feel inadequate. It is vital to ensure that the elicitation of ideas is facilitated within a positive, supportive environment. As Smith and Peacock advice, tutors "require empathy and sensitivity to probe contradictions and encourage growing understanding". Elicitation must lead to intervention otherwise it will leave teachers resentful and confused. The focus upon teachers' alternative ideas through research and inservice activities must not lead to a 'deficit' model of teachers.

iv. The nature of my own learning

I have gained a better understanding of the significance of metacognition as an important element in adult learning. This is as true for me as for the adults I have taught. Thinking about and trying to understand one's own learning is a challenging but valuable activity. I will return to this overarching insight in Chapters 11 and 12.

v. The nature of children's learning

Analysing the work on the school-based days, listening to teachers discuss their own work in school and reading in order to prepare for sessions and this thesis has considerably increased
my understanding of children's learning in science although it was not the main focus of this enquiry. I offer as evidence of this the writing I have done at the same time as this thesis (Ollerenshaw and Ritchie, 1993) and examples of case study analysis (e.g. Case Study 8, pp 176-189).

vi. The nature of science

Another area in which I consider this enquiry has helped me develop improved understanding that affects my practice is in terms of the nature of science. For example, I consider Case Studies 4 and 5 provide evidence of my naive view of the nature of generalisation and an implicit misunderstanding of inductivism. In part this was related to my view at that time that the differences between teachers' science and scientists' science were less significant than I now consider them. I thought that the parallels between the way teachers' worked on scientific activities and the way scientists approached experiments were straightforward, in that both were attempting to develop generalisations to explain phenomena. I now recognise that teachers' activity cannot and should not be seen to be leading to generalisations of the order suggested by the parallel.

vii The nature of inservice education

The earlier sections of this chapter during which I discussed the outcomes of the approach I was using on the DES 20-day courses indicates an increase in my understanding of the way INSET outcomes can be conceptualised. The following section will provide further examples of how my understanding of inservice education has developed during the enquiry as I discuss the way in which I consider the course addressed issues raised by the national evaluations. However, there are key points to raise here. There is little doubt from my experience that implementing a constructivist approach is hard for tutors and teachers. It is also evident that such an approach, and indeed it might be claimed any trying to address such
fundamental aims as improving teachers' subject base, take considerable time to be effective. Where there have been thorough investigations of this in the area of science (Smith and Neale, 1987) the findings have been similar.

This section has outlined the areas in which I consider the enquiry has led to improved understanding on my part about my practice as a tutor in initial teacher education and on inservice education. The next section will focus upon the DES 20-day course and a discussion concerning the strengths and weaknesses of that course.

10.6 Response to issues concerning the DES 20-day courses raised in the national evaluations

This section should be read in the context of the national evaluations which offered further evidence that the DES 20-day courses were successful in achieving outcomes in the two main areas discussed above. The BCHE course was included in the HMI evaluation and the response to those visits has been documented in Chapter 9 (Section 9.4). Therefore the response to concerns that arose from those evaluations should not detract from their overall findings which were positive.

The evaluation report produced by HMI (DES, 1992b, see Chapter 5, Section 5:6) raised a number of issues and concerns about the designated courses. Although the HMI report was published after the cohorts involved in the enquiry had finished their courses it is appropriate to consider the extent to which the concerns were addressed by the BCHE model.

HMI expressed the view that only a few science courses had 'the flexibility to respond to individual needs' (para. 48). This was reiterated by Harland and Kinder (1992, p58). The importance of differentiation was integral to the constructivist approach. Tutors did not plan sessions on the basis that all students would be doing the same thing and starting from the
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same base-line. The emphasis upon eliciting existing ideas and assessing existing scientific skills and using these as the basis of the next step was a strategy that enabled learners differential needs to be addressed. Similarly, the emphasis in encouraging learners to take responsibility for their own learning is evident in the case studies and provided another means of ensuring the course addressed their individual needs. The approach to assessment and self-assessment through strategies such as the use of concept mapping provides further evidence of differentiation being seen as important. That is not to suggest that the approach was universally successful in its aims. The extent to which our intentions were met, as the case studies show varied. However, it was an issue we were very aware of and explicitly tackled. There are areas, such as self-assessment, that need more thought. The approach during Case Study 5 (see analysis in Case Study Volume, p125) provided a potential area for further development.

HMI claimed the most effective courses, in terms of classroom impact, were those that set the knowledge to be learned explicitly within the context of the National Curriculum and included sessions on teaching methods (p3). This raises several points. The BCHE model undoubtedly contextualised the work within the National Curriculum, and went further by developing the 'big ideas' approach of helping teachers prepare for revisions that were not even suggested at the beginning of the course. However, the HMI comment indicates a perception of subject content and teaching methods as distinct and requiring separate attention. The BCHE course adopted a much more integrated and holistic approach during which, as I have discussed, the teaching methods modelled by tutors on the course, and tried out by teachers during school-based days, brought the development of subject knowledge of the teachers and their professional development together in a way not articulated by HMI in this report.

When reporting on teaching methods (p8) HMI criticise the use of some workshop approaches where the scientific concepts were only addressed when the opportunity arose.
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The BCHE model, although encouraging learners to take control of their own learning, offered a carefully planned structure for this which ensured scientific concepts were addressed in a systematic and planned way. The use of 'big ideas' as a planning framework was productive in this respect and provided a model of planning which teachers could adopt in their own classrooms. HMI reported some courses avoiding content areas perceived as difficult for teachers (p2). The BCHE course was planned to address challenging areas, such as forces and energy but the starting topic of materials was, as noted earlier, chosen as a less threatening first cycle. Interestingly, HMI cite less than half the courses covering biological areas. The cycle on living things, not covered by data collection, indicated our recognition that teachers' subject knowledge was in need of support in this area as well as the more obvious physical science areas. However, the BCHE course made no attempt to cover all the National Curriculum content and this is in line with another point made by HMI that the most successful courses set limited targets.

The calibre of tutors was, according to Harland and Kinder (p4) a key factor in the successful impact of courses. They cite subject knowledge, familiarity with primary practice and skill and experience in teaching extended courses as necessary for effective tutoring on the course. I consider the main tutors involved in the BCHE model met these criteria. The advisory teacher experience that several of us have had was particularly valuable.

HMI questioned the value of written assignments (p8). My own evidence would challenge this. HMI found that teachers do not like writing assignments. This may be true, but it does not mean that the process is not one which enhances teachers' learning by encouraging them to clarify what they have learnt and discuss its implications to their practice. My claim is that although teachers found assignments challenging they also found producing them a valuable activity. Some of them used their accounts to share ideas with colleagues and as the basis for discussions about the nature of children's learning. Assignments are also a means of encouraging teachers to take responsibility for their learning by focusing upon a topic and
developing their understanding. The way in which the BCHE assignments were related to key themes: the links between process and content; assessment; dissemination, meant that the case study evidence, which was a required element of the assignment, encouraged them to explore all three areas in their own school context. The BCHE course was accredited and successful completion of assignments led to a Certificate of Advanced Professional Studies in Education (CAPSE). However, I consider the teachers gained benefits from writing assignments which were more important than simply obtaining a certificate.

Both HMI (p7) and Kinder and Harland (p43) raise the issue of the use of school-based days. The experience of the BCHE course and the parallel one at Bristol Polytechnic is that these days, properly planned and organised, are a valuable element of the approach we adopted. My colleague has made a strong case for these elsewhere (Ollerenshaw, 1993) and the arguments do not need to be repeated here. It is evident from HMI and the other evaluators' reports that school-based days have been unsuccessfully used elsewhere. However, to use limited evidence from small-scale evaluations to revise the guidelines and limit the number of school-based days to three is considered inappropriate by our course team.

The key concern from both evaluations was related to dissemination. HMI found it was only successful in a minority of schools (p4); a finding supported by Harland and Kinder's evidence (p5). Although this concern extends beyond the scope of my enquiry, it is appropriate to make some observations about this vital institutional outcome. The status of the DES designated courses was high according to the national evaluations and we attempted to reinforce this by involving headteachers and sharing with them our aims and intentions. The course members' headteachers on Cohort 1 attended the precourse meeting and an afternoon during cycle 3. Cohort 2 headteachers were invited to a cycle 3 day and received letters about the course intentions. The focus of early cycles was concerned with course members' own teaching and classroom work. However, the focus for cycles 4 and 5 shifted to work with colleagues. Cycle 5 involved work with less-confident colleagues on day 3 and the
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topic for assignment three was this aspect of the work. Tutor input also addressed dissemination strategies drawing upon my experience, and that of other tutors, as advisory teachers. Examples of case studies in this area are reported elsewhere (Ollerenshaw and Ritchie, 1993, Chapter 8). The use of advisory teacher support in following up the course was also an important factor in encouraging colleagues to disseminate the course outcomes to their colleagues. In conclusion, I do consider the BCHE course provided a model with more potential than some other discussed by HMI and Harland and Kinder to have an institutional impact and affect the classroom practice of colleagues.

Although the DES initiative provided more contact time for teachers than most other inservice courses, which was appreciated by teachers and evaluated as successful by national evaluations, twenty days does not provide adequate time to address the needs of the majority of primary teachers in terms of their background knowledge and understanding of science. As Andrea (Cohort 1) said in her final evaluation report "What about a part 2 next year?".

It should also be recognised, as I noted above, that the use of a constructivist approach on these courses was extremely difficult and challenging for tutors and teachers alike. It is not an easy option, and as Harland and Kinder found the enthusiasm of others who tried to adopt the approach waned before the end of the course and they resorted to 'lecturing' teachers (p94). However, for us the experience gained was sufficient to convince us that in terms of our current understanding of inservice work with teachers, it provided and continues to provide an appropriate and, according to the evidence, an effective approach to adult learning. The next section addresses the extent to which the insights I gained from the case study analyses were applied to other aspects of my work. This provides evidence of the 'application' phase of my enquiry. How has the restructured knowledge I gained during the enquiry been applied in different contexts?

10.7 Application of a constructivist approach in other contexts
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This section will briefly outline ways in which the insights identified above have been applied in my teaching.

The constructivist approach has informed much of my teaching in science and in other areas in the light of this enquiry. For example, I developed a model for a Design and Technology course in collaboration with Somerset LEA which was underpinned by a constructivist approach and was based upon a similar course structure to the DES 20-day course. This course ran from September 1990 to July 1991. It allowed me to explore strategies developed during the enquiry in a different curriculum context. Orientation, elicitation, intervention, review and application were used but in slightly different ways - for example during the generation of designs. My work on this course is reported elsewhere (Ritchie, 1991e).

Subsequently this course model has been developed further and has been approved by the DFE as a proposal for a designated 20-day design and technology course.

In a very different area, I have used aspects of a constructivist approach during inservice courses for headteachers focused upon National Curriculum assessment, recording and reporting. The strategies I have used on this have involved eliciting headteachers’ existing understanding about the way in which children’s progress can be assessed and recorded in order to challenge their current understanding with new perspectives. The four day courses (fourteen cohorts from January 1991 to July 1992) were structured in terms of elicitation (day 1) intervention in terms of new perspectives (day 2); action planning to decide upon individual implementation strategies (day 3). A period in schools was then used to implement these plans and a fourth day was used for review and further planning. The follow-up work in schools was based upon materials which have been published (Ritchie, 1991). Unit B1 (p55) offers an example of how the units are structured to encourage teachers to clarify their existing understanding (in this example concerning their present record-keeping procedures) prior to
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exploring new strategies and developing a new understanding.

My work on a college inservice unit (Educational Enquiry, OAR101b) dealing with research methods has also allowed me to adopt an explicit constructivist approach, beginning with an elicitation phase during which participants share and structure their existing ideas about the nature of research. Group discussion, readings and input from the tutor are then used to challenge their constructs in order to help them restructure an understanding that matches ‘accepted’ understanding in terms of research paradigms and methods. Concept mapping has proved useful in this area of knowledge. In the context of the research unit, application comes during small-scale research activities in their own classrooms.

The enquiry has also led to specific developments with further DES 20-day cohorts which have been indicated in the earlier chapters (8 and 9). In 1991-92, three cohorts ran and Chris Ollerenshaw joined the college staff and the collaboration that had been cross-institutional now focused upon the BCHE courses and continued to inform course planning, implementation and evaluation. During 1992-93 a further three cohorts are on course and a further cohort is following a new distance-learning based designated course in science. This development has resulted, in part, from numerous references in the case studies to the potential uses of distance-learning materials and how they might be used to support follow-up work and the application phase. Our experience of implementing a distance-learning based course, again underpinned by a constructivist philosophy, is proving valuable in this area.

Greater emphasis has been placed upon dissemination to colleagues for more recent cohorts and this is now the focus of the school-based days during Cycles 4 and 5 and more support is offered in terms of specific strategies to use with colleagues (see Ollerenshaw and Ritchie, 1993, Chapter 8). The development of a new inservice centre specifically furnished and resourced for science courses has also enhanced course provision. The pattern of the courses has changed in that consecutive days are no longer used. The course team resolved
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that a week between days 1 and 2 was desirable to allow for reflection and school-based elicitation work which informed day 2.

Another aspect of the application phase of this work concerns the extent to which my enquiry, which during the 'investigative stage' was focused upon inservice activities, would lead to insights that could be applied to undergraduate work with B.Ed. students. During the period of the enquiry a change of role within the college led to a reduction in my undergraduate teaching and therefore this aspect was not as important as I first anticipated. However, during 1991-92 my work with B.Ed. students on their science course was considerably influenced by the enquiry and strategies developed during it. I found no evidence to challenge the assumption made in Chapter 4 that the similarities between initial and inservice teacher education were such that insights gained in one context could be applied in another. In particular I found being able to draw upon examples of work from inservice teachers carried out in their own classrooms considerably enhanced my teaching of students. The experience of the school-based days was also used to build similar experiences into the Year 4 course, although the time constraints and practical problems involved in organising this meant it was not as successful as intended.

Further aspects of the application of my new understanding will be discussed further in Chapter 12.

10.8 Conclusions

This Chapter outlined the outcomes of my enquiry in terms of an evaluation of the constructivist approach and the course model of which it was a fundamental part. The evidence available allowed me to make tentative claims to outcomes in two main areas - impact
upon professional practical and knowledge and impact in terms of scientific knowledge and understanding. The two areas are inextricably linked in terms of the way they have been conceptualised in this thesis. The role of metacognition has been identified as a significant outcome which links the development of professional knowledge with the development of scientific knowledge and understanding. It is through reflecting upon and trying to understand their own learning that teachers can develop an improved understanding of the learning of children and use this to inform their practice. Metacognition is an outcome of INSET which was not explicitly identified by Kinder and Harland (1991) and its identification in this enquiry adds an important category to their typology for conceptualising INSET outcomes. My own evaluation supports their claim that the framework developed by Joyce and Showers (1980), although useful in some respects, restricts the outcomes of INSET and devalues, affective outcomes.

This chapter has summarised my own learning in the area of adult learning through inservice education and demonstrated how my own metacognition has been a factor in making my own learning effective and ensuring new understandings become embedded in my practice. The last section has been an attempt to illustrate through specific examples how that new understanding has been embedded in my subsequent practice. My education values, particularly in terms of valuing learners’ existing understanding and building upon that in a constructive way is evident in those later examples.

Section 6 summarised some issues related to the implementation of the DES 20-day courses which are intended to inform other course providers about one approach to address concerns identified through national evaluations.
Chapter 11 - Reflections upon the enquiry

11.1 Introduction

This chapter will discuss the issues that have arisen from my enquiry concerning my use of action research. The last chapter can be seen as dealing with my summary of the 'content' dimension of the enquiry and this chapter's focus can be regarded as the 'process' dimension of the enquiry (as discussed in Chapter 6, Section 6.5.6).

The discussion begins with an overall reflection upon my use of action research as an approach to self-evaluation and an evaluation of a teaching approach and the course which was based upon that approach. This section revisits the extent to which the enquiry has led to me being better able to live out my educational values in my professional practice. The advantages and disadvantages of my approach to practitioner-centred research will be considered in terms of the exploratory phase and investigative phases of my research. The identification of concerns and the way I dealt with them was an aspect of my approach which I consider to be innovative. The use of the framework I developed for analysing and dealing with multiple concerns will be evaluated.

The validity of my enquiry is then addressed drawing upon my own set of criteria based upon some of those discussed in Chapter 6. My criteria will be grouped in terms of scientific, educational, ethical, collaborative and communicative aspects of the enquiry. This section will consider the scope and limited intentions of the enquiry in the context of claims made for action research as 'emancipatory'.

The chapter concludes with a discussion about the extent to which my enquiry might appropriately be described as 'constructive action research', in that a constructivist epistemology is used to understand my own professional development through the use of action research methods. This section discusses the phases of a constructivist approach to teaching and their parallels in the enquiry.
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11.2 The process used in my enquiry

The process in which I engaged does not match in any exact way the schema in the literature on action research which I discussed in Chapter 6, although the elements of plan, act, observe and reflect are evident in each case study and in that way the influence of Lewin’s spiral of steps and Kemmis and McTaggart’s (1982, see Chapter 6, Figure 6.1) model are apparent. The first case study with its emphasis, as I perceived it, upon exploration of my practice has similarities to Elliot’s (1991, see Figure 6.3) and Ebbutt’s (1983, see Figure 6.4) ‘reconnaissance’ phase at the beginning of their cycle 1, with a recognition, similar to Ebbutt, that this involves analysis. However, none of these schema allow for more that one key concern to be addressed. This became, as the case studies and reviews indicate, an important feature of my enquiry and in this area the work of McNiff (1988) influenced my approach. Her notion of ‘generative action research’ which was descriptive and not prescriptive; that was educational and had explanatory adequacy (p43), helped me recognise that it was possible to address, through action research, more than one concern at a time. This motivated me to consider ways of doing this which I will discuss in a later section.

The approach taken to analysis during my enquiry is one to which I have found no direct parallels in the literature on action research. The multi-levelled analysis which I used through the series of reviews I conducted is an innovative aspect of my work which I consider addresses an important aspect of validity as I will explore later. It also offers an approach to analysis which is thorough and systematic. In my view the literature on action research offers little guidance on the way in which analysis can be tackled.

Other aspects of the approach I have adopted which I consider significant concern the extent to which the enquiry was a self-evaluation, an evaluation of an approach and an evaluation of a course. These three inter-related strands were constructive in that one strand informed and drew upon others. The emphasis of the case studies and Reviews 1, 2 and 3 was essentially concerned with improvements to my practice and my understanding of it. However, Review 4
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drew upon other evaluative data to allow me to gain insights into the nature of the approach my colleagues and I had used and the outcomes of the course during which that approach had been adopted. In some respects, it is impossible to separate the course and the approach since they were so inextricably linked. The course had aspects to it which were not part of the 'constructivist approach' discussed in Chapter 2, Section 2.9, although those additional elements, such as the school-based days, were based upon a constructivist epistemology and intended to support adults’ active construction of their own knowledge. In that way the course represented the course team’s interpretation of the best way of implementing an INSET activity, based upon a constructivist approach, in a coherent and effective manner.

The involvement of colleagues in this enquiry, in a role beyond acting as validators, also added an important and in some ways innovative dimension. The opportunity to collaborate closely with professional colleagues in a co-teaching situation provided numerous benefits. Observing colleagues' professional activity informed my own practice; using data collected by colleagues from sessions added to the validity of my own data and allowed different perspectives to inform the picture of teaching sessions generated; sharing my analysis and concerns with colleagues added to the validity of my claims and provided me with creative ideas for ways of proceeding with the enquiry and improving my practice. The collaborative aspects of the enquiry were important to the self-evaluative dimension and the approach/course evaluation.

11.3 The nature of the concerns addressed through my enquiry

The case studies indicate that I raised nearly two-thirds of my concerns from the first two teaching sessions. The reasons for this can be identified in the orientation phase of my research. The period during which I was thinking about engaging in an enquiry, talking to colleagues in my own institution and at the University of Bath, doing background reading and reflecting in a fairly ‘unsystematic’ way upon my practice, was leading me to consider my
educational values and what aspects of my practice seemed to deny those values. The use of ‘unsystematic’ to describe this work is not intended to suggest it was unimportant or inappropriate. As with science, an unstructured, open-ended approach to exploratory work in the early stages can be productive and creative in terms of question raising and clarifying the parameters of an enquiry. The orientation period, over several months, had already fostered my curiosity about what a close look at my practice would reveal and suggested to me potential concerns. That is not to suggest that I had preconceived ideas about the detail of the concerns those first sessions would highlight, but the ‘theme’ areas I subsequently used for my first level of analysis were evolving. It is therefore hardly surprising that the exploratory phase when my examination of my practice was more systematic and rigorous enabled me to identify the range that I did. The wording of those concerns was changed very little during the enquiry, and in retrospect this was a mistake because attempting to reword and clarify the concern formulation at the review stages might have been productive. However, the context in which the concerns arose meant the wording was generally concise and unambiguous.

In reflecting upon parallels between my enquiry and the constructivist approach used in my teaching, I have already indicated how I came to conceptualise phases of my research as ‘orientation’ and ‘exploration’. The exploratory phase, like that with adult and child learners in science, was concerned with question raising and the structuring of existing thinking. As I stated in the last chapter, elicitation is for the benefit of the learner and the tutor. During the exploratory stage of my research, ‘elicitation’ can be conceptualised as the period during which I was clarifying and structuring my ideas about my practice and adult learning and sharing that existing understanding with my supervisor and my colleagues. I will now return to the nature of the concerns I identified.

Whitehead’s (1989b) view of the importance of the practitioner at the centre of enquiries and his emphasis upon ‘I’ in questions was one which I came to understand during the early stages of my enquiry. The majority of the concerns I raised were, most appropriately, formulated as ‘I’ questions, even in a context where co-teaching and collaboration with colleagues was so
significant. It was clear to me that it was 'my' enquiry, although I was drawing extensively upon my colleagues (for support, advice and criticism), and, I hope, informing their practice. The appeal of Whitehead's approach, discussed in Chapter 6, was also related to its less prescriptive emphasis and its parallel in the work of Popper (1972). This is discussed by Denley (1987, p194) in the context of Foster's (1982) study, whose formulation of similar statements to Whitehead's was not, incidentally, in the context of an action research enquiry. The Popperian parallels add to the coherence of my approach in that the view of science and the view of action research have similar origins. Whitehead's work caused me to give more attention to the nature and origins of my concerns.

Recognising the importance of making my educational values explicit led me to reflect upon which of my concerns were related to a denial of my values in action. During Review 1, I recognised this in terms of dilemmas I faced (based upon the view of Pollard and Tann (1987)). For example an early concern about whether sessions should be so tightly structured (Concern 4) resulted from the dilemma I faced regarding my values related to the importance of independent learning and learners being given control of their own learning. The majority of my concerns could, however, be seen as grounded in an evident denial of an educational value. Other examples include the value, based upon my constructivist epistemological assumptions, of recognising the inappropriateness of a transmissionist approach to communicating accepted scientific ideas set against the need to share that information with students (Concerns 16 and 19). This set up a tension for me which had contradictory elements but was, I considered, a dilemma I faced which could be resolved without recourse to 'dialectical logic' (Whitehead and Lomax, 1987). Another dilemma was evident in my belief that learning should not be 'threatening' to learners and yet finding that eliciting their existing ideas can be perceived by them as 'threatening' (Concerns 10 and 20). I considered time for orientation and exploratory work was vital to effective learning but the constraints of the time available during sessions and the pressure to cover 'content' forced me to recognise this dilemma (Concerns 1 and 13). I believe learners should be treated as individuals and their individual needs met. Work with a large group made this difficult and led to a dilemma about
where the focus for my intervention should come (Concerns 11 and 18). As a teacher I want to provide the best learning experience possible for learners but my own lack of experience and knowledge can deny this in action (Concern 12). Consequently, the majority of the concerns I identified can be conceptualised as an apparent denial of my educational values in action and my enquiry was an attempt to resolve some of the dilemmas I faced as a practitioner. The later reviews (3 and 4) indicate that, in terms of my own perception at least, I consider that my practice is now changed, and better than it was at the beginning of the enquiry, in that my educational values are now lived out more fully in my practice (Whitehead, 1989b).

The concerns also indicate that at the outset of the enquiry I had not clarified the relationship between the self-evaluation and the approach/course evaluation. The concerns are mainly, as discussed above, related to the first intention; however two of them (Concerns 5 and to some extent 7) might be better seen as questions related to the evaluation of the approach, although both have, as the case studies and reviews indicate implications for my practice and led to changes in that practice. Retrospectively, I consider that a more explicit recognition of the different dimensions to the enquiry would have be desirable.

11.4 Dealing with multiple concerns

McNiff (1988) recognised the need for action researchers to address more than one concern in their enquiries and proposed a new model (Figure 6.5) which indicates how a cycle of an enquiry can generate new concerns which lead to new distinct cycles, separate from the original. McNiff's model, whilst helpful, had limitations and crucially offered little practical guidance for those trying to deal with multiple concerns. The means of dealing with these was implicit in her case studies, not explicit. Her approach, whilst having appeal as a potential solution for my problem about dealing with multiple concerns, did not seem to allow for those concerns to be dealt with in an holistic way in which the new cycles were seen as part of the overall enquiry aimed at addressing one overall question such as, "How can I improve the quality of my teaching through the use of a constructivist approach?". I wished to deal with
multiple concerns within one plan/act/observe/reflect cycle. I recognised this would require me to hold a number of ideas and strategies in my mind simultaneously, but this seemed to reflect the complex nature of teaching. My concept of dealing with multiple concerns did not involve concerns spiralling off in all directions from the main focus of the enquiry, but perhaps more appropriately conceptualised the additional spirals within the main focus as indicated by Figure 11.1.

Figure 11.1: Action research spiral
Therefore I decided I needed a means of analysing each concern to clarify the nature of potential solutions and a means of summarising this analysis in a way that helped me hold on to the range of action proposed. The framework that resulted has been discussed, in Chapters 8 and 9, in terms of its usefulness. Developing and applying the analytical framework led me to a better understanding of the context, origins and nature of each concern. Use of the framework helped me to focus upon the ways in which that concern could be addressed and recognise the difficulties and scope of those solutions. The diagrammatic representation of that analysis became a working 'map' of the variety of routes I intended to take towards my overall destination of 'improved practice'. The use of the framework at each review stage led to a refinement of my understanding of each concern and the success or otherwise of my action. It helped me prioritise and identify those concerns which needed more action and those which had been resolved (an issue to be explored in the next section). More significantly, use of the framework also led me to clarify the relationship between these concerns and recognise the key ones which were worthy of further reflection and action.

There is an inherent difficulty about 'advocating' such an approach to other action researchers. I recognise that it can be criticised as a 'technical' and tightly structured approach. In one sense, it implies a prescriptive approach which I have criticised others for advocating. However, I am not making a claim that this approach would suit all individuals or all contexts. My claim is that this approach is one which I 'constructed' to deal with the problem I encountered. It was not developed as a new 'variant' of action research but as a specific technique for a specific purpose in a particular context. If sharing my use of it offers useful insights to other action researchers who see some potential in a similar approach then I will be pleased but of more significance is my claim that action researchers should be prepared to construct their own approaches to enquiries based upon their particular context and inclinations that, if appropriate, recognises that multiple concerns can be dealt with. I am an individual who likes to approach things systematically and in an organised manner - I like to be clear about what I intend to do, when and how. My approach to problem solving in other areas is similarly...
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‘technical’ in approach. Therefore a framework for analysing concerns and the development of a multi-levelled approach to analysis was a result of that aspect of my personality. Others will need to find their own solutions.

Reflection upon the use of the framework highlighted an issue about the extent to which my inclination to approach things in an organised and ‘technical’ way and the use of the framework as a tool to support this resulted in me identifying and addressing ‘technical’ concerns. The majority of my concerns were, in some ways, quite straightforward in terms of their origins and nature, although my relationship with students/teachers was involved in nearly all of them. The means of addressing them was often itself ‘technical’ in that it involved changing the structure of a session or using a different technique - for example, for eliciting students’ ideas. That is not to say that such concerns and solutions were not important nor that they did not lead to significant improvements in my practice. However, I now recognise, as Review 4 highlighted in terms of my concern about the way in which child and adult frameworks can be used (Concern 14), that my data collection and analysis could have had a greater focus upon ‘me’. The importance of the affective outcomes, discussed in Chapter 10, may have resulted from factors not considered in the enquiry related to my relationship with individuals. For example, my response to them at the beginning of a day and the way I related to them during breaks etc. These factors might arguably be covered by the ‘ethos’ category I used, but there is limited evidence that during the enquiry I took a sufficiently broad view of the factors affecting learning.

This aspect of my development of knowledge through my enquiry can be compared to Habermas’ ‘knowledge-constitutive interests’. Although I have referred above to the ‘technical’ nature of the concerns and my solutions, in terms of Habermas’ framework these are more appropriately viewed as ‘practical’ rather than ‘technical’ interests. I have already indicated in Chapter 6 that seeking Habermas’ ‘emancipatory’ knowledge through action research (in the way Carr and Kemmis’ (1986) claim that it can be developed) was not an intention of mine. However, it is appropriate to note that the inclusion of the category
'impossible' as one level of difficulty was recognition that the approach to action research I was using could not be used to address all concerns. I do also recognise that there may have been factors concerning my practice where 'emancipatory' knowledge could have been developed had I approached the enquiry differently, for example by analysing the nature of my dialogue with colleagues in planning meeting more thoroughly. My objectives were of a different order, but nonetheless valuable to me as a practitioner. However, the extent to which constructivism has become a common approach for all DFE designated courses at the college, and in some senses the new 'paradigm' in which we are working, might be interpreted in 'emancipatory' terms.

The use of the framework and revisiting concerns at different times and drawing upon different evidence did help me explore potential strategies to address concerns. There is a risk that action researchers might accept their first 'imagined solution' as the only one possible to address a concern. However, the collaborative aspects of my enquiry, the use of the framework and the time-scale over which the enquiry extended led to a thorough consideration of a variety of options. This is an aspect of my enquiry which has been 'tidied up' to some extent in the telling of the story. The case study analyses indicate the origin of concerns and sometimes indicate proposed action, the reviews clarify the nature of the concerns and the action proposed, but the discussion with colleagues which led from this stage to detailed session planning has not be recorded and presented in this account, although it is evident in subsequent case study evidence and analysis. The subsequent reviews are evidence of my developing awareness of these concerns and the way they have been addressed. I recognise retrospectively that more detailed records of the development of action plans would have been valuable.

The key question in evaluating the use of the framework is to ask 'What value was it to me as a practitioner?'. The answer to this, I claim, is in the evidence of the reviews and particularly Review 4 where it is clear that the framework led me to identify those concerns which required most consideration and as that Review shows, revisiting those key concerns, in the light of
additional evidence, led to new insights and professional understanding which had not resulted from the earlier reviews. It is also significant that although at that stage I revisited the other concerns in the light of the new evidence and further background reading I did not find that exercise as useful in terms of new insights as the attention I gave to the two key concerns.

There is also evidence that dealing with multiple concerns was 'generative' in that reflection upon one caused me to 'generate' personal theories which informed and supported the generation of new theories related to other concerns. For example insights gained in consideration of Concern 10, 'To what extent should I encourage individuals to expose their ideas?' led to the generation of ideas that in part led to the later identification of a related concern, 'How do I make constructivism less threatening?' and my thinking about this was informed by and developed further than that resulting from the earlier analysis.

The phase of the enquiry from the first to third reviews can be conceptualised as the investigative phase during which I engaged in a systematic examination and development of my practice. It is the phase when my existing ideas, clarified during the exploratory phase, were challenged and restructured. During this phase 'intervention' in the form of challenges to my existing understanding can be seen to come from my experience of engaging in action research cycles, from the comments of co-tutors and students and from my supervisor and professional peers with whom I shared my data and claims. Evaluation of this collaborative aspect of my enquiry highlights another area where I am dissatisfied with my enquiry. The planning meetings and the responses of colleagues and students led to entries in my journal which were used in future planning and analysis. Notes of these meetings were also made for circulation to the teaching team. However, I now realise that audio-taping some of these meetings and using the data more explicitly for validating my work would have been useful.

Similarly more structured discussions with colleagues whose teaching I observed and who observed mine would have provided additional insights and data. This would have also
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enhanced my approach to the triangulation of data, which was again an aspect of my enquiry of which I am critical.

Review 3 was a key point in the enquiry prior to the application phase, and in that way Review 3 can be conceptualised as the stage of my enquiry that is equivalent to the review phase of a constructivist approach. It was at this point that I articulated what insights I had gained and ways in which my practice had changed. The next section considers the application phase and the extent to which new understanding had become 'embedded' in my practice in similar and different contexts.

11.5 Embedding changes in future practice

For restructured understanding of scientific concepts to be of value to the learner the constructivist teacher recognises that the ideas need to be applied and used in new situations. This is why the application phase is so important to effective learning. A parallel can be drawn with the outcome of an action research enquiry. If the changes to a practitioner's practice and the new understanding they have gained from an action research enquiry is to be of use to them those changes must become embedded in her/his work and be applied in a variety of contexts. Section 10.7 of the last chapter provided evidence of that in terms of my own practice.

During the reviews of my enquiry I used the term 'addressed' to indicate a concern had been tackled and evidence found to indicate that the action had been successful. However, that implies the concern has somehow disappeared and as I discussed at the end of Chapter 8, this was not the case. 'Addressed', I came to recognise at the time of Review 3, was my way of claiming that the insights I had gained from plan/act/observe/reflect cycles related to that concern had become embedded in my practice and did not need to be the explicit focus of further cycles. Revisiting those concerns in Review 4 was a means of 'checking' that the claim was acceptable in the light of new evidence, further reading and additional reflection. The
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difficulty rating used as part of my framework for analysing concerns can be seen as an indicator of how far from being 'embedded' in my practice were the tentative insights I was articulating at a particular stage.

11.6 Evaluating the enquiry

This section indicates the criteria I consider can be used to evaluate my enquiry and includes a discussion of the extent to which I claim those criteria have been met. These criteria were introduced in Chapter 1 to alert the reader to the significance of the discussion below as representing a self-assessment of my enquiry.

Having examined the approach of Winter (1989) and Whitehead and Foster (1984) in Chapter 6, I now intend to draw upon their approaches in constructing my own. I have decided to group the criteria under the following headings: scientific; educational; collaborative; ethical and communicative. Each of these areas will be addressed through a series of questions, although I do not intend to structure the discussion by addressing each of the questions individually.

To what extent is the enquiry scientific?
* Was a systematic process used?
* Is there evidence of hypothetical thinking?
* Have tentative ideas been tested against experience?
* Was the data collected authentic?
* Was the analysis systematic, critical and rigorous?
* Are claims supported by evidence?
* Have the claims been validated in other ways?
* Has the researcher been open and considered other perspectives?
* Are the practitioner's epistemological assumptions consistent throughout the enquiry?
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To what extent is the enquiry educational?
* Are the practitioners educational values made explicit?
* Was the enquiry of relevance to the practitioner, his colleagues and others?
* Is there evidence that the practitioner was open to changes in his practice and prepared to take risks?
* Are changes to the practitioner’s practice evidence of his educational values being lived out more fully?
* Is there evidence that these changes are embedded in his current practice?
* Is the practitioner aware of the nature of his own learning?
* Is the interaction between theory and practice evident in the enquiry?
* Is there evidence that the enquiry was original and of value to others?

To what extent was the enquiry ethical?
* Was the researcher aware of and able to articulate the ethical issues related to the enquiry?
* Were ethical principles established and followed?
* Was the primacy of the practitioners teaching evident throughout the enquiry?

To what extent was the enquiry collaborative?
* Did the practitioner engage in a collaborative enquiry?
* Is there evidence that the collaborative dimension enhanced the enquiry outcome?
* Was the collaboration used to validate the claims made by the practitioner?

To what extent has the enquiry been communicated effectively?
* Is there evidence of a logic the the form of presentation?
* Is the enquiry related in an honest form which does not distort the nature of the enquiry or its outcome?
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* Is there evidence of alternative perspectives or a pluralistic view?
* Is there an aesthetic dimension to the work?

In tackling each of these groups I will briefly discuss the origins of the criteria and then explore the extent to which I consider my enquiry met the criteria. This evaluation should be read in the context of the criticisms I have already raised about some weaknesses of my enquiry and ways in which it could have been improved. This self-critical dimension is of course an essential element of the first criterion.

To what extent is the enquiry scientific?

The debate about the nature of science has been raised several times during this thesis and I have established my own view as distinctly different from that of positivists. The use of ‘scientific’ as a criterion for an action research enquiry was introduced in Chapter 6 (page 217). It is a criterion which has been identified and used by Carr and Kemmis (1986), Denley (1987), Hayward (1992), McNiff (1988), Whitehead and Foster (1984) amongst others. Denley, in particular, because of the nature of his enquiry, provided a thorough treatment of the nature of science and its relevance to evaluating a practitioner-centred enquiry.

In terms of my own enquiry, I consider that there are a number of ways in which my claim to be scientific can be supported. The epistemological position I have adopted, viewing (scientific) knowledge as provisional and generated through the action of knowledge-seekers (scientists) engaging in rigorous processes intended to test the validity of hypotheses, is consistent throughout the enquiry in terms of the generation of my own knowledge and of that of the adults I taught. Philosophers of science, such as Popper, Kuhn, Lakatos and Medawar recognised the generation of scientific knowledge as a human activity where “objectivity is often determined through inter-subjective criticism and where the creative phases of an enquiry are acknowledged” (Denley, 1987, p387). Knowledge is not seen in absolute terms but as in need of constant testing against the challenges offered by other
knowledge-seekers. My approach to this enquiry therefore has parallels with the way scientists can be viewed as generating knowledge. I have noted above the similarities between the approach to action research advocated by Whitehead and Popper’s view of scientific enquiry.

Denley quoted Medawar’s view of scientific method which provides a sound basis for considering my enquiry:

The scientific method is a potentiation of common sense, exercised with a specially firm determination not to persist in error if any exertion of hand or mind can deliver us from it. Like other exploratory processes, it can be resolved into a dialogue between fact and fancy, the actual and the possible; between what could be true and what is in fact the case.

Medawar, 1969 quoted in Denley, 1987, p388

This indicates the essential need for an enquiry to be rigorous. My claim is that the enquiry I conducted was systematic; that there was a logic in decisions taken at each stage and these decisions were justified in the account; that data collection techniques I used were used as thoroughly and as carefully as was necessary to obtain as authentic an account of teaching episodes as was needed to allow informed decisions to be taken; that my analysis was systematic, logical and justified in my account; that the multi-levelled analysis demonstrated my commitment to using the data in a critical and rigorous way; that there is evidence of hypothetical thinking and an evident commitment to testing out hypotheses; that claims I made were supported by evidence and that evidence can be located by tracking back through the case studies; that the claims have been tested against the views and evidence of others including my colleagues and professional peers; that I have been open-minded in my approach and thoroughly surveyed the views of others and taken that into account in my enquiry. I therefore claim my enquiry demonstrates “principled action based on rational thought” (McNiff, 1988, p124).
To what extent is the enquiry educational?

This criterion is not conceptualised in this form in the frameworks for evaluation proposed by Winter (1989) or Whitehead and Foster (1984) although the questions I have posed are ones their writing would suggest they would endorse. Carr and Kemmis (1986) and McNiff (1988) highlight the significance of enquiries being 'educational' as the discussion in Chapter 6 indicated. The notion of 'relevance' which I have included in this section draws upon the recent work of Hayward (1992, p150). The inclusion of a criterion related to metacognition is based upon my developing understanding of the extent to which this has been a factor in my own learning, as I claimed it was in the learning of the adults I taught (see Chapter 10).

My educational values were made explicit in Chapter 1, although these became clearer during the enquiry and were not formulated in the terms used in Chapter 1 at the beginning of the enquiry. However, I claim my education values have been evident in previous writing (eg. Ritchie and Ollerenshaw 1989; Ritchie, 1989a and b). The reviews indicate the changes to my practice and provide evidence of those values being lived out more fully in my professional life. I recognise that education values are not easily, and indeed should not be, seen as discrete simplistic statements, since these can mean all things to all people, do little to communicate the meaning of those values, and disguise the complex nature and interdependency of values. It is for that reason that throughout the reviews I have not made constant reference to value 'x' or 'y'. It is my view that educational values are appropriately understood in the context of the practice, they inform it rather than being separated from it, and I claim that my values are evident in that practice.

Pursuing an enquiry of this nature involved taking 'risks' and being open to changes in my practice and my educational values. 'Risk' was one of Winter's principles (1989, p60). At the outset I did not have a clear idea of where the end of my 'journey' would be nor what the outcome might involve. I set out with a direction in mind, my curiosity aroused and, like a scientist recently interviewed on the radio before setting off to explore an unvisited area of...
Chapter 11 - Reflections upon the enquiry

jungle, "armed only with my senses fully alert and whatever experience I can manage to bring to bear on what I find". Indeed, even at this late stage of writing-up, the final chapter is not yet fully charted and may provide an unexpected revelation. I approach it with a clearer understanding of the purpose of my journey and with an almost complete map which I have produced en route. It is, of course, a map of one route out of the many I could have taken having started in the same direction. To continue the metaphor a little longer, the map covers a fairly restricted area of my professional life. However, the benefits of ‘travelling’ have encouraged further risk-taking and the motivation to ‘explore’ other aspects of my practice.

Chapter 10, Section 10.7, provided evidence of the extent to which changes resulting from the enquiry have become embedded in my practice in other contexts and in doing so indicate the value of the enquiry to me.

The relevance of this enquiry is also I hope obvious to the reader as she/he shares my attempts to improve the quality of my teaching. The innovative, although not unique, nature of the approach to adult learning in the context of the need to improve primary teachers’ scientific knowledge base adds to the relevance of the enquiry to others. The demands made upon teachers by the National Curriculum for Science will ensure that there is an ongoing need to address this concern, for at least the next decade, in both initial and inservice teacher education. The contribution of this enquiry as an example of one way of approaching the teaching of adults is the basis of my claim that it has relevance to me and others involved in science education. However, I also consider my claim to relevance can go further. Recent announcements by the Department for Education (DFE, 1992) concerning new designated courses in History, Geography and Design and Technology offer potential for the approach to be used in other curriculum areas. The BCHE proposals for these new courses, recently approved by the DFE, are all based, as discussed above, upon a constructivist approach to teaching and draw upon our experiences of the science (and mathematics) courses.

The value of the enquiry to others is a judgment I cannot make, although I am encouraged by
the extent to which the enquiry has informed the work of my colleagues on the DES 20-day courses and undergraduate courses. I recognise its value to me in terms of considering myself to be a better and more knowledgeable teacher as a result, however, I await with interest the response of others, beyond my immediate colleagues.

A key intention throughout my enquiry has been to understand my own learning and consider the extent to which a constructivist epistemology can help me in that endeavour. The fruits of that have been discussed in Chapter 10, Section 10.5, and that is further evidence that I have met the 'educational' criterion. I will consider this again in the final chapter. Related to this aspect of metacognition is, I claim, evidence that my enquiry demonstrates an interaction between educational theory and practice which goes beyond the conception of theory and practice postulated by positivists and interpretists. In this claim, I am addressing an area prioritised in Winter's (1989) framework. He called it 'Theory, practice, transformation'. Hayward (1992) challenged this and suggested a better conceptualisation of this was 'Practice, theory, and transformation' (p165). The attempt to consider which comes first is a somewhat sterile discussion of the 'chicken and egg' type, which I do not consider was intended by Winter. My claim would be that in educational contexts practice is not possible without some form of personal theory and that personal theory is based upon and grounded in practice, a view I consider to be in line with Winter's. An attempt to separate such interdependent and interrelated parts of a whole is unproductive. My enquiry is evidence of the dynamic between theory and practice and as such is neither best conceptualised as 'theory, practice transformation' nor 'practice, theory transformation' but as 'theory-practice interdependence'. My enquiry began by exploring my practice and the personal theories that were inextricably linked with that practice. It led to a reconstruction of those personal theories which were grounded in new practice that resulted from the enquiry. That is not to say that my personal theories were not informed by the theories of others, for example, those explored in Chapter 2. However, those 'theories' only became useful when they were restructured in terms of my own understanding of them and used in a practical context.
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A final consideration in this area is the extent to which I was aware of the constraints and limitations of my enquiry in terms of its intentions and the way I pursued it. I discussed in Chapters 6 and 7 the claims made by others for action research as emancipatory (Carr and Kemmis, 1986) and contributing to a ‘living educational theory’ (Whitehead, 1989b) and earlier in this chapter reminded the reader that I recognised the limitations of my approach. There is no doubt in my mind that the knowledge I have gained does not justify the label ‘emancipatory’. However, I am less sure about my contribution to a ‘living educational theory’ in that I hope the reader will find evidence that this enquiry has led to me to an account in which

the explanation contains evidence of an evaluation of past practice, evidence of an intention to produce something not yet in existence and evidence of the present practice through which the intention is being realised in action.

Whitehead, 1989b, p6

My understanding of my practice is in the process of active reconstruction every time I act in a teaching situation and reflect upon that action - whether that warrants the label ‘living educational theory’ or not is a question I leave unanswered.

To what extent was the enquiry ethical?

Chapter 7, Section 7.5, set out the ethical principles which I adopted and claim to have used. These indicate my awareness of the ethical issues involved in an enquiry of this nature. In particular I consider the case studies and reviews indicate the extent to which my teaching concerns were always at the forefront of my thinking in terms of making decisions about potential changes to my practice and planning action. Much of the discussion above in the section concerning the ‘educational’ criterion is related to the ethical approach I adopted to my enquiry and it is within the ‘ethical’ criterion that Whitehead and Foster (1984) highlight the importance of a practitioner’s educational values and the extent to which they become embedded in her/his practice.
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To what extent was the enquiry collaborative?

Action research does not have to have a collaborative dimension and this has been less evident in the work of some than others. Winter (1989) used the term 'collaborative resource' to describe this criterion. Carr and Kemmis (1986) place considerable emphasis on the need for an action researcher to avoid working on an enquiry in isolation:

> The self-reflection of a lone subject ... requires a quite paradoxical achievement: one part of the self must be split from another part in such a manner that the subject can be in a position to render aid to itself ... (furthermore), in the act of self-reflection the subject can deceive itself.

There was evidence of collaboration throughout my enquiry, with colleagues with whom I taught, with other colleagues with whom I shared my work and with students and teachers I taught. Collaboration was a valued and essential feature of my enquiry adding to the validity of my claims and supporting the work in a critical and creative way. The perspective of others informed the direction and outcome of this enquiry and the reference to 'i' in many sections would have been more appropriately labelled 'we'. However, I cannot speak for others and therefore offer the claims as my 'own', despite their construction in a collaborative social context, and it is for me to defend those claims. I would again wish to remind the reader that the course model I have used and described as the BCHE model, the approach to teaching and the specific techniques and strategies were not developed by me in isolation. They were the result of a collaboration between professionals sharing a common goal of wishing to improve their practice and the learning of adults involved in the courses and sessions taught. This collaboration was not simply an attempt to produce a consensus. Our meetings and discussions were the coming together of different perspectives and educational values. As a result of our discussions we all moved forward in our thinking but ultimately took responsibility for our own decisions concerning the implementation of sessions. This led to me having the opportunity to observe and draw upon the professional practice of others in a way that considerably enhanced the enquiry and informed my practice as I suggest the case studies
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demonstrate.

Ebbutt (1985) cites the value of a 'critical friend' to action researchers who can offer support
and a critical perspective. The references to my collaboration with Chris Ollerenshaw
throughout my recent professional life evident in this thesis and culminating in our most
recent publication (Ollerenshaw and Ritchie, 1993) is indicative of the extent to which she has
acted as a valued 'critical friend' during my enquiry and in that sense was a key 'collaborative
resource'. Even during the writing-up phase this input has been invaluable. As a specific
example, a conversation with her a few minutes ago about my 'journey' metaphor caused me
to reflect upon the extent to which an action researcher, writing up an enquiry should know
the end of the story - is the writing a vital and generative part of the process? Is the same true
for a scientist dealing with quantitative data from the physical world? I tend to think Medawar
might agree with me that an open-minded researcher would stay alert to the unexpected until
the last word is written. Similarly, I would wish to acknowledge the extent to which my
supervisor, Paul Denley, has taken on a similar role and his constant support and criticisms
have played a major part in the enquiry.

To what extent has the enquiry been communicated effectively?

The way in which an action researcher's account is made public is important since it is this
attempt to share findings and validate one's experience against a public audience which
meets Stenhouse's (1975) need for practitioner research to be a 'systematic enquiry made
public'.

This criterion requires me to justify the format of my account. As I indicated in Chapter 1, I
considered a variety of approaches and even explored the use of 'Hypercard' stacks using a
computer database. However, in the context of submitting my enquiry for examination I am
required to use a more traditional format. Whitehead and Winter would encourage me to use a
dialogue, as a means of communicating my enquiry. Whilst I have considered this and can
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appreciate, particularly in the case of some of Whitehead's writing (Whitehead and Lomax, 1987) how this can be effective when attempting to communicate an enquiry based upon dialectical logic, it is not a format that I considered the most appropriate for effectively communicating my own enquiry. In some ways, the dialectical tension Winter (1989), Whitehead (1989b) and Hayward (1993) discuss is a tension that I have experienced in my own enquiry in terms of the extent to which my educational values have been denied in my practice. However, perhaps because of the 'technical/practical' rather than 'emancipatory' nature of my enquiry I concluded that a dialectical logic was not appropriate and a form of commincation based upon dialogue was unnecessary. This is also related to my earlier discussion about 'process' and 'content' in action research enquiries. Perhaps because of my professional biography, a propositional form of communication remained the one which I considered myself most able to use effectively to communicate my understanding of the literature related to my enquiry, in order to contextualise it and to communicate to others the course of the enquiry and its outcomes. The reader will be aware of changes of style between the background chapters, the enquiry story and these later chapters. The enquiry story has appropriately been written in a more personal style and this chapter has a more personal style than the last and is an attempt to reinforce the extent to which the writing of this thesis has been a 'dialogue with self'. The case studies and earlier reviews were similarly a 'dialogue with self', but a dialogue grounded in the discussions I was having concurrently with colleagues and students. Throughout, the account has been an attempt to communicate in a honest way the processes in which I was engaging that involved a complex dynamic interaction of thought and action. The use of different styles, in this way, is not a compromise. For me it has been a means of communicating different aspects of a coherent whole. This also offers, in a limited way, evidence of Winter's 'plural structure' (1989, p62). Another aspect of my enquiry which relates to this is the attempt to offer different perspectives through the different levels of review. Each review caused me to revisit earlier case studies and approach my concerns again in the light of new evidence, additional experience and additional 'collaborative resource'. The development of different, but inter-related strands in this thesis also offer different ways of looking at issues I have raised. The coherence of these strands is based upon a common
A final consideration in terms of the way I have communicated the enquiry is to address the extent to which the thesis has an aesthetic dimension. This criterion is based upon Whitehead and Foster's (1984) work. Their view of this was to ask whether "the reader can vicariously experience the process in which an individual struggles to give form to his or her life in education" (Denley, 1987, p391). Such a judgment will need to be made by the reader. However, I wish to raise another 'aesthetic' consideration for the reader. Aesthetics means 'pertaining to the appreciation or criticism of the beautiful' (the Shorter Oxford English Dictionary) and I therefore invite the reader to consider whether ideas can be 'aesthetic'.

Duckworth discussed, in the context of teaching and learning 'the having of wonderful ideas' (1987). Keats also relates beauty to knowledge,

Beauty is truth, truth beauty - that is all
Ye know on earth, and all ye need to know.

Ode to a Grecian Urn

My work on this thesis has led me to appreciate certain key ideas in this enquiry as 'aesthetic'. For example the conceptualisation of a constructivist epistemology having the explanatory power to deal with my own learning, that of adults I taught and that of the children they teach; the use of the same epistemology to explain the development of science and professional knowledge and understanding; the extent to which the approach to teaching I used could be used by the adults I taught and could be used to conceptualise stages in my own learning. Each of these key ideas generates an aesthetic response in me. Appreciation of 'beauty' is concerned with an individual's response and therefore what is beautiful to me may not have the same appeal to others. However, I share this, not in order to make profound claims about its significance but to indicate another aspect of my own evaluation of this enquiry and its outcomes.
Chapter 11 - Reflections upon the enquiry

11.7 Conclusions

This chapter has involved me reflecting upon my enquiry and evaluating its strengths and weaknesses. I have provided my own set of criteria for carrying out this evaluation in order to consider the extent to which the enquiry has led to professional development. The use of these has led me to consider myself justified in claiming the thesis provides an honest account of an aspect of my professional development in which I claim through critical reflection I have explored my understanding of my practice and communicated it to others.

This reflection has confirmed a view that has been evolving during the enquiry that the term 'constructive action research' is an appropriate one to describe my enquiry. This captures the key epistemological element evident in my enquiry. I am not the first, of course, to have recognised that a constructivist epistemology can be used to explain action research and such a view is evident in the work of Carr and Kemmis (1986). They identify constructive and reconstructive elements in each plan/act/observe/reflect cycle (see Chapter 6, Figure 6.2). However, there is little evidence in the literature that a constructivist epistemology has been used explicitly by action researchers to conceptualise their own learning.

A constructivist view of knowledge has underpinned my approach to action research and that approach has been constructive in several senses. It led me to construct an understanding of the means of dealing with multiple concerns, in this case a framework for analysing concerns through a number of reviews. It was also constructive in the sense that it enabled me to construct an improved understanding of my professional practice and construct new and more effective strategies and approaches to teaching. A constructivist epistemology enabled me to understand the nature of my own professional knowledge and action research provided the tool to develop changes to my practice. Therefore the term constructive action research seems appropriate.

Like children in the classroom or teachers on inservice courses I approached my own learning
with existing ideas about teaching and learning. These ideas affected subsequent learning. A recognition of this led me to consider the way in which the phases of the constructivist approach to teaching I was using could be helpful in conceptualising my own learning through the enquiry. Therefore I explored the extent to which orientation, elicitation/structuring, intervention/restructuring and application were phases evident in my research. In my science teaching I also identified the orientation/elicitation phase as being exploratory (involving relatively unstructured activity intended to raise questions) and the intervention phases as being investigative, when the questions raised are addressed through learner-devised investigations. I consider these phases to be descriptive of the activity involved. The following diagram (Figure 11.2) summarises how I have conceptualised my own constructive action research in terms of phases of a constructivist approach to teaching, although with emphasis upon the cognitive activity (structuring/restructuring) rather than the teacher’s role (elicitation/intervention), and the ‘activity’ phases. Although illustrated in a linear form, this over simplifies the process involved as I have already discussed in terms of teachers’ learning through the same process.
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Figure 11.2: Constructive action research

<table>
<thead>
<tr>
<th>Constructivist phase</th>
<th>Activity phase</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>Exploration</td>
<td>Preparing proposal, background reading, discussions, unsystematic reflection.</td>
</tr>
<tr>
<td>Structuring (Elicitation)</td>
<td>Investigation</td>
<td>Case Studies 1 and 2 - systematic analysis, raising concerns, clarifying ideas, re teaching/learning.</td>
</tr>
<tr>
<td>Review</td>
<td></td>
<td>Review 3 and 4 (Chapters 8 and 9) Write-up.</td>
</tr>
<tr>
<td>Application</td>
<td></td>
<td>Use in other contexts (Chapter 10, Section 10.7).</td>
</tr>
</tbody>
</table>

The detail of these activities has been discussed earlier in the thesis and this summary brings together those elements into a coherent overall framework. Recognition of this framework as a useful one for action researchers will I hope make a contribution to the literature and provide a means of others conceptualising their enquiries in this way and recognising the purpose and potential of each phase, both in terms of the cognitive and practical domains. The orientation period can help the would-be researcher become aware of the range of potential aspects of their professional practice which might be explored and leads to the general concern they
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decide to address - in my case, How do I improve the quality of my teaching through the use of a constructivist approach? The structuring phase is intended to help the researchers clarify what they already think and through exploration of their present practice raise more specific questions, such as, Do I allow students adequate time for practical exploration and investigation? This leads to the systematic implementation of further plan/act/observe/reflect cycles intended to investigate improvements to that practice. The outcomes of this investigative stage and the restructuring of understanding which has resulted from it need reviewing to help the learner understand the nature of those changes and the implications for future practice. The application phase is when new understandings and teaching strategies are tried out in different contexts in order to embed them in the practice of the researcher.

There is no intention in conceptualising action research in these terms to provide a prescriptive template for would-be researchers. It is simply offered as a framework which was supportive of my enquiry and which may be supportive of those of others. It is flexible and as with my understanding of the same framework in the context of science education the phases overlap and inform and are informed by each other. It is proposed as a tentative contribution to the action research literature.
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12.1 Introduction

This final chapter of my thesis brings together the various strands of my enquiry. It begins by considering several areas of my work where my review of the literature and the exploration and investigation of my practice have led me to reconsider my understanding of key educational issues. These involve the role of an individual and social context in theories of learning; the importance of 'process' and 'content' in terms of a science curriculum; the emphasis upon knowledge and understanding or skills and processes in terms of learning science; the nature of theory and practice in education; the significance of 'process' and 'content' strands in action research enquiries. In each of these areas there is evidence that some educationalists and teachers tend to emphasise one aspect over another where both may, more appropriately, be regarded as playing an essential part and be linked in an inextricable way. My own understanding of these issues, which I consider to provide a more holistic conceptualisation, will be discussed.

The key question of this enquiry was: How can I improve the quality of my teaching through the use of a constructivist approach? The extent to which I was successful in addressing this central question has been discussed in Chapter 10 in terms of the evidence collected that teachers with whom I worked gained an improved understanding of scientific ideas and that my teaching led to changes in those teachers' professional practice in the area of the teaching of science. Chapter 11 has discussed the process through which that key question was addressed. Therefore the conclusions and implications that follow are offered in the context of the claim that my enquiry led to an improvement in the quality of my teaching and that the constructivist approach that I used was successful in terms of the learning that resulted for the adults with whom I worked.

The outcomes of my enquiry will be considered in terms of their contribution to the
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knowledge base other practitioners can draw upon. The implications of the insights I have gained will be discussed in terms of primary education in general, initial teacher education and inservice education.

12.2 An holistic understanding of key issues

Work on my enquiry, reflection upon my previous understanding of my practice and reviewing the literature caused me to question the extent to which debates about education are so often polarised into apparently opposing views which can lead to practitioners adopting pedagogical approaches which are not necessarily in the best interests of the children they teach. The articulation of different perspectives with undue emphasis given to one dimension over another tends to set up, in teachers' minds, what might be termed a 'false dichotomy'. Chapter 2 included a detailed discussion about the views of Piaget and Vygotsky on children's learning. Piaget emphasised the role of the individual, Vygotsky the significance of the social context of learning. Both, it is evident from reading their work recognised the extent to which the other factor, be it social or individual, influenced a child's learning although the emphasis they placed on these factors was significantly different. The Piagetian view, with its notions of stages of development, was taken up by educationalists and teachers and led to approaches to teaching which were based upon 'readiness'. This restricted learning opportunities provided by teachers and led them to encourage children to become individual explorers and discovers of the world around them. Social constructivists, by contrast, used Vygotsky's work to advocate collaborative group activities and a 'scaffolding' role for the teacher. This has, in some ways, led some teachers to neglect the role of the individual and the active role that individual must play in coming to a unique and personal understanding of the world around her/him. My own work, as evidenced by the approach documented in the case studies and my analysis of teaching episodes, has been based on a view of learning which recognised the inextricable links between the individual and social aspects of learning. I discussed this position in Chapter 2, Section 2.6. My view is that this attempt to adopt a more holistic view of the nature of learning is one which should be articulated within the science
education community where there is some evidence that the 'individual' aspects of learning, originating in the work of Piaget, are still emphasised and the importance of the social context sometimes ignored. In attempting to understand the relationship between these two aspects of learning I have considered a number of metaphorical models for conceptualising these issues. The 'vine' metaphor proposed by West and Pines (1985) and discussed in Chapter 2 (page 57) was helpful in reinforcing the 'interwoven' nature of the two dimensions and the recognition that neither the individual's intuitive knowledge nor formal instruction can be exclusively identified as the 'source of new knowledge'. I also considered conceptualising the two aspects of learning as a continuum but recognised that the notion of adopting a centralist position would imply the part played by each aspect was somehow reduced in significance. This led me to think of the ends of the continuum being folded back and interwoven to produce a new 'centre'. The weft and warp of woven cloth offered another way of conceptualising the links. Another model involved conceptualising learning as a bridge held up by pillars; one representing the individual's contribution to learning and the other representing the social contribution. A bridge remains stable and horizontal if both pillars are supporting it equally but an imbalance leads instability. In the learning context if the individual and social aspects are not equally recognised this can lead to less effective learning. I also considered the extent to which dialectical logic might help in terms of seeing two opposing elements as held together in contradiction. But the notion of 'contradiction' did not seem appropriate. However, regardless of the metaphor or analogy used the key point remains, that in terms of my own understanding both individual and social aspects of learning are essential and the constructivist epistemology that underpins this thesis accounts for both individual and social perspectives.

The parallels between this discussion and the role of the individual in an action research enquiry is interesting. As Chapter 6 indicated, and my enquiry has illustrated, the social context of an enquiry is also significant in terms of the individual construction of an action researcher's professional knowledge. In some ways it could be argued that action research cannot be isolated from the social context in which it occurs. However, action researchers can
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approach their work as individuals in isolation from other professionals. This may not lead to the same outcomes and I would claim that the professional development and professional understanding constructed in collaboration with others is qualitatively better than that which could be constructed by an individual working alone.

The next area in which two apparently ‘opposing’ views are evident is in the science curriculum and concern ‘content’ and ‘process’. This debate was explored in Chapter 3 and is another area where my enquiry and my reading of the literature has helped me clarify the relationship between these two aspects of the curriculum. The polarised positions sometimes adopted by educationalists and teachers have, I would again claim, acted against the best interests of learners. The emphasis on process in primary science, encouraged by the Science 5-13 Project and other initiatives is still evident in the approach of some primary teachers, who, despite the National Curriculum for Science, continue to emphasise that it is the way children approach science rather than the content they cover which is of most importance. In the secondary phase it could be argued that the emphasis upon content in which science is seen as a body of knowledge, defined by syllabi, which has to be learnt by pupils is still implicit in secondary science teaching, despite considerable attempts to encourage a ‘process’ approach. The National Curriculum for Science, to its credit, does reflect a more balanced view to the science curriculum which makes explicit, at least in the Non-Statutory Guidance (NCC, 1989), that the curriculum should be seen in terms of inextricable links between process and content (see Ritchie, 1990a, p85). However, there continues to be a need to reinforce this view, in the approach to inservice and initial teacher education. The approach documented in this thesis does, I consider, view the science curriculum as one that has process and content strands which cannot and should not be separated in terms of the experience provided for learners. Curriculum planning may be facilitated by a framework, such as that provided by the National Curriculum for Science, which recognises the contribution to learning of the two strands, but implementation of that curriculum should reflect the links. The nature of the science curriculum and learning in science are obviously related. The process/content curriculum issue is paralleled by skills and
knowledge and understanding in terms of learning. The nature of learning in science evident in this enquiry is based upon a view that these cannot be separated and one should not be emphasised to the detriment of the other. This view is also evident in the Non-Statutory Guidance of the National Curriculum for Science (NCC, 1989, A7), which recognises the links between the development of knowledge and understanding and the processes and skills used to gain that understanding for scientists and for pupils. A constructivist approach to learning in science does not necessarily lead to learning which is in line with this perspective. It can lead to an over-emphasis upon knowledge and understanding at the expense of the development of process skills and an understanding of process. This is a criticism I have made of some approaches to DES 20-day courses in Chapter 5, Section 5.7. The constructivist approach used during my enquiry does, I would claim, reflect the importance of learning involving both process skills and scientific knowledge and understanding. The significance of this position has been highlighted by the discussion in Chapter 10 about the extent to which the structure of the National Curriculum and the apparent emphasis upon knowledge and understanding (in terms of the number of Attainment Targets), despite the explicit weighting between AT1 and the Knowledge and Understanding ATs and the reduction of Knowledge and Understanding Attainment Targets to three, has led some primary teachers to view the learning of science as essentially concerned with ensuring children learn a body of knowledge.

The debate about process and content in science education also has parallels in my enquiry. The issue about ‘process’ and ‘content’ was discussed in Chapter 6 and at that stage I recognised, in the context of my enquiry, the need to see the two strands as linked and of equal importance. The treatment of the outcomes in Chapters 10 and 11 indicates the extent to which I consider there to be significant outcomes in both areas. There is a risk that separating the outcomes in the way I have somehow suggested that they are not linked, and, as I stated in Chapter 6, I recognise the use of ‘process’ to describe the action research dimension is not unproblematic in that action research could be claimed to have a ‘content’ of its own. However, I consider the terms do represent two important aspects of my enquiry and I
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consider the links between those aspects to be evident in the discussion about both. My understanding about the 'content' of my enquiry resulted from engaging in the process of the enquiry. Indeed, the quote from the Non-Statutory Guidance in Chapter 3 (page 36) could be reworded:

For the action researcher, as for the scientist or the pupil learning science, the way to understanding depends both upon existing ideas and the processes by which those ideas are used and tested in new situations.

based upon NCC, 1989, A7

Throughout my thesis the importance of and the relationship between the process and content aspects of my enquiry have been evident.

The nature of educational theory and practice is another issue addressed in this thesis where I have identified two opposing views. However, in this area the two perspectives cannot be conceptualised in the same way as those already discussed. In the previous areas it has been claimed that the 'resolution' of the apparently opposing views is to recognise the inextricable links between the two views and therefore the resulting view is a bringing together of two dimensions which are both of significance and equal importance. It an holistic view since the sum of the two parts is recognised as more than the two parts in isolation.

Theory and practice has been discussed in some detail in Chapters 6 and 11. Action research provides a distinctly different way of looking at theory and practice which Winter (1989) saw as a transformation. In Chapter 11, Section 11.6, I conceptualised my own view in terms of theory-practice interdependence. The theory-practice relationship is not conceptualised by positivists and interpretists as two ends of a continuum, with theory at one end and practice at the other. The difference between their perspectives concerns the relationship between the two. In this sense the positivist's end of the 'continuum' would view theory as preceding practice and informing it whereas interpretists would see practice preceding theory and theory being grounded in practice. My claim is that this enquiry has led me to a different view which is
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not simply a bringing together in some simple way of these two positions but is a more radical reconceptualisation. It has led me to a view of theory and practice as two inseparable aspects. From a practitioner’s perspective attempts to separate theory and practice are, in my experience, uneducational. This is particularly significant in the context of initial teacher education where theory and practice are sometimes seen as ‘separate’ by students, tutors and politicians (McNiff, 1993).

Therefore, in several areas of my enquiry my reconstructed understanding has led me to develop an holistic perspective to educational theory and practice.

12.3 The outcomes revisited

Chapter 10 provided a discussion of the outcomes to my enquiry relevant to adult learning - both my own and that of the adults I taught. Chapter 11 explored my own learning further in terms of the enquiry. The implications of these outcomes will now be considered.

12.3.1 The teaching of science in primary schools

It is unlikely that science will lose its status as a core subject within the National Curriculum and the teaching of science will remain a priority for primary teachers. This enquiry provides evidence to indicate that primary teachers can adopt a constructivist approach to teaching science and that such an approach is one many find congruent with the educational values they hold. The enquiry did not set out to provide evidence of the effectiveness of that approach in terms of children’s learning although evidence of that is available (Ollerenshaw and Ritchie, 1993; SPACE, 1990-92). The constructivist approach, if introduced as a framework which accommodates a variety of teaching styles and organisational strategies, is accepted by teachers as practical and educational. Since the enquiry began further pressure
has been exerted upon primary teachers to modify the nature of their teaching. These changes, although not addressed in any direct way during the enquiry, deserve attention at this stage. A recent DES report *Curriculum Organisation and Classroom Practice in Primary Schools* (DES, 1992a) set an agenda that the Secretary of State for Education, the Office for Standards in Education (OFSET, 1993) have referred to since it was published. Three key issues are: the teaching of separate subjects in primary schools as opposed to a more integrated topic approach (DES, 1992a, p21); the adoption of different organisation strategies (p27), particularly whole-class teaching; and the use of specialist teachers in areas such as science (p43). These issues require some primary teachers to question fundamental values they hold concerning their professional role. It is not my intention to rehearse the various arguments for and against different positions nor to articulate my own view. However, in the context of this enquiry, it is appropriate to address the extent to which the approach advocated through my teaching is able to accommodate the potential changes to primary practice under discussion. The first issue is unproblematic since the key criteria for primary science activities advocated through my teaching and discussed in the case studies (eg Concern 8) are relevance and the need to set science activities within a context that makes sense to the child and gives purpose to the work. Planning science work within an integrated topic is one way of doing this, but not the only way. Indeed, throughout the DES course, the emphasis was not on fitting the science into a topic, as it had been on previous inservice courses and in the literature (Ritchie, 1990b), but on orientating children to the specific science conceptual area selected by the teacher. The organisation issue is more problematic in that the use of whole-class teaching raises a more fundamental question about the nature of knowledge and how it can be learnt and taught. Explicit in the advocacy of whole-class teaching is the idea that knowledge can be taught didactically and transmitted from teacher to child. This is obviously at odds with the view of learning underpinning the constructivist approach. However, as stated earlier, a constructivist approach does not imply a particular organisational strategy. Although it is vital for a teacher to elicit individuals’ ideas and challenge those ideas this can be achieved through the use of whole-class, group and individual work. The DES Report (1992a) advocated a balanced approach and this is consistent with the
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constructivist approach. The OFSTED follow-up report (1993) reiterated this (p14). In my own
enquiry, there is evidence in each case study of whole-class, small group, paired and
individual work and therefore the teacher 'role-model' provided by me and other tutors was
one indicating the appropriateness of a balanced approach, but not one that involves didactic
teaching. This model included 'exposition' and provided an approach to whole class teaching
which could be used by teachers - using an interactive form of exposition rather than a
'lecture'.

The final issue concerns who should teach science. The enquiry was carried out in a context
where is was a requirement for every classteacher to teach science. It is my view that
classteachers, with their ongoing relationship with a group of children, are in the best position
to implement science in an effective way. This view is consistent with that of headteachers and
advisers, identified by HMI (OFSED, 1993, p13), particularly in Key Stage 1 and the first part of
Key Stage 2. There was greater sympathy amongst this group for 'semi-specialist' teachers in
Years 5 and 6. I am less convinced of the value of this since my own frustrations in secondary
science teaching concerned the difficulty of facilitating learning in science within time-tabled
slots. The more holistic approach possible in a situation where a teacher is with the class all
day was evident to me and my subsequent experience in primary schools confirmed this view.
However, this enquiry highlights the difficulties teachers find in teaching science and
improving the background knowledge and understanding of primary teachers is also, from the
evidence of this enquiry, not easy. Therefore there is some logic in proposing that specialist
teachers should take responsibility for science. 'Specialist' is used in this context to describe a
teacher who concentrates on teaching science to different classes of children, not just her
own; 'semi-specialist' would be a classteacher who took other teachers' classes for science
but retained a responsibility for her own class. Such teachers are likely to be more confident in
teaching science, and in principle, at least, have a sounder background knowledge in science
than other teachers in their schools. Although the 'specialist' would normally be expected to
teach science as a separate subject and in a time-tabled slot, there are ways in which team-
teaching or collaborative work can lead to the specialist teacher’s sounder knowledge base
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and the classteacher's knowledge of the individual children being brought together in the interests of the children's learning. Another issue might be where will all the specialist teachers come from? This thesis indicates that there are not sufficiently qualified science specialists within the system and therefore the need for professional development of teachers, even specialists, in primary science will continue for many more years. The nature of the courses and training needed for specialists is unlikely to be substantially different for the current model under discussion. In conclusion, therefore, my claim would be that this enquiry and its implications are relevant in a context where significant changes to the nature of primary education are proposed. The need for primary teachers and initial teacher education students to given support in the area of primary science will be essential, even if in the future the target group is 'specialist' rather than generalist teachers.

12.3.2 Implications of the enquiry for the inservice education of teachers

This thesis provides the first detailed account of a constructivist approach being used with adult learners in the area of primary science. It provides evidence that such an approach, used within the context of a substantive INSET course, is practical and results in outcomes in two key areas: improved scientific knowledge and understanding of the teachers involved and improved competence to teach science. The account is also indicative of the difficulty of using a constructivist approach and has highlighted some areas of concerns. In summary, reasons for the success of the approach and the DES 20-day Course it was used on were:

i. It was a teaching approach which was used with teachers consistently and was one that could be used by them in exactly the same way in their work with children;
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ii. It was an approach which encouraged learners to take responsibility for their own learning and allowed tutors to respond to individual needs;

iii. It required teachers to tackle science activities at their own level;

iv. As adult learners teachers were encouraged to reflect upon the nature of their own learning and use that reflection to help them understand the learning of children;

v. Tutors provided role models upon which teachers could reflect and the school-based days allowed them to try out new strategies in a supportive environment before exploring the same strategies with their own classes;

vi. The inextricable links between process and content/skills and knowledge and understanding were made explicit in terms of their own learning in science;

vii. Application of learning from the course to their own classrooms was structured into the course and based upon action enquiries over which they had control;

viii. Work with children and reflection upon the nature of children's existing ideas was used to help the teachers identify gaps in their own learning;

ix. Dissemination activities with less confident colleagues was used as another strategy for teachers on the course to apply their own learning in terms of scientific knowledge and understanding and pedagogy;

x. It was substantive and provided time for teachers to pace their own learning to suit their individual needs.
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It is hoped that other inservice providers will find these points helpful in terms of planning INSET. In particular the approach adopted clearly indicates how the enhancement of subject knowledge and pedagogical and dissemination skills need not be separated but can be integrated in an holistic way. It is my view that courses aimed at developing primary teachers' scientific knowledge base in isolation of classroom practice are unlikely to be as successful.

It is worrying that for many of the teachers involved in the courses it came as a surprise to be asked to work at their own level. It would seem that this had not been a requirement on previous inservice activities they had experienced. It raises a question of whether inservice providers have adequately challenged teachers in the past.

The analysis of the outcomes in Chapter 10 also highlighted an aspect of evaluating INSET which I consider to be innovative. The typology used was proposed by Kinder and Harland (1991) and I found it helpful. However, the success of the course and the approach was also a result, I consider, of the metacognition of the teachers in terms of their own learning. This is an outcome that does not feature in the typology and I consider deserves to be added. Encouraging metacognition is an outcome which could be given a higher priority by inservice providers.

My experience through the enquiry has also raised issues that also deserve the attention of other providers. These were discussed in more detail in Chapter 11 but as a summary:

i. Children's common alternative ideas should be introduced to teachers with an awareness of the possibility that these alternative ideas may become the 'accepted' understanding of the teachers in the future. It is vital that their 'alternative' status is reinforced and that accepted scientific ideas are revisited and emphasised.

ii. The social context of learning is vital, however, in that social context 'alternative'
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ideas introduced by participants can become the 'accepted' ideas of others unless they are identified and challenged by tutors. The status of the contributor can be significant in terms of the extent to which 'alternative' ideas are taken on as 'acceptable'. A confident course member can make intuitive ideas seem very convincing to a teacher who recognises gaps in her/his knowledge base. Tutor monitoring of such interactions or some form of record is essential.

iii. Eliciting existing ideas and encouraging learners to structure these ideas into more coherent frameworks may lead to 'alternative concepts' becoming 'alternative frameworks' which can be more difficult to challenge. It is therefore essential that the elicitation phase leads to tutor intervention to challenge ideas and encourage restructuring. Eliciting ideas without then doing something about it can do more harm than good.

iv. Restructuring is not a straightforward process and varies from individual to individual and from one conceptual area to another. It is necessary to be aware that some intuitive ideas, such as 'impetus forces' in moving bodies, are much more difficult to challenge than others.

v. The affective domain is one that needs considering when planning inservice activity in science and the need to provide a supportive and unthreatening environment for learning should be prioritised.

These points are revisited as a reminder for would-be users of a constructivist approach with adults that it is not unproblematic and should only be used with an awareness of these concerns and a commitment to deal with them.

A final point to make in this section, addressed to Inservice providers is to restate the extent to which a constructivist approach is not simply an approach to science inservice. My own
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experience and that of my colleagues has shown the potential of the approach in other areas. These include more generic courses such as research methods or assessment courses and other curriculum areas such as design and technology and mathematics. Staff at BCHE have recognised the value of a constructivist approach to work on all the new designated courses (history, geography and design and technology). A coherence of approach to INSET will, we hope, have benefits when coordinators engage in dissemination activities if other coordinators from their school have been on designated courses.

12.3.3 Implications of the enquiry for the initial education of teachers

The beginning of Chapter 5 highlighted the ways in which initial teacher education course and inservice courses can be conceptualised as similar in terms of the learners involved; the intentions and the context of the teaching. The investigative stage of my enquiry focused up work in inservice contexts. I also indicated in Chapter 10 that the emphasis of my work changed during the period of the enquiry and now involves less initial teacher education. However, the insights from my enquiry have implications for initial teacher education. Many of the points made in the last section apply to initial teacher education courses and I consider my enquiry to provide evidence to indicate that a constructivist approach can be used in initial teacher education. The importance of work with students over a period of time using a consistent approach and a common tutor is indicated by the success of the DES courses. One-off workshops are no longer considered effective in inservice education and an initial teacher education course made up of a series of such ‘workshops’ is also likely to be ineffective. A coherent and consistent approach which encourages metacognition as an outcome is as appropriate in an initial teacher education context as it is in an inservice context. At BCHE use of the constructivist approach with B.Ed students has led us to recognise the importance of student control of their own learning and self-assessment. This has resulted in the development of student profiles with specified competencies. These include explicit aspects of metacognition to encourage students to think about the nature of their own learning. The competencies specified in the profile include some related to the students’
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scientific knowledge and understanding as well as other related to the teaching of science.

The length of individual sessions has been raised earlier in this thesis. The sessions included in Case Studies 1, 2 and 3 were only 1.5 hours long. This proved inadequate for allowing the sessions to be structured in the way we, as tutors wished, with time for elicitation, intervention and review. As a result of our concerns about this future sessions were extended to 2 hours and 3 hour sessions remain an issue under discussion. This was an area where action research cycles were not able to address a concern and structural changes to the course and the college time-table were necessary.

Initial teacher education is undergoing changes at the present time and two particular issues are worthy of attention in the context of this enquiry. One concerns the pressures upon institutions to deal with ever-increasing student numbers without related increases in staffing. This leads to what is commonly referred to as stiffening SSRs - or worsening staff student ratios. In the context of the B.Ed. this has led to larger teaching groups and increased time for 'directed activity' to offset less direct contact with tutors. The use of directed-time has been informed by my enquiry since this time has potential for self-directed orientation and elicitation activity at the start of a new content area; use of distance-learning material as a resource during the restructuring/intervention phase; and independent problem solving activities as part of the application phase. Developmental work on the use of directed-time is at an early stage but potential exists for linking directed activities with the student profile.

A more fundamental challenge to the nature of initial teacher education has come from the moves, initiated by the Secretary of State (DES, 1992c), for more initial teacher education to be based in schools. Whilst there are many good reasons for this line of argument and my present institution has been moving in this direction by increasing the time spent in schools over a number of years it also raises a major concern in the context of this enquiry. An important part of initial teacher education in the present climate needs to be focused upon improving students' knowledge base. There is little likelihood that this situation will change
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dramatically for at least a decade, by which time all new entrants will have experienced the National Curriculum throughout their schooling and should be better qualified when they enter initial teacher education. However, in the meantime improving students scientific knowledge and understanding remains an important task. The key question is if the bulk of initial teacher education were to be based in schools how would this aim be achieved? The present knowledge base of most primary teachers is causing them difficulties in terms of teaching the National Curriculum for Science to their pupils - it is unlikely that they could adequately support student needs in this area. This concern is being voiced widely in the education press (Hart, 1992).

This enquiry has provided an example of a constructivist approach being used with B.Ed. students and there is no reason to believe that such an approach would not be equally effective with postgraduates on Postgraduate Certificate of Education (PGCE) courses. Indeed, colleagues at BCHE are adopting such approaches with success. I therefore feel confident in claiming it is an approach which is equally suited to student and teacher groups. In some ways, its use in initial teacher education can be more problematic in that it is an approach that takes time - content cannot be covered quickly. The early case studies indicate how much time was spent simply exploring and discussing a simple circuit of a dry cell and lamp. It might be claimed that much more content should have been covered in that time. My claim is that the pacing of those sessions was based upon the nature of the students’ existing understanding and their learning needs, not from my needs to cover specific content. The content might have been limited but I consider the learning to have been effective. It is therefore necessary, I claim, for tutors to defend a constructivist approach which may not allow the whole National Curriculum to be covered in the time available but that does lead to effective learning and to student understanding of their own learning which will enable them to work in their own time, and at their own pace, on material not covered in tutor-led sessions. In the same way as the DES 20-day courses did not attempt to cover all aspects of the National Curriculum Programmes of Study I consider initial teacher education courses should have limited aims.
12.4 A new approach to action research

My enquiry, as discussed in Chapter 11, had some innovative aspects which I will summarise, as my contribution to the literature on practitioner-centred action research.

It provides an example of an enquiry that involved a practitioner in dealing with a range of related concerns in an holistic way, intended to make a number of concurrent changes to practice and evaluate those changes through single plan/act/observe/reflect cycles. In other words, a range of actions were implemented and evaluated at the same time and the evidence collected used to inform decisions about all of these. To facilitate this two key strategies were employed: the use of a framework for analysing the concerns in terms of the nature and potential resolution; the use of multi-levelled analysis through a series of reviews over a number of months. These two strategies ensured that the complexity of dealing with multiple concerns did not lead to a reduction in the rigour of the enquiry. The reviews, which led to the data being revisited and reconsidered in the light of new evidence ensured a systematic approach. For the practitioner this multilevelled analysis can lead to new insights not evident from initial analysis and discussion with colleagues. The process can also lead to a developing awareness of the inter-relatedness of concerns and to the identification of key concerns which require most attention.

Additionally, a similar framework could be used to analyse a range of potential actions in order to decide upon the most appropriate/practical/efficient strategy available.

The framework and multi-levelled analysis, although used in an enquiry related to science education, and specifically the use of a constructivist approach, could be used in any enquiry although the categories might need adapting.

In the previous section the parallels between science education and action research were
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indicated and another parallel exists in terms of the framework. It is similar, in principle to a framework developed in collaboration with children and used to analyse the range of questions they were raising within a topic (Ritchie, 1991a) in order to decide which had most potential for scientific investigations. An 'impossible' category was not proposed by the children, although it might have helped them deal with one of their questions - 'How long is a snail's birthday'!

Another innovative dimension to the enquiry relates to the relationship between the self-evaluative and approach/course evaluation. My enquiry provides an example of how those two aims can be dealt with holistically in order for evidence to be used for both purposes. Recognising the evaluative purpose of my enquiry, beyond simply attempting to improve my practice, led me to collect data which was illuminating when considered as part of my self-evaluation. Similarly the self-evaluative dimension enriched my attempt to make evaluative judgments about the constructivist approach and my use of it. The discussion of these two strands has remained integrated throughout and as I indicated in Chapter 11, a clearer conceptualisation of these distinct strands earlier in the enquiry would have been desirable.

The collaborative dimension to my enquiry has some interesting features, in that in a context where co-teaching was involved, my enquiry was considerably enriched by the opportunity to observe other colleagues teaching the same group and receive comments from colleagues about my own teaching. This provided teachers on the course with further evidence of 'practicing what we preach' since as tutors we were encouraging them to recognise the benefits of collaborative work with fellow course members and with colleagues back in their schools. Our explicit use of a collaborative mode for our own professional development reinforced the value of this.

The other contribution I consider my enquiry and account make to the action research literature concerns my conceptualisation of the enquiry as 'constructive action research'. Chapter 11 provided a discussion of this in terms of the identification of phases of orientation,
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structuring, restructuring, review and application. The latter has particular significance in an account as a means of providing evidence that the changes an action researcher has made have become embedded in practice. The use of a constructivist epistemology to account for professional knowledge developed through an action research enquiry is the fundamental link between the 'process' and 'content' strands of my enquiry and it is through that epistemology that I consider those inextricable links can be articulated and the holistic nature of the enquiry be exemplified.

12.5 Coherence and holism

At the outset of this enquiry I did not realise the potential constructivism offered as a view of knowledge and a view of learning which would link all aspects of my thesis. It is this, that in the final stages of writing up, has excited me and renewed my enthusiasm for further enquiries. My understanding of constructivist epistemology is by no means complete and, like the teachers on the DES 20-day course who became aware of gaps in their scientific knowledge, I have become well aware of gaps in my own knowledge about knowledge through this enquiry. However, I have come to recognise the way in which a constructivist view of learning, with its recognition of the learner as the active constructor of her/his own knowledge and understanding, can be used to conceptualise learning at three levels: children's learning of science in the classroom; adults' learning of science and of professional knowledge in initial and inservice education; the development of my own professional knowledge through this enquiry. This has become the 'big idea' of my enquiry. It has enabled me to recognise similarities between children's learning in science and adult learning in science and the area of professional knowledge:

i. scientific and professional knowledge is provisional and subject to change;

ii. knowledge can be gained through the testing of ideas against experience and the ideas of others;

iii. all learners approach new learning with some existing ideas based on past experience or values they hold - whether it be children's ideas about how a toy...
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moves or teachers’ concerning how a classroom should be organised;

iv. the development of new ideas is a result of existing ideas and what learners do with new information and experiences;

v. learners will retain existing ideas unless they find them inadequate in some way;

vi. learners can benefit from time and support to structure existing ideas and articulate those ideas before having those ideas challenged;

vii. restructuring is an active process for the learner for which s/he needs to take (some) responsibility;

vii. new ideas, integrated into a conceptual framework are only of value if they can be used in new contexts, beyond the specific context in which they have been met.

Each of these statements holds, in my experience, whether the ideas are scientific or professional and whether the learner is a child or adult. The importance of knowledge development as an individual activity in a social context is also implied in these statements and holds true for scientific and professional knowledge.

If this epistemological foundation for the thesis is sound then the pedagogical implications in terms of an approach to teaching need to be examined in terms of whether or not they hold for adult learners and that has been the central focus of the evaluative aspects of the enquiry - is a constructivist approach effective with adult learners? The answer would seem to be yes, based on the evidence collected. However, this is not a claim that this approach is better than others, just that it is effective and based upon an explicit epistemology. However, the argument of my thesis is that the approach adopted, with phases of orientation, elicitation, intervention, review and application, is not only applicable as a pedagogical framework for teaching children and adults science but also provides a framework for conceptualising my learning throughout the enquiry. This would seem to add weight to the case for it being regarded as an appropriate approach to teaching. Of course, my own learning is not the result of teacher or tutor-structured learning in the same way as classroom learning or learning on inservice courses. My own learning has been self-motivated and self-controlled. However, there is no reason why a framework for teacher-use in structuring learning should not be
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equally relevant for individualised, independent learning. The explanation in Chapter 11 for my own learning in terms of orientation, structuring/elicitation, restructuring/intervention, review and application offers a framework for action researchers to conceptualise their work which, I consider, can enrich and enhance their professional development.

The coherence of the thesis also extends to the view of science which is underpinned by the same epistemological assumptions. That view of science, discussed in the first chapter (Section 1.11), is one which informed my teaching of science, and, I intended, the teaching of science of those whom I taught, and crucially the view of science which underpinned my enquiry and was discussed in Chapter 11. In this way the 'big idea' of constructivist epistemology generated a second order 'idea' of the nature of science, which also permeates the enquiry and acts as a cohesive factor.

The conceptualisation of these three key ideas - a constructivist epistemology, a constructivist approach to teaching and a constructivist view of the nature of science, provide the coherence for my enquiry in terms of its 'process' and 'content' dimensions. My desire to focus equally on 'process' and 'content' and recognise and develop their inextricable links has, I claim, had an holistic effect. Attempting to carry out such an enquiry and present it has been demanding for writer, and I anticipate, reader. However, I hope at this late stage the coherence of my claims is evident and the reader recognises that such an holistic approach has been more fruitful than the sum of the parts.

This enquiry has improved my understanding of science and of my practice through my attempts to improve the understanding of science and science teaching of those I taught in order that they could improve the quality of learning for the children they taught. I hope somewhere there is a five year old claiming 'I've just had a wonderful idea'.
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AN EVALUATION OF A PRACTITIONER'S APPROACH TO THE INITIAL AND INSERVICE EDUCATION OF TEACHERS IN PRIMARY SCIENCE BASED UPON A CONSTRUCTIVIST VIEW OF LEARNING

VOLUME 2

submitted by

Ron Ritchie

for the degree of PhD of the University of Bath

1993

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Case Study Volume - General Information

Introduction

This volume contains the case studies from my enquiry which are referred to throughout my thesis. Each case study consists of data collected during teaching sessions and an analysis of that data. The processes of data collection and analysis are outlined in Chapter 7 of the main volume. The analysis contains concerns, in the form of questions which were raised during reflection upon the data. The analysis also indicates proposed action at times. The detailed plans for each session have not been included although outline plans relating to sessions covered by Case Studies 4-9 are included in the main volume as Appendix 5.

The next page provides a list of all the case studies covered in this volume.

Each case study begins with information about the group involved, the session(s) date and time, the techniques used for data collection and the aims of the session.

The data section is followed by an analysis or analyses in cases where the data has been revisited (for example after interviews and classroom observations in Case Study 1). These are presented in chronological order. Each analysis begins with information indicating when it was written.

The data is presented in the following format:

9.10 RR Utterances (explanations) [actions]
bvbjhjkjkh . . . . (pauses in seconds) mnjguayihjb
hghjgjg . . . (indicates a period of time when data not collected or transcribed - not in seconds)

RR indicates my utterances and actions. Students are identified by initials or first names. In some cases (for example in the case of B.Ed. students interviewed and observed) these have been changed. Other tutors, in Case Studies 4 to 9, are identified by initials and named at the beginning. Again these names have been changed. S, S1, S2, Ss are used to label an unknown student(s).

The line numbering is continuous within each case study. Page numbering is continuous throughout the volume. References within the analysis sections are to lines in the data. For example (CS1: 35) refers to line 35 in Case Study 1. Concerns are given numbers in the analyses and these are consistent throughout the enquiry and referred to in Chapters 7 to 12.
## Details of the Case Studies

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Case Study 1: BEd Yr.4 Electricity

Group 1: Early Years (working with 12 with little or no previous experience of electricity and 4 specialism students on extension activities because they had experienced a similar workshop recently).

Session: Weds 18.10.89, 9.00 - 10.30am

Data Collection:
- Tape of full group discussions
- Students' annotated drawings
- Students' evaluation notes

Aims for the session:
1. To develop students' confidence in introducing simple electricity experiences to Key Stage 1 children;
2. To develop students' background knowledge and understanding of science up to and including level 4 (AT 11) of the National Curriculum;
3. To provide students' with an example of constructivism in action for adaption in their own teaching
4. To encourage the appreciation of the tentative and provisional nature of scientific knowledge.

9.00 Students were asked if they minded having the session taped for research purposes - all agreed. They were given a torch to handle in pairs and asked to produce a drawing to show how they thought it worked, without dismantling it.

9.10 RR We're going to look at electricity and that is why we've got a group working separately. They have gone through this kind of experience as a specialism group and are therefore going a bit further this morning looking at magnetism. It's not separating them because they're better, they've been through this before. My reason for doing electricity is that if there is any area of content used by teachers as a reason for their lack of confidence it's electricity. Many express concern and therefore if you can deal with that (electricity) it makes other areas of content less threatening.

I also want to put into practice the approach I outlined at the beginning of the term and I think underpins the whole course - that of starting from your ideas. I want you to think about that process - how I've elicited your ideas and based activities on those rather than having a prescribed session in mind.

It is very important to start any session on electricity with a health warning .... bulbs and batteries are OK, appropriate for young children and part of the National Curriculum but
Case Study 1: BEd Yr.4 Electricity

children must be warned never to play with mains electricity ...

With children I would start with a general discussion - what is electricity, what works by electricity? and then talk about the dangers.

There are some ideas about electricity elicited from children (aged 5 to 11) on the board over there for you to refer to.

There is also a yellow booklet (A Challenge Approach to Electricity, Avon LEA) available for follow-up work, please don't refer to it at this stage.

The first task was to draw how you thought a torch worked and we've already got some evidence to work from.

The principle of getting early ideas using familiar equipment (eg a torch) is one you should use in the classroom. What it immediately tells me is that you're all aware that there are batteries in a torch, there is a bulb and somehow there has to be some link between the battery and the bulb. I can also see many of you are unsure about how the bulb connects to the battery and so that's a good starting point to come in on.

Your adult experience will inevitably have told you that batteries come in different shapes and sizes.....

9.15 [RR shows a variety of different batteries and introduces a 4.5v flat battery]

I'm also going to keep a record on the whiteboard of your comments and ideas and any key words. If anybody this morning 'barks' (reference back to a term used in a previous session) a scientific word I might ask them to explain that word to us and so I hope we're going to do this in a fairly secure environment of being prepared to share ideas we may not be very sure about. It is very important that if this is going to work that you do share with us even your most shaky ideas - maybe you need to start with, "I think maybe ..." rather than necessarily making it a very clear statement. I'm going to put up the word 'connect' which I used and hope you are all happy about that meaning 'to join something up'.

So let's get straight into an activity that will help clarify perhaps what we need to know about how a bulb works and connections between bulb and battery. The task is simply to make one bulb light up with one battery (4.5v). Do it individually but then I would like you to be very clear about where the battery has to connect with the bulb and I would like you to draw a large illustration of a bulb and show in as much detail what's in a bulb and how you think it works. This may require annotating your diagram with some labels. In a few minutes we will draw together your ideas and see if we can agree a consensus picture of what a bulb is like and how it works.

This is going to be a fairly slow process and we might not get very far but I hope we'll all have a shared understanding of the ideas we've discussed.
Case Study 1: BEd Yr.4 Electricity

9.17 S Ah! (lights her bulb)

RR Close observation is important, look carefully at where you've
touched it (bulb on battery) to make it (bulb) work.

9.19 RR Go on try it on your own, it will be possible (to a student
having difficulties making bulb work who was watching her
partner).

RR Where do you have to touch it?
S1 The silver bit (base of bulb) on one and the black bit
(insulation at base) on another.

RR That's why I think close observation is necessary.
S2 No it's not (referring to S1's comments).
RR I think you've got an idea you're locked into, are there other
possibilities?

 RR Show where you connected the battery to the bulb.
I think I should push you to some labelling. You're doing
beautiful drawings but try and commit yourself to some labels.

9.24 RR What kind of materials are involved? Make a prediction and write
down what you think (to a pair).

9.27 RR Can we try and bring these together. When you change anything or
add to your diagram will you put a 'd' in brackets to show they
came from the discussion.
Everyone happy about the connections [draws battery terminals
connected to side and base of bulb].
Be aware many children will persevere with the idea that both
(battery terminals) must touch the bottom. Indeed adults hold
the same idea and there is no implied criticism of some of your
ideas - why should you think differently, you've had no
experiences to change your ideas. But we need to be aware of the ideas children bring.

What's inside (the bulb)? That's glass, that's metal [labels drawing on board].

BS Two wire things and then half way down there's a ... (insulating plug).

RR What is it?
BS I don't know.

RR Anyone got any ideas?
S Plastic.

RR What might its job be?
AT Insulate?

RR What does insulate mean [writing it on the board]?

AT Stop the current.
RR Sarah, what do you think?
SS To keep heat or electricity in.
ZP A barrier between two things.

RR We're thinking it might be some kind of barrier ...

Belinda can you go on with the explanation?
BS At the top there's a thin wire going across.
S It's thicker at the top.
ZP No it's not, it's a coil.
S Isn't that a filament?

RR Most of us have come across the word 'filament' [writing it on board] in domestic bulbs etc.
I want you to think about what's inside here. Terri come and bring your finger here.

What I want you to do is help us think about how the bulb might work. How do you explain to yourself what happens? How could you explain how a bulb works?

TW You have to use a battery and create electricity.
RR What happens to the electricity?
TW It converts energy? ... No ...

RR No suggestion? Any words associated with electricity that might help? What happens to electricity when say an electric fire works? ..... Any other ideas about how electricity might make a bulb work?

S1 Heat.
RR Where does heat come from?
S1 Electricity, it's changed.
S2 It's conducted.

RR What do you mean [adding word to list on board]?
S2 It's going round.

RR Now Terri, if we talked about a concept of electricity going round where might it be going round from?

TW From the battery.

RR Show me with your finger (on the drawing on the board) how electricity might be going round.

TW Say that (the bulb base) is connected to that (wire supporting
Case Study 1: BEd Yr.4 Electricity

RR Hang on you have made a big leap there - you said 'say that's connected to there'.

TW It is.

RR But that's not on our drawing so what must be inside?

TW Something to join that so the power from the battery is carried through that thin bit (filament).

RR So we're predicting that [adds line between base and upright on board drawing]?

Is anyone not happy? I think it's your personal responsibility to shout if you are not happy with anything we agree. But for the present can we accept with Terri that the electricity must get there (upright) and so there's a connection (to the base).

TW Can they both come up to make the bulb work [indicates with finger electricity coming up both pins and meeting in the filament]?

RR Terri has come up with an idea.

.... further discussion about where the terminals connect with the bulb ....

TW One must go to the bottom but that doesn't make sense 'cos you don't turn the battery round to make it work.

S Or when you touch the bulb it doesn't matter where on the side you touch it because it is all metal. There can't be a certain place that the wire goes to it must be drawn to the side.

RR Would it matter where that wire (points to line draw inside bulb base) touches if it's metal?

NA Metal conducts so it doesn't matter where it is.

RR This explanation [finger demonstration of electricity travelling from base of bulb, through filament and out of the side of the bulb base and back to the battery] seems to be reasonable but this contradicts Terri's idea that may be electricity is coming up from both sides and meeting in the middle. I want you to make a prediction. Put up your left hand if you agree with Terri's model and a right hand if you agree with the other model. [4 left 8 right]

We've got existing ideas that we need to address if we are going to help understanding.

BS Doesn't the electricity flow from positive to negative?

RR Would that help? Couldn't Terri argue that it comes from both sides?

Can we leave that for a minute and give more thought to how the bulb lights up?

ZP ... when electricity forces its way though a fine wire it heats it up so it's glowing white hot we see as light.

RR How many are happy with that [about 10 hands go up]?

Quite a lot. She talked about electricity forcing its way
through the thin wire.

NA Yes that's right, 'cos when the ... it gets too hot the filament
breaks and that's when the bulb goes. If you look at it when its
gone you can see that the filament is actually broken in half.

220 RR Is that true?

Ss Hmm

RR How could we test that idea that thin wire heats up and burns
out?

S Use a stronger current.

225 RR Yes, we could do that. We could by perhaps putting two or three
batteries together. I could give you a bulb with a finer wire or
perhaps equally if we take some very fine wire for example
brillo pad wire what's likely to happen if I put that (brillo
pad wire) across the two terminals?

230 S Heat up.

RR It might even give out light?

9.40 ZP Isn't it because there is a vacuum?

RR Hang on [RR demonstrates thin wire burning].

Its definitely giving out light for a little while.

235 TW Is that what you call combustion?

RR [writes word on board in brackets] I'm going to put that in
brackets and I think we might come back to that.

What did Zandra mean by 'vacuum'? Rather than challenge her why
has she introduced the word?

240 NA In order to catch fire you have to have air. There's no air in a
vacuum so it couldn't burn.

RR What's a 'vacuum', what's your concept of 'vacuum'?

S A sealed unit with no air.

245 ZP An area with its air removed.

NA In that case wouldn't it be like those coffee things .. vacuum
packed. There is air inside (the bulb) but no more can get in.

SI ......under pressure ......

RR If there is nothing in there what would happen to ...

250 SI It would collapse.

RR So there might be a small amount of air that gets used up.

There might be air under pressure ... I don't understand.

SI Pressure is lower ...

RR Less pressure?

255 SI No.

TW There's another gas like argon or neon, I don't know its name.

RR What could we say about it?

TW It's replaced the air or the oxygen.

ZP It's good at aiding conduction of electricity and not letting it
catch fire.

260 RR Why are we arguing there must be a gas in there? What were we
worried about?

S Without air it can't burn

RR Is that reasonable?
It needs something in there so it can't collapse.

I think we have explored that enough. The accepted scientific idea is indeed that there is another gas in there.

My boyfriend's got a motorbike and his headlight is a lamp that you can't touch, so that (small bulb) must be different 'cos you can touch this. His has got something inside it and the heat of a hand can ...

OK so there are different kinds of bulbs. With this bulb and domestic bulbs there is another gas inside that doesn't let things burn.

But it does, 'cos when the bulb blows the filament is broken.

Why?

A sudden surge of electricity?

Anything else?

Getting old.

Tired, worn out? Yes, it's going to start getting tired after it's had things happening to it like electricity being forced through it .. it will start getting tired, eventually it will wear out.

You hear a ping.

My explanation, for what it's worth is that it doesn't burn it just get's hotter and hotter until it gets tired enough to break a part.

... further discussion (poor tape quality) about the difference between burning and other changes caused by heating.

..

Heating can cause changes which aren't the same as burning.

Can we move on - it has taken a long time. Do you see how important it is to explore even the simplest of components and so often that's done in the classroom in five minutes. And with young children it requires a lot of exploration of their ideas.

What is the gas, hydrogen?

I don't know ... I don't have all the answers by any means. The word I have heard associated with this gas is 'inert'.

Does that mean it's not a vacuum?

No it's not.

But when you drop a bulb it implodes.

How do you know it implodes?

I dropped one a week ago - a fluorescent strip.

It just smashes doesn't it?

No it didn't, it didn't go all over the place and it made a different kind of sound.

I'm not sure about a fluorescent strip - I might suggest the gas get's out quickly and air gets in from the outside. I don't know, I'm into exploring my own existing ideas here!

Let's move on.

I think the next thing I can safely suggest is using a bulb holder.
Case Study 1: BEd Yr.4 Electricity

9.49 .... warnings about giving children bulbs in holders before they have had experience of where a bulb connects to a battery and the dangers of children using plastic covered crocodile clips and assuming electricity travels through plastic...

9.51 RR In pairs use two wires, a bulb and holder, a screwdriver and a battery to make a permanent circuit. Think about the questions children might ask. There I am introducing a new word, 'circuit'.

S No, we used it.

RR Thank you, I have been trying hard not to introduce words.

S Something going round, like a racetrack, continuous.

TW We didn’t sort out which way it goes!

RR No, I know. Hang on in there Terri, we need to go a bit further and come back to it.

9.52...

[Pairs work on constructing circuits - lots of discussion in pairs]

9.57 RR Sarah had a question about whether the wire got hot so we’ve stripped off the insulation. What do you think?

SS It might get hot slowly.

S Why has this gone off when you have got that piece of wire there (she had accidentally produced a short circuit with a small piece of wire)?

RR Can you keep quiet about that for a minute (to S). Will you all make a prediction. Put you left hand up if you think the bulb will stay on if I put this piece of wire across the battery terminals, inside of the wires to the bulb. Put your right hand up if you think it will go off.

[1 predicts it will stay on, 11 off]

It is quite an important strategy this (left and right hands) for getting everyone’s views efficiently.

[provides demonstration of short circuit]

It goes off.

What if the wire is on the outside of the wires to the bulb?

[8 predict on, 4 off]

It goes off [demonstrates new short circuit]. We’ve got an important area for exploration.

Why did it go off?

10.01 ZP If you try it with a very long piece of wire it will work (stay on), it will try and take the shortest possible route.

RR OK, Zandra has provided us with the first of our tests that if it’s to do with the shortness of the wire - I’m not quite sure how that helps us with the inside/outside issue?

360 ZP I don’t think it makes any difference, it was a red herring.

RR It was, but it is what a lot of people think and I think I was justified in throwing it in 'cos it caused a lot to change their
Case Study 1: BEd Yr.4 Electricity

opinion.

ZP But that was because you said it not because they thought it.

365 S Yes, 'cos the first one, if you haven't got a clue about and
then you guessed the second one. I put up my hand the second
time 'cos I didn't know.

RR OK a fair point but let's not waste a lot of time analysing it.
If I take a longer wire will the bulb stay on?

370 ZP It's not to do with the length but the ease of passage. So if
the electricity has got to go through the wire and the bulb ...

RR Will the bulb go out?

ZP Yes ... no.

RR [demonstrates - ZP laughs embarrassed] Now if you go for a much
longer wire? It's a very important idea so don't devalue your
own idea. What will happen?

S It will make no difference.

RR Does anyone think it will stay on? [no-one]
[Demonstrates - bulb glows]

380 Any explanation for the route electricity will take?

S The easiest.

RR Yes, I think of electricity as lazy - when we have a long thick
wire it was fairly hard for the electricity and some was
prepared to go through the bulb.

385 S1 Why though, I don't understand that - with this you have to have
two separate wires (to the bulb) and you've just got one.

RR All this is doing is giving the electricity a way of getting
from there (+ terminal) to there (-ve terminal). We still
haven't tackled whether the electricity is going from both sides
or around a loop.

S1 I would assume with one wire nothing would happen at all. Why
doesn't one wire work with the bulb then?

10.07 ... discussion (poor tape quality) ....

S ... bulb is extension of the wire, like part of the wire.

395 RR Let's see if we can do something about Terri's idea - I call it
Terri's idea but I know several of you share it. It didn't
matter which way round the bulb went so if we swapped the wire
it still worked OK. If I take a buzzer which is something else
we can think of as being 'in a wire' ... if I connect it like
this (black wire to +ve terminal) absolutely nothing. If I swap
it over it works [demonstrates].

BS Doesn't that work like a battery through positive and negative?

RR But the problem we're trying to confront is about electricity
coming from both sides or going round a circuit and there is
some evidence (with the buzzer) that might help - the way round
seems to be important. The other way we could look at that is to
measure the electricity using a meter. Here is another, using a
motor which reverses in direction if we turn it round
[demonstrates and refers back to a recent video of children
working with a buggy powered by an electric motor that was going
forwards and backwards].
Case Study 1: BEd Yr.4 Electricity

Therefore there is evidence for us to see some kind of direction in a circuit from one side to another. At the moment we have no evidence to say which way it’s going and I don’t think that’s particularly relevant.

But the idea of going round a circuit is the accepted scientific one. Your idea (to Terri) about it coming from both sides is a widely held idea but not the scientifically accepted one.

Are you saying that with the buzzer you have to have it a certain side. Terri’s theory implies it doesn’t matter which way round the wires go but that’s not true.

Does that seem reasonable?

Yes.

Terri, do you agree?

No!

Then how does your theory work for a buzzer? If you’re right why does it matter which way round it goes?

’Cos I thought like it was something to do with earthing one side.

I think with ‘earthing’ you are getting thinking about mains electricity rather than the sort of electricity we’re working with which is much simpler in terms of a circuit.

I think we’ll do a couple of other things ...

What kinds of materials conduct electricity?

or look at circuits with more than one bulb – like this problem [demonstrates an Xmas card with 3 real lights on a tree] – so that if you take one bulb out the others stay on.

But what’s happening in the battery?

I’m concerned we’ve spent a long time talking as a large group. But is that a general concern?

Yes (what happens in the battery).

Let’s pursue that. What are your ideas about what’s in the battery to make electricity?

It’s a chemical reaction.

Like in the battery in your car.

So it’s a chemical reaction. Young children have a concept of things being mixed together. I wouldn’t use the term chemical reaction (with them) but you can talk about there being substances in a battery so that when they mix together they produce electricity. But are they producing electricity all the time?

Isn’t it just when they are connected?

No they must be ‘cos batteries wear out.

Right, if you leave a battery on a shelf they eventually go off but it takes them much longer to run out but if you use a battery in a torch or circuit it will run out quite quickly.

If you have a battery in a torch that hasn’t been used it goes off really quickly.
Case Study 1: BEd Yr.4 Electricity

RR Does it?
ZP Yes, it runs out without necessarily being used.
RR But that takes months.
ZP I know what you mean.
465 RR Something does happen to the substances after a certain amount of time that means they can't produce electricity. My question is when are they going to get used up most quickly?
S When they are used.
470 RR A battery only produces electricity when there is a circuit available for the electricity to travel around. For primary aged children explanation doesn't need to go much further.
S What about differences with a car battery?
RR If you are asking for an explanation at your own level I could refer you to this book (How Things Work by Macauley). Because scientists aren't fully certain about how electricity is produced, they have ideas but their ideas are only their best ideas at the moment, they're not definite right answers.
...
[Further exploration in group of circuits and conducting materials]
...
10.25 RR You're trying to blow the bulb? Yes go on do it (to TW). That one (with two batteries in series) is much brighter isn't it?
485 (to group) Terri was determined to go back to one of our first questions - she's used two batteries and blown the bulb.
10.30 RR ... I hope, although we haven't got very far we have all gone away with a better understanding. You've constantly raised questions in my mind that I need to go away and think about more ...

Example of Student Evaluations (immediate and written)

495 TW After the lecture I did feel more confident in understanding how to explain electricity to children, but at my own level I feel still not 100% happy at how a circuit/battery works. I feel I needed more direction in where to take the explanation of electricity after the initial discovery - what type of lesson may this lead on to. I did however find the lecture interesting and beneficial for I have never been shown how to use simple materials to light a bulb.
...
BS A valuable session which allowed us to question our own ideas.
505 Not enough time - much better working in twos than larger group. Better understanding of electric circuits - still unsure about how batteries actually work though. Better understanding of a bulb and how electricity actually makes light.
...
510 ZP I felt the session worked well from the point of view that we
Case Study 1: BEd Yr. 4 Electricity

_all_ had bulbs and batteries to experiment with ourselves and we started at our own level - exploring ideas we had already formulated about electricity and how it functions. I feel a definite uneasiness with electricity due to my lack of experience and a session such as this is what I needed - starting with basic ideas and using language we were familiar with to explain how it works. I feel I would benefit from another session with electricity before I would feel confident about tackling it with infants - perhaps more facts and simple definitions from the lecturer so that I had a basic knowledge from which to work. I understand the method he was using - to make us explore/think through and solidify our ideas and felt this was successful - perhaps with more time more input from the lecturer would be possible. I felt a little hesitant about the tape recorder being on during the session, especially as I was sitting near to it, but I understand its use as a means of recording the session and I should not be put off by it.

..
Case Study 1: BEd Yr.4 Interviews

Interview - 26.3.90

These were conducted individually with Zandra and Terri

Data collection: Tape

530 RR By looking at these, can you tell me how a bulb needs to be connected in order to make it work?
ZP So that the metal protrusions from the top of the battery get to touch two different areas - the bottom and the side.
RR Now can you give me a description of how you think the bulb works in your own terms.
ZP The electrical charge in the battery - stored - is flowing through one metal thingy, through the bottom of the light bulb ... and passing through whatever structures it takes to get to the side of the light bulb and through the other thingy.
540 I can't remember but you have to assume there is some kind of wire to the side ... to make sure that ... obviously these two (base and side) are isolated from each other..
RR What was happening inside the bulb?
ZP The two protrusions, sticky up bits, with a very thin filament of wire connecting them and when this current passes through that thin filament it heats up and it lights up ... the charge going through it builds up cos its such a thin piece of wire and the charge is trying to force through it .. there is a resistance there. It causes it to get hot.
550 RR What does resistance mean?
ZP What it says, if something big is trying to funnel through something small there is a resistance.
RR Anything else about what's in the bulb?
ZP The whole thing's in a vacuum? What did we say it was? Or is it something else. I can't remember.
RR Which makes most sense to you?
ZP I just know if you drop a light bulb it implodes, doesn't it. So therefore the air rushes in so I assume it must be a vacuum.
RR Can we have a look at these four drawings ... will you look at each of these four and explain which one you are happiest with.
ZP The first one says there will not be any current in the wire attached to the base so it must be right.
RR If there is no wire there will it operate?
ZP No, if there's just wire going out and not coming back then it's not making a circuit.
RR Will the electricity leave the battery, get there (to the bulb) and stop?
ZP I suppose so.
RR Let's look at drawing B (electricity from both sides).
ZP That's not right. I'm assuming one's got to go one way and one the other way to make a circuit. How can that be? How can you
Case Study 1: BEd Yr.4 Interviews

make it go that way? ... a circuit to me means something going round.

575 RR These are just examples of how people explain circuits.
575 ZP Oh, I see.
575 RR Let's look at C.
575 ZP There is less current in the return wire. Yes, true.
It won't be the same (as in D) 'cos some of the current is going to be absorbed, heating the filament. I think C is right.

580 RR What can you tell me about how a battery works?
580 ZP It's a method of storing electrical charge .. you can get different kinds, chargeable and non-rechargeable. This is non-rechargeable. It is a chemical mixture in there designed in proportions that allow it to fizz away giving off a little charge. Once tapped it cannot be replenished.

585 RR Does it give off that little charge all the time?
585 ZP Presumably it's reaction was contained within the battery and the charge was meant to come out when its connected to something. But batteries do go off so I assume it's only got a certain life ... everything got a life ... maybe (it goes off) because the reactions done and that can only last for so long. The chemicals themselves go off when the terminals come in contact with each other.

590 RR Will it run down faster when connected?
590 ZP I suppose so ... I've never measured it. It depends on the make of the battery.

595 RR Would some batteries run down faster on the shelf than being used?
595 ZP Yes, a cheap battery not being used will run down faster than a Duracell. A cheap battery in a torch would run out before a cheap battery on a shelf. But it depends how you keep them ... if it's damp or not.

600 RR You haven't used bulbs and batteries on school experience so far, would you?
600 ZP If I found the equipment and (the right) attitudes. You meet the view that this kind of thing is not quite the kind of thing for reception.

605 RR Do you think it's appropriate.
605 ZP Absolutely, if I can do it they can.

610 RR Any reflections on the session?
610 ZP Yes I went home wanting to find answers to things ... 'cos we talked about strip lights and what was in them ... that's why I'm convinced there's not a vacuum in the bulb.

615 RR It's an inert gas. Did you look anything up?
615 ZP Yes, and I asked a friend.

620 RR Were there useful aspects in terms of organising science activities?
620 ZP Yes and no. The thing that bothered me most was that when children think of electricity they think of switches and lights (mains) not batteries. I would have difficult explaining
Case Study 1: BEd Yr.4 Interviews

electrical charge comes from batteries, although some will have
toys with batteries in.
RR Was there anything significant about the way of working?
ZP I'd go about it that way. You allowed us to have a go.... you
were trying to find out our misconceptions and things that we
thought and get us to explain what we thought and get us to put
them to everyone else.... I definitely go for the idea of
finding out what the children think and discussing it with the
group.

Interview - 29.3.90

RR Can you tell me how you need to connect a bulb to a battery?
TW You had to put that (the bulb) in the middle (of the terminals)
and make sure that (the base) touched either side.
RR Where?
TW I can't remember if they touch that (the bottom) or that (the
side). I'd have to test it, but I think the bottom.
RR Try it.
(Tries unsuccessfully at first then makes bulb light up)
TW There, they're both touching the bottom.
RR Are you sure?
TW Yes.
RR Try again.
(Tries again but bulb had blown and needed replacing) ....
TW One touches the bottom and one the side.
RR How does a bulb work?
TW The power had to go on a circuit round .... it must go up into
the bulb, across and back down.... the string bit .. filament
makes the light ... the filament passes the current.
RR What is is about the filament that makes it produce light?
TW The material ... phosphorus or something like that?
RR Do you remember any part of the session that dealt with that?
TW I remember writing it down but I can't remember what.
RR Do you remember the brillo pad wire?
TW Yes
RR What happened to that?
TW It frizzled.
RR Why doesn't the filament frizzle, what must be inside the bulb?
TW Some kind of gas.
RR What is special about it?
TW I don't know.
RR Have a look at these drawings of children's ideas about
electricity. Which do you agree with?
TW I think C is right because obviously its used .. it won't be the
same strength as it has used some of the battery's energy.
RR How does a battery work?
TW Obviously its some materials working with each other ... 
chemicals ... reacting.
Case Study 1: BEd Yr.4 Interviews

670 RR Do they react all the time?
TW No something has to stimulate them ... like the bulb or metal ... you've got to connect it, the battery's got to be made to make something work.
RR Look at A .. is electricity getting to the break and stopping?
675 TW I'd say there's no electricity in the wire, you only get it when there's a circuit.
RR Why does a battery run out?
TW The chemicals run out .. get used up.
RR Do they get used up more quickly if used?
680 TW Yes, but they do have a life expectancy.
RR What else do you remember about the session?
TW You had to have a circuit and how to connect a bulb.
RR Did you take anything away about how you might work with children?
685 TW Yes, how to first look at the bulb closely and let them have time to experiment ... don't show them automatically, let them find out, don't show them. If they find out it sticks with them. I can't remember (any more about) the session.
RR Why didn't you use electricity with children?
690 TW Confidence at first but when I felt more confident I had run out of time.
Group: Y1 children (Mark, David, Katherine, Jenny) working with Terri W

Session: Weds 23.4.90, 10.30am

Data Collection: Tape of full group discussions
RR notes
ZZ notes

Aims for the session:

1. To introduce the children to work on simple circuits.
2. To elicit the ideas children have about electricity.

10.28 TW Do any of you know anything about electricity?
J My dad got two lights, a cable, a motor and he put the cable between the lights and put the connection cables and he put the lights in the garden. They worked.
TW That's great, you seem to know a lot about electricity.

705 Did something happen to them?
J They lit up.
TW Have any of you seen electricity make lights work?
K In my house, in the classroom.
TW They're (the lights) not on

710 D It's too light.
TW Why do we need light?
K It's sun shining now.
TW Is that why we don't need it?
M Once, I think ... once ... If you touched it and it's on your hand might blow up and kill you ... there's an advert on the telly ... electricity, and a boy went in and they got killed by electricity.
TW Do you think it's dangerous? We've got to be very careful with it, have we?

720 M Yes.
TW Do you know what this is? [gives out bulbs]
K Light bulb.
TW That's right.
K There's electricity inside.

725 J When it comes out of here the motor works, my dad said.
TW Does it need anything else to make it work?
J It needs a motor with electricity inside it.
K It needs a plug.
TW What do we do with a plug? Do you think the plug is the electricity?

730 K Yes.
TW What comes from the plug?
Casestudy 1: School-based Session

J Electricity ... it comes into the wire.

735

TW What can you see inside the bulb? [gives out magnifying glasses]

J A little green thing with two bits sticking out.

....

? There's something holding them together.

J Electricity passes through there (the filament).

TW Can you see it David?

D I can't see it. I can see the two spikes.

K It's silver.

J It's like a spring and the electricity goes through the wires to a motor.

....

745

TW Can you see anything David?

D A green thing stuck inside there.

TW What else is there in there?

K Under the green thing there's loads of wire.

[TW gives out batteries]

750

TW What do you think you can do with this (battery)?

....

10.36 [K & J unsuccessfully try to connect bulb and battery, TW works with boys observing bulb - M unable to see filament] ....

J What it needs (to make the bulb work) is a motor and a cable.

755

TW So for electricity to work it always needs a motor and a cable?

J Yes.

TW What do we call this?

J A battery.

TW If I get a torch [finds one] it hasn't got any cable or a motor and it still works.

J It's got electricity but it's all inside there.

TW What have I got inside here?

J Batteries.

TW I haven't got any cables so what do you think is giving me the electricity?

765

J The batteries.

TW What happens if I take the battery out and then I try?

K Might work (with one battery).

[TW demonstrates that it doesn't work]

770

TW What do you think is making it work David?

M A cable or a motor.

10.39

TW What makes this work [demonstrating a bulb working when it touches the battery terminals]? There's another battery, I'll show you something? I haven't got any cables or motors. [K & J make bulb work, although think both terminals are touching the bottom of the bulb, TW demonstrates to M who tries]

D Oww [makes bulb light up]

TW It didn't hurt, did it?

780

D Oh, it's hot.

TW What makes it hot?
Casestudy 1: School-based Session

(to K) Look, I'm touching both together (at the bottom) and it doesn't work.

J You've got to do it straight. The light has to touch both.

TW Electricity comes from the bottom.

K You've got to do it straight and then goes back down again?

J Yes, it comes up one side and across and down.

TW Do you think it comes up the side and then goes back down again?

K Yes, it comes up one side and across and down.

J It goes across the middle.

TW It goes through the wire.

D It's (the battery) too hot.

TW Try this one (a new battery), this one's not too hot.

[David carefully makes the bulb work and observes it with a magnifier]

J The wire lights up and that (the bulb) gets hot.

TW Why is it working now (with bulb touching both terminals), but not now (touching one)?

K You can see the wire better when it lights up.

J It's lighting up in the middle 'cos that's where it gets hot.

TW Why is it working now (with bulb touching both terminals), but not now (touching one)?

K You can see the wire better when it lights up.

J It's lighting up in the middle 'cos that's where it gets hot.

TW Why is it working now (with bulb touching both terminals), but not now (touching one)?

K You can see the wire better when it lights up.

J It's lighting up in the middle 'cos that's where it gets hot.

800 ....

805 Is that what you think David?

M I think the same as Jenny.

K So do I.

D I don't know.

10.47 [TW probes D but he is reluctant to explore or comment, confirms others are clear how to connect the bulb to the battery.]

TW We've got some crocodile clips, what are they made of?

D Metal

J Plastic

K Wire?

M Metal at the end.

TW Do you think electricity is going to travel through the wire?

J Yes

K You've got to clip it on.

[Children explore using wires bulb holder and battery]

M You've got to clip the other one on (to D who does it but it doesn't work)

TW We'll have to play with it to see if we can make it work.

K You've got to clip it on.

[Children explore using wires bulb holder and battery]

M You've got to clip the other one on (to D who does it but it doesn't work)

TW We'll have to play with it to see if we can make it work.

M It's still not working.

[TW probes D but he is reluctant to explore or comment, confirms others are clear how to connect the bulb to the battery.]

J It's going on and off. It needs electricity?

TW Where is the electricity coming from?

J The battery.
Casestudy 1: School-based Session

TW So it's not coming from the bulb like you first thought.
TW What's happening?
K It's going around in circles.
D It's working! I put it on the battery and clipped these (crocodile clips) on that.
K If you do that (unclips circuit) you stop the electricity. It takes a while for the electricity to get out of the battery.
TW If we had a short wire would it get there quicker?
J Yes
TW If we look at David's (with shorter wires) do you think it's got more electricity going round?
K I don't know.

TW Do you think a battery goes on forever?
M No, it runs out of electricity. You have to charge it up with a charger. I've got a remote-control car and it works by batteries and you have to charge them up.

[TW demonstrates a motor connected to a battery - attaches paper to axle to make it easier to see rotation - each tries it and talks about how it works]

10.58 ...
K That's (the motor) probably what makes aeroplanes and things work (paper looks like a propeller).
J I saw inside a plane and it had a motor, it was a model plane.
TW Does a car have electricity? What does mum and dad put in a car?
M Petrol.
K There is an electric car - of the future.
J I saw a motor on a railway. It takes electricity in the tracks.
TW What have we decided ... where does electricity come from?
All Batteries.
TW That's right, in the beginning you all thought ... what did you think when I first gave you this (bulb)? You thought it had electricity in it.
J It comes from the battery and comes in circles.

INTERVIEW

RR Does the electricity come out of one side, go round here and in the other side or does it come out of both sides and meet in the bulb?

K,J,M think it comes out of both sides, D thinks it comes out one side and goes in the other.
Casestudy 1: School-based Session

Group: Y1 children (Gregory, Lisa, Jason, Kelly) working with Zandra P

Session: Weds 23.4.90, 11.15am

Data Collection: Tape of full group discussions
RR notes
TW notes

Aims for the session:

1. To introduce the children to work on simple circuits.
2. To elicit the ideas children have about electricity.

ZP I've got a story to tell you about this little chap (shows picture). But first, have you ever been inside a cave.

G Yes

ZP What's it like?

905 G Dark.

ZP Dark, yes .. do you think it might also be a bit cold and scary? This is Bloop, and where Bloop comes from everyone lives in caves... they want to make a light for their caves.

910 J He's got bright colours (picture of Bloop includes fluorescent colours).

[they investigate looking at picture between hands to see "in the dark"]

ZP What did you notice about that then?

L It's dark in there.

915 ZP That's alright because Bloop is used to living in the dark. He wants to live with a bit more light. Has anybody got any ideas about how we could make his cave lighter?

J We could get a light.

920 ZP What kind of light?

R I know, one of those things with candles in and you put fire in.

ZP ..... I know, a sort of lantern.

J I'd take a torch.

925 ZP It just so happens that in this box I've got a torch but ....

G I used to have a torch, but mine broke.

ZP Here's our torch, see if you can make it work. [gives torch to J who switches it on] Why do you think it's not working?

J Its got no batteries in and those ones don't work...

ZP I've got some batteries, how can you make it work?

930 G I'll try [ZP removes the top when G fails]

ZP Where do the batteries go?

J In there [points inside torch body]
Casestudy 1: School-based Session

ZP Let's ask K ...
G Can I wind it back up (screw on the top)?

935 ZP Let's see what K does first....so she's putting the batteries in...
J The right way.
[J replaces top and makes the torch work]

ZP Suppose Bloop now has gotta go home and tell everybody about the torch and how it works ... what would he do?
G He could take it.
ZP What if they ask him how it works ... shall we have a look and find out how a torch works?
In this box here ...

945 J Lights ... we need a little light.
ZP These little light bulbs ... have one each ... what else do we need?
J Something to go on there (the bulb) ...
ZP Wire

950 J Metal
G A switch
ZP Lets look and see what we’ve got (in the box)
J And glass [ZP produces a switch]
G Where’s the switch?

955 ZP What else do we want .. we’ve got a light bulb, wire .. what do you think it’s made of?
G Plastic/wire.
ZP What’s inside?
G/J Wire

960 ZP And what is wire made of?
K Metal
ZP What else do we need to make the light work? ... What did K put in?
J Batteries.

965 ZP Do you think we need a battery?
We've got these kind of batteries (4.5v).
Have a battery each.
Who thinks they can make their light work now?
[G makes bulb light up immediately]

970 G The metal has to touch the other metal.
ZP Show L, tell her what you have done.
[G takes L’s and shows her how to make it work .. K succeeds ...
L succeeds]
J I did it a minute ago but it stopped.

975 ZP Is it important do you think to put the bulb carefully on top of the battery or can you put it on any old how?
G Carefully
ZP Let me see if I can do it. How do I do it? [G takes ZP’s bulb and battery and shows her how to light it, she tries gain]

980 Mine's not working, can you help me, J?
L It's easy, you have to put it up the side.
Casestudy 1: School-based Session

J The black bit on the bottom's got to touch.
ZP I've got the black bit touching J, now what do I have to do?
J Copy me

985 ZP So the black bit's got to touch the bottom and the side's got to touch as well?
J We don't need this the wire)
There's another way.
I need another battery.

990 ...
L When you put the light on and put your hand over it it makes it red.

....
K When it's on it feels hot?
ZP I wonder why?
G I know, because it is light.
...
ZP What do you think is in the battery to make the light work?
J Gas

1000 K Heat
G Electric
ZP What do you think L? ....... you don't know? ....
G In a cave it would be pretty titch!
ZP Too small?

1005 L There could be a battery inside it.
ZP A battery inside the light bulb?
L Yea
ZP If there was battery inside the light bulb, would it work on its own?

1010 L No
G You have to put it on metal.
J Or put a switch.
K What do you think K, do you think there is a battery inside the bulb?

1015 K No
[G exploring the bulb and battery]
G It goes off when I put my finger on it.
ZP Why do you think that is?
G ... cos there's shadow.

1020 ZP So the shadow from your finger makes the light go out, does it?
G Yes
ZP [gives out bulb holders] Has everyone got their lights in a holder?
Have you seen these things before (wires with crocodile clips)?

1025 J Wires and clips.
G Crocodile clips.
ZP Why are they called crocodile clips?
G 'Cos their mouths are full of teeth.

11.23 G [ZP gives them two] Why do we need two?
1030 ZP Let's see who can make their bulb light up using the wires.
[L asks ZP to clip hers on to the plastic parts of the holder]
[K succeeds, L tries putting bulb holder on to battery terminals.]

L I think the battery's run out.

1035 J I don't
ZP Try this bulb, has the battery run out?
L No
G I'm going to try it a different way.
J I can't 'cos I've got to put the screws back in.....[succeeds]

1040 ZP J, look at what L's doing. is it the same as you?
J No [J shows L], Your battery's run out. I cheated, I took the screws out....
That's (L's) run out I can tell.
ZP How can you tell?
J They've got to be quite heavy and that one isn't!
L It has run out, it won't work.
ZP K's is working. K you look at L's. Why's hers not working?
What's different?
G I'm going to try it a different way.
[puts L's connectors on the screw terminals]

1050 ZP Why has it got to go on the screws?
J 'cos that is connected up
[has 2 clips on one terminal]
ZP (to G) Has it got to go on the same one?
G No [succeeds]
At least I made it work.
ZP Who is going to have a go at telling me what they think is happening?
G When these (clips) go on there (bulb holder screws) it goes in there (bulb) and it doesn't light and then the wires go here (battery terminals) and it turns on.

1060 ZP What makes it turn on?
G The battery.
ZP An what's inside the battery?
J Electricity.

1065 G Electricity.

ZP I see.
L If you put the battery in it works.
G It's not working now (turning off) when I put my finger there.
ZP So your shadow doesn't make a difference?

1070 J Where does the electricity come from and where does it go to?
G Up through there ( terminals). If you haven't got any wires it stays like it, it's wasted.
K ... when you touch it it lights. Electricity comes out and makes the light light.

1075 ZP It goes through there, and up there and the light works.
G I think you've worked very hard to make the light work.

INTERVIEW
Casestudy 1: School-based Session

1080 RR Let's look at this one (circuit) Where's the electricity at the moment?
   J In the battery, no in the light.... no in the wire, it travels
   ...
1085 G No, in the light it goes up there (wire from battery),
   through them (screws) in there (bulb).
   RR The first time your finger went down that wire ...
   J It's only that wire that does it.
   RR So you don't need this wire (other wire connected to battery)?
1090 J Yes, it must have something to do!
   RR What do you think G?
   G It comes down one side ..it goes through there (screw on bulb holder) it goes up there (into bulb) and it lights.
   RR What does it do then? ....
1095 Is there any electricity in this (other) wire?
   G Yes, if you take this one off ... this one (other) has to have one on the other side to light. There's not that bit, so you have to ...
   RR Do you think electricity is coming up both wires or one?
1100 G Both
   RR What about L?
   L If you take that (one wire) off .... some heat makes it ...
      (inaudible) ... somebody puts the electricity in ....
      (inaudible)
1105 RR K can you tell me how you think electricity is making the bulb work.
      K (inaudible)
      RR Does anybody think electricity might go down one side and back the otherside?
1110 [all shake heads, although G not quite sure]
Analysis of Case Study 1

Group: Early Years B.Ed Yr. 4
College session: 18.10.89 (Electricity)
1st analysis: 23.10.89
Interviews: 03.90
School-based sessions: 23.4.90
2nd analysis: 25.4.90

The nature of the teaching approach

The session lacked an explicit orientation phase. The students had been given several weeks notice of a session on electricity, electricity had featured briefly in a video they had worked on two weeks before and as they arrived they were encouraged to handle torches, think about how they worked and immediately try and draw a diagram to illustrate their ideas. However, when the session formally started I provided no further opportunity for unstructured exploration of the materials and equipment. Although it may be reasonable to assume all of the students had already had a variety of experiences in their everyday lives that should have helped them form ideas about electricity an orientation phase immediately prior to the session, or as an introductory orientation activity, may have been appropriate.

To what extent should I ensure an orientation period for adult learners?

The constructivist approach being adopted was made explicit to the students (CS1: 11) and they were referred back to a more extensive introduction two weeks before. The approach had informed work on the course but this was the first time that it had been made so explicit to them. The student evaluations indicate that several of them were able to appreciate the two dimensions involved - the use of the approach to develop their own knowledge and understanding and the demonstration of the approach as an example for them to adopt in their own practice.

The latter was reinforced on a number of occasions during the session by making reference to the implementation of the approach in the classroom and through examples from work with children. A number of teaching strategies were encouraged which are outlined in a later section on classroom practice. The students were also provided with examples of ideas elicited from children of the whole primary age range (CS1: 24). Other evidence of the approach being made explicit
include the use of the whiteboard to record shared ideas, words used and the meanings given to them. This is an important strategy for several reasons. It provided me with a developing record of the session and the ideas we had agreed, but perhaps more importantly it was an indication to the students that their ideas were valued, being taken seriously and were the basis for the shared understanding we were striving to achieve. It was also a clear indication of the need to be careful, in a classroom situation, of assuming understanding if the correct word is used and of putting too much emphasis on providing the right word and an accepted scientific definition before the need arises and the learners are able to understand the word's meaning. Firm ground rules about the use of scientific words were established (CS1: 42). I was careful not to introduce new words into the discussion and indeed apologised (CS1: 324) when I thought I had introduced "circuit" before others had used it. I clarified the meaning individuals gave to words when they were introduced (CS1: 129).

Should I introduce appropriate scientific words if they do not come from the group?

On two occasions, at least, I made mention of the time needed to work in this way. Near the beginning I warned the group (CS1: 65) about the slow progress we were likely to make and thirty minutes later (CS1: 293) reminded them of how long it had taken to explore our ideas about the bulb.

The session was underpinned by the assumption that all of the students brought existing ideas about electricity to the session. There is clear evidence of attempts to elicit these existing ideas and in some cases they needed encouragement to expose these. The use of drawings was useful but there was a tendency for them to concentrate their efforts on the quality of the illustration rather than the annotation (CS1: 103).

What other strategies can I use to elicit students' existing ideas?

The students' ideas were taken seriously (CS1: 184) and used as the basis for further discussion or investigation throughout the session and there was little evidence that any of them were threatened by this, even when (as in the idea referred to above) the idea proved unacceptable to the rest of the group without modification. It was made explicit to the group that their existing ideas were in for critical scrutiny (CS1: 205). Although they were also reminded not to "devalue" the importance of their own existing ideas (CS1: 375). I also shared my own concerns about my existing ideas and the extent to which they were under scrutiny and perhaps in need of restructuring (CS1: 308).
Throughout most of the session the questions I asked and the activities I suggested provided the basis for the elicitation of their ideas and in this way I had quite a tight control of the session's direction. However, there were examples (CS1: 334, 337 and 370) when the ideas arose naturally from the exploration. The latter provided an appropriate link with further development of the students ideas about short-circuits. The session also developed in a direction I had not anticipated in response to the student question about how a battery works (CS1: 440). At this point I expressed my concern about the need for more practical exploration but the opinion of the group was that further group discussion was desirable. The size of group made this amount of group discussion somewhat problematic but none expressed concern about this during the session or in their evaluations.

Should sessions be so tightly structured, paced and controlled and should this depend on the particular content involved?

The extent to which students restructured their existing ideas during the session is a crucial question. There is evidence that Nicola (NA), who appeared to hold the idea that electricity entered the bulb from both sides of the battery was convinced by the evidence offered and indeed made a very clear restatement of that evidence (CS1: 420). However, Terri seemed less convinced (CS1: 426) and categorically refused to accept the evidence (CS1: 400) or the explanation offered. Zandra introduced the idea of the bulb containing a vacuum (CS1: 232) and although the discussion went on for several minutes about why it couldn't be a vacuum and what kind of gas might be in the bulb she still asked for personal confirmation (eight minutes later) that her initial idea was incorrect (CS1: 300) and was prepared to continue to look for evidence to support her idea (CS1: 306). This seems to be an indication of her holding on to her existing idea very strongly in the light of considerable argument to counter it. Whether she restructured her idea is questionable.

How can I collect evidence of students restructuring their ideas?

The session finished with a reminder (CS1: 474) that secondary sources of information can be necessary for confirming accepted scientific ideas.

Although the session included the opportunity to apply ideas to a specific problem (CS1: 438), too little time was available for this and no attempt made to encourage further application of these ideas through a directed task.

How can I encourage students to apply their restructured ideas in novel situations?
Encouraging socially constructed understanding

Although a constructivist approach recognises the individual is the active constructor of their own understanding the role of others in that process is also vitally important.

This aspect was addressed early on in the session by my request for the creation of "a fairly secure environment" (CS1: 45) in which individuals could share ideas. I also stressed (CS1: 65) that we were attempting to construct a "consensus" model and a "shared understanding" of the ideas discussed. At one stage (CS1: 176), I stressed that it was their personal responsibility to indicate if there were any aspects of the shared understanding that they were unhappy about. On occasion, particular ideas became associated with the individuals who first introduced them such as Terri’s idea about flow from both sides of the battery (CS1: 200). However, the group were encouraged to appreciate others shared the same idea (CS1: 396) and that it was a group responsibility to explore the idea to agree or reject it. I restated the nature of the shared understanding at the very end of the session (CS1: 480) in an attempt to emphasise this aspect of the session.

I was conscious of the need to have an indication of the ideas individuals held and those that were constructed within the group. For that reason I asked them to indicate on their drawings any additions or changes made during discussions (CS1: 109).

There were several examples during group discussions of how different individuals within the group contributed to a shared understanding. The discussion about the bulb’s filament (CS1: 135) illustrates this. There was, as already noted, an example of an individual taking on other’s ideas and restating them in an attempt to make them their own (CS1: 420)

There was an implied criticism of my manipulation of the way ideas developed, particularly the way I introduced the "red herring" about short-circuits (CS1: 360). This deserved further attention within the session but I decided time did not allow this (CS1: 368).

The nature of science implicit in the session

There were several times during the session when I made statements relevant to this. The tentative nature of an individual’s scientific ideas was indicated early on (CS1: 48) although the invitation to prefix remarks with "I think maybe ..." was not taken up during the session. Later the term "accepted scientific idea" (CS1: 266) was used as opposed to "fact", even though in the particular example, about the gas in a bulb, it would have been reasonable to imply more
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certainty about the information and this may have been misleading to the group. During the same discussion I also reminded the group that I did not have all the answers (CS1: 298) and later suggested that scientists do not have all the answers either (CS1: 275).

The session depended on students developing their ideas through practical exploration and investigation although the inextricable links between the two National Curriculum Profile Components may not have been obvious.

Another interesting issue that arose was the extent to which process skills, like observation, are influenced by individuals' ideas and theories. The evidence that observations were being influenced by existing ideas is clear when they were making statements about where the battery terminals touched the bulb (CS1: 91). Several came to the session believing a bulb needed to touch both terminals at its base and convinced themselves that that was what they were observing, even when questioned closely about it (CS1: 77).

What view of science do students take away from sessions like this?

Alternative frameworks held by individuals

As already mentioned several students held alternative ideas about where a bulb needed to make contact with a battery or wires from a battery (CS1: 77). This finding is similar to Shipstone's (Driver, 1985, p34) findings with children. Others have looked at (children's) alternative ideas (Arnold & Millar, 1988 pp149-51). The idea about electricity travelling from both sides of a battery and meeting at the bulb (CS1: 181 and 327) has been found to be commonly held by pupils (Harlen 1985a, p13). The evidence offered to counter the idea may not have been convincing enough and needs further thought.

Another student talked about electricity "being drawn" to where the wire connects (CS1: 193). This was not probed further and deserves further exploration. Of a similar sort is the idea that a gas "aids conduction" (CS1: 259). The students' ideas about vacuums (especially Zandra's) (CS1: 259) appear not to match an accepted scientific idea.

Many of the group appeared to hold ideas about short-circuiting (CS1: 391) which needed restructuring although there is evidence that this evidence is based on their guesses rather than explanations (CS1: 365).

Zandra had ideas about batteries running out quickly without being in a circuit (CS1: 459). This would should contradict with her everyday experience although she claimed to have specific evidence
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to support her idea.

There are other areas where it is possible alternative ideas were fostered or not elicited and challenged during the session. For example, when a circuit is broken did students hold the idea that electricity flowed to the gap and then stopped? Others are discussed in my evaluation of the session below.

Supporting the students’ work in the primary classroom

At the beginning of the session I discussed the way in which electricity could be introduced to children, stressing the safety aspect (CS1: 18) and the need to talk about their everyday experiences of electricity (CS1: 20). Unfortunately, I did not stress the importance of an appropriate context for the work with young children (Lighting a model room, eyes for the 'Iron man' etc). This was addressed implicitly much later in the session when the Xmas card problem was posed (CS1: 438).

How can I emphasise the importance of context for scientific activities with children?

When eliciting children’s ideas I suggested the use of familiar items such as the torch they were using (CS1: 31). I introduced some strategies for eliciting everyone’s ideas like the use of left and right hands (CS1: 205 and 346) but did not explore other means of eliciting and recording children’s ideas, such as floorbooks. The process of a constructivist approach in the classroom was illustrated and I "stood outside" my role on occasions and highlighted key points. These included the importance of less structured exploration and not rushing children through experiences (CS1: 295); the dangers of using bulb-holders and plastic covered clips before the children have had appropriate experiences with bulbs and bared wire (CS1: 314) and considering the questions children may ask (CS1: 321).

General Concerns

There were several occasions when I used the term "predict" (CS1: 174, 204, 341) and I am concerned about whether it is appropriate use. Most ended up guessing since they had no experience on which to base their "prediction".

When should I use the word "predict" and do I understand its meaning?

The group dynamics and the confidence of individuals are key to the success of this approach. I "picked on" individuals several times to offer their view (CS1: 143). There may be considerable risks in
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terms of the group dynamics of doing this, especially if it is a group I have not worked with before.

To what extent should I encourage individuals to expose their ideas?

There is also a concern in my mind about the extent to which individuals dominate the group discussion (CS1: 212 for example). There were a number of students in this group who offered very little in the large discussion and were not responsive to encouragement to share ideas.

There were examples during the session when I did not confront student's existing ideas that did not match accepted scientific ideas (e.g. the exploding bicycle lamp (CS1: 268) and the earthing of circuits (CS1: 429)).

Should I deal with every alternative framework identified or focus upon common ones?

I used a number of metaphors to explain ideas such as the "tired, worn out" wire (CS1: 280), "lazy" electricity (CS1: 282) that I feel unsure about.

To what extent did the metaphors I used foster misunderstanding in the students?

There were other examples of my use of language that may have caused students to retain existing alternative ideas or indeed develop new ones. The explanation I offered about how a battery works (CS1: 448) and the way I dealt with "earthing" (CS1: 431) need further consideration.

Finally, I am left wondering whether the evidence I offered students to counter Terri's idea (CS1: 181) was adequate to cause them to reconsider their idea. Is there a better way? Should I use meters to indicate the direction of flow? Could a computer simulation be used?
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Comments after interviews in March 1990

Zandra and Terri were chosen for follow up interviews because of their interesting responses in the sessions and because, as their professional studies tutor, I was aware that they had very different teaching styles (ZP thoroughly planned and organised, TW more spontaneous and casual).

Zandra provided some very encouraging answers during the interview indicating that she had retained a considerable amount from the specific session and her follow-up reading. She clearly remembered the session content. When asked how to connect the bulb and how it worked, her response was immediate and fairly complete (CS1: 533, 544). Her use of "electrical charge" was interesting since the term wasn’t used during the session. Her use of the term (CS1: 536) initially seemed correct but later she uses current and indicates an alternative idea in terms of current being "absorbed" in the bulb (CS1: 578). Her understanding of resistance is reasonable (CS1: 551). Surprisingly, her immediate response to what the bulb contains was a "vacuum" (CS1: 554). This was the same as her response in the session (CS1: 259) that was discussed on page 32 of this analysis. However, later in the interview she returned to this herself (CS1: 613) and contradicts herself by saying, "I’m convinced there’s not a vacuum in the bulb". This was as a result of reminding herself of the discussion and reading she had done after the session (CS1: 615). When exploring ideas about circuits, she confirmed my concern (page 33 of this analysis) about student’s thinking electricity flowed to a break in a circuit and stopped (CS: 568). She offered a good explanation of how a battery works (CS1:581) and the alternative idea about battery shelf life (see page 32 of this analysis) is no longer held.

Her general comments about the session are nearly all positive and her point about relating bulbs and batteries to children’s experience of mains is well made and worth attention. Her summary about the approach and its appropriateness (CS1: 624) is particularly pleasing.

By contrast, the interview with Terri was less positive in terms of ideas retained and awareness of the approach adopted. Her answers were limited in scope and needed constant prompting. She claimed to remember very little about the session. Her inability to even remember how to connect a bulb is disappointing (CS1: 637), although she did through practical activity find the correct connections. She held on to her restructured idea of a circuit and electricity flowing around it. This contrasts with her idea in the session of electricity entering from both sides of the battery (C1: 181) and suggests my concern on page 32 of this analysis is unfounded. She retained the idea that the bulb contained a gas (CS1: 60) but could
not remember why. This suggests recall of knowledge but lack of understanding. She demonstrated an alternative idea, not evident during the session about the current returning to the battery being less than that leaving it because, "it has used some of the battery's energy" (CS1: 666). Her explanation of how a battery works was reasonable (CS1: 668). She did not hold the same alternative idea as Zandra about electricity flowing to a break in a circuit and stopping (CS1: 675). Her views on approaches to classroom work taken from the session (and one can presume other similar sessions) is acceptable as far as it goes but it is rather limited.
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Comments after school-based sessions in April 1990

Zandra and Terri both agreed to be observed working with a small group of infant children. They were asked to plan a 45 minute session to introduce the group to simple electric circuits.

Both sessions show considerable evidence of the students using aspects of the college session they had experienced six months before.

The nature of their teaching approaches

Both students had planned and implemented sessions that provided the children with practical activities. There is also evidence that they both set out to establish the children's existing ideas. TW begins her session with an eliciting question (CS1: 700) and there are numerous examples throughout ZP's session (eg CS1: 927).

Neither provided opportunities for much free exploration and there is little orientation although TW begins with an attempt to start from their previous experience (encouraged during the college session, CS1: 20) and ZP sets the scene with a story she has written especially (CS1: 900). This is particularly interesting since it provides a context for the work with children of the type I had suggested, but not provided, in the original session (CS1: 438 and analysis p29). The children seemed to have responded well to the context and much later in the session (CS1: 1003) Gregory explicitly refers to the story line. There is some evidence that the story and the pictures used diverted the group away from concentrating on electricity (CS1: 909) when they started exploring whether they could see Bloop in the dark. However, it provided a need for a torch (CS1: 918) and a purpose for explaining how it worked (CS1: 928).

Although I had stressed the need for safety warnings during the college session neither introduced this to the children. TW did respond to a child's comment about safety (CS1: 714) by suggesting the need for care, but did not distinguish between mains electricity and batteries in terms of safety.

ZP and TW were generally good at letting the children try things or themselves, although TW did demonstrate how a bulb worked (CS1: 773) before they had had time to try and discover a way of doing it on their own. Nevertheless she had the children handling the materials very early in the session and they were attempting to light a bulb within six minutes of the start. ZP had the children handling the torch almost immediately (CS1: 930). The length of the session also meant that in neither was there adequate time for the children to carry out the practical exploration that would have been desirable. The fact that this was not provided in the college workshop may be
significant in this respect although I did encourage them to provide plenty of time for free exploration (CS1: 295).

It was encouraging that both students drew out key words from the children (CS1: 757) and rarely introduced their own words. This shows adoption of the approach used in college sessions (analysis p26).

There is also evidence that other suggestions made during the college session were used. For example, they had been warned about the problems using a bulb holder and crocodile clips can cause (CS1: 314). Both introduced the bulb holder after work with a simple bulb (CS1: 821; CS1: 1023) and discussed with the children how electricity was travelling through wires, before using the crocodile clips (CS1: 815; CS1: 958).

As noted, both students successfully elicited the children's ideas about electricity and checked their understanding throughout the session. For example ZP asked the children what was needed to make a bulb work (CS1: 963) and then asked the children to explain why she had not managed to make her bulb light (CS1: 978). She also used the strategy of getting one child (who had been successful) to explain why another child's circuit was not working (CS1: 1047).

TW picked up acceptable scientific explanations, offered by the children and encouraged them to develop them. For example, Jenny talked about electricity "passing through" the filament (CS1: 738) and "going round" (CS1: 805). However, she failed to develop a latter comment from Jenny about the bulb getting hot (CS1: 794).

Evidence of children's alternative ideas

Katherine suggested "there's electricity inside (a light bulb)" (CS1:724) and also thought a plug had electricity in it (CS1: 731). Jenny believed "a motor with electricity inside it" was needed to make a light work (CS1: 727) and developed the idea of a motor (CS1: 743). This may simply be inaccurate labelling since later, when the term battery had been introduced, she corrects herself, "electricity comes out of the motor .... the battery" (CS1: 803) or confusion as a result of her everyday experience (see below).

In ZP's group, Lisa thought there was a battery inside the light bulb (CS1: 1005) and Gregory thought a shadow could turn off the bulb (CS1: 1019). Jason thought a battery that had not run out weighed much more than one that had (CS1: 1045). He also said of an incomplete circuit, "If you haven't got any wires it stays like it, it's wasted" (CS1: 1072). This was one of the areas of concern I had about students' understanding after the college session (see analysis p29) and an alternative idea that arose in CS2 (CS2: 436).
The interview after both sessions indicated seven of the eight children thought electricity came into the bulb from both sides of the battery (CS1: 875, 1020). Only David thought it went around the circuit. Neither student pursued this aspect during the sessions. Another area of concern relates to ZP's treatment of where a bulb needed to touch the battery terminals. She stated, "So the black bit's (insulation) got to touch the bottom and the side's got to touch as well" (CS1: 985). This would seem to indicate a misunderstanding on her part since she never corrected herself nor recognised that the child was making an inaccurate observation. This is surprising since she was clear during her interview (CS1: 533) of how to connect the bulb, indeed far more confident and accurate than TW. It is of particular concern, in the light of the original workshop, since considerable emphasis was placed on this aspect of circuit work.

Evidence of children drawing on their everyday experiences

There is some indication about the origin of the children's existing ideas. Jenny tells us about her dad's electrical work (CS1: 701) and introduces cables and motor at this point. It may well be that the motor involved was a generator and hence it was indeed the source of electricity on that occasion. Her dad's ideas are also referred to later (CS1: 725). The are other examples of children relating the ideas used in the session to their everyday experience. Mark drew on his experience of charging batteries for his remote controlled car (CS1: 845). Jenny talked about seeing a model plane with a motor similar to the one shown her (CS1: 855) and also referred to an electric train she had seen (CS1: 860).

Evidence of the students challenging children's existing ideas

Both students took the children's ideas seriously and used them to develop the session. There were numerous occasions when the children's existing ideas were challenged by the students. The idea Jenny introduced about cables and motors being necessary (CS1: 725) was well countered by TW using the evidence of the torch (CS1: 764). She also referred to Katherine's idea about the bulb containing electricity (CS1: 724) later in the session when the children had evidence to draw upon (CS1: 831) and at the end of the session when she summarised what ideas they had had and what they had learnt (CS1: 864). Another example concerned Jenny's idea concerning the significance of the length of wire used (CS1: 838). ZP challenged Lisa's idea that there was a battery inside the light bulb (CS1: 1008) and about the battery having run out (CS1: 1036). Gregory's alternative idea about a shadow causing the light to go out (CS1: 1019) was not challenged at the time but much later ZP did refer back to this idea and confirm that it was no longer held (CS1: 864).
Analysis of Case Study 1

1069).

The nature of science implicit in the sessions

The students conveyed to the children the importance of practical activity as a means of developing understanding. They did not imply that they had all the right answers and suggested that explanations were to be worked at and sorted out together. TW stated, "We'll have to play with it and see if we can make it work" (CS1: 824). In a similar way, ZP asked for help from the group, "Mine's not working, can you help me?" (CS1: 980). She was putting into practice the view she expressed in the interview about finding out what the children think and discussing it with the group (CS1: 625).

ZP made the co-operative nature of the activity explicit on a number of occasions and also tried to involve the quieter girls (CS1: 935, CS1: 1103). TW tried to encourage David to become more involved several times during the session (eg CS1: 810).

Overall, both students were capable of organising a session on electricity with their chosen age group that showed they had been able to use the approach encouraged during the college workshops and adapt the content of the electricity session.
Case Study 2: BEd Yr.4 (Gp 2) Electricity

Group 2: Later Years (working with 6 with little or no previous experience of electricity and 4 specialism students on extension activities because they had experienced a similar workshop recently).

Session: Weds 1.11.89, 9.00 - 10.30am

Data Collection: Tape of full group discussions
                       Students' annotated drawings
                       Students' evaluation notes

Aims for the session:

1. To develop students' confidence in introducing simple electricity experiences to Key Stage 2 children;

2. To develop students' background knowledge and understanding in science up to and including level 4 (AT11) of the National Curriculum;

3. To provide students' with an example of constructivism in action for adaption in their own teaching

4. To encourage the appreciation of the tentative and provisional nature of scientific knowledge.

Pairs: Sarah/Beri, Stephanie/Melanie, Debi/Julia

(Students were asked if they minded having the session taped for research purposes - all agreed. The session began in a similar way to CS 1 and I introduced the reasons for the separate group and the choice of electricity.)

Nearly every one of you comes with the feelings Beri has already expressed - you don’t know very much about electricity at all. But if I’m going to practice what I preached when I showed you the video about the nature of children’s learning then we accept you all have some ideas and what I want to try and do this morning is elicit your ideas and use them as the basis of our investigations. So what we will end up with is a shared understanding ... we won’t get very far this morning ... we’re not going to build complicated circuits ..... but I want us to move step by step with agreed understanding if we can. That depends on you shouting very loudly if something is said that you don’t understand and it also requires you to share what you believe, what you understand at the moment and that’s why you’re particularly lucky to be working in a small group in a way ... there should be an opportunity for you to share your...
views if you feel confident enough to do it and I hope you will. There is no right or wrong answers here that we're looking for. .. critically we're looking for what you understand at the moment.

Whenever you do electricity with children and it is part of the NC, it is a part of the core content that children should be offered in school, it is vitally important that you remind children at the outset that playing with bulbs and batteries is safe but working with mains electricity and sockets is very dangerous and shouldn't be done and so that health warning I would want to see at the outset of any work with children. You can't hurt yourself with these bulbs and batteries and so don't concern yourselves about the dangers.

With children, as well, the context is going to be very important for this kind of work but what I'm not suggesting you do with children is kind of cold ... ie this is an electricity lesson. Find a way to contextualise it, perhaps when they have been making model rooms and they want to add a light or they're making Xmas cards and you want to put working lights on them - some context, some purpose for understanding electricity is going to, we hope, provide much more motivation than just saying this is electricity because teacher thinks it is a good thing to do.

One of the things I've been doing with other groups is starting the session by asking them to draw what they thought was inside a torch. Every group knows there is a battery ..... Most know there is a bulb but going on previous drawings most are unsure about how the bulb connects to the batteries and how the switch works ....

We'll skip that (stage) and go on to the next stage which is perhaps more important, that is to focus in on one part and see if we can understand how the bulb works. If we can end up at 10.30 with an understanding of how a torch works we'll have understood quite a lot.

[...[introduction to 4.5v battery and reason for using it, set task 1 - light a bulb using only a battery]

Draw your ideas - a large drawing of the bulb - show where you have to touch it and show me what's inside.

St Beforehand?

RR No, get it working first, try and make it work. Some of you will know how to do that others will need a few minutes but whatever you do don't panic (to Beri)!

Try and work it out for yourself 'cos it's important that this first stage ...

[most succeed quickly, except Beri and Melanie (who was making the right connections)]

Either your battery is rather low .. try that bulb and see if it
Case Study 2: BEd Yr.4 (Gp 2) Electricity

makes any difference (to M).
M No, I think I've got a flat battery.
RR Yes, try this one.
M Oh, that's better [succeeds ... B causes bulb to flash]
RR (to B) Be convinced about where you are touching the bulb, can you touch it in other places?
B It won't go now!
M Where do we go next?
R A large drawing ....

[RR moves to other group, Ss comment about the tape, giving each other different names - discussion in pairs about task]
M Do you know how an electric circuit works?
B No, not the principle of it.
Sa I'm not sure, connecting them both, isn't it?
B That's the anode and that the cathode isn't it?
Sa This little green bit is where the electricity is ..

[RR returns and overhears last comments]
RR Ah, there's another rule today I must remind you .. when you use words like anode ...
B You have to explain them?
RR You're there before me!

B Anode is positive and cathode is negative [RR writes them on whiteboard].
RR Alright we'll come back to that in a minute.
B That's all I remember from '0' level.
RR I'd be particularly interested for you to think about what might happen in here (base of bulb). Where you can't see ..
B Describe it?
RR Yes, I would have labels, what materials and what they might be for.
B Conducting electricity.
St Artistic talents are showing.
RR Don't spend too long making it look pretty, no colouring in right!
Sa (to B) So what generates the light?
B When the positive electricity and the negative electricity meet there (points to filament). That (?) generates from the bottom upwards.
RR Try and hold on to your own idea.
That's very interesting Beri (refers to drawing with both battery terminals to base of bulb). Do you want to bet me any money, you look like a betting person, do you want to bet you can light up your bulb like that?
B No!
RR Have another go and observe where you touch the bulb [B tries].
B One goes to the bottom and one at the top.
RR But you've got them both at the bottom?
Case Study 2: BEd Yr. 4 (Gp 2) Electricity

[further discussion about where contacts are made]

120 RR One of the key things most people bring is the idea that the bulb is going to touch at the bottom and therefore you almost force yourselves to believe that what you see is it touching at the bottom.

S I have!

125 RR You haven’t.

S One is on the bottom though.

B And one is on the side bit.

RR On the black bit?

S No, I thought it was but it was touching underneath.

130 RR You can touch it right near the top, can you?...

Let’s go on together....

Try and build up your drawing but put a (d) when you add words while we discuss. Can we think about ... and remember to complain if you’re not happy or don’t understand.

135 We all agree where the battery touches and there’s a black piece there.

[discussion about the bulb]

....

B ... a conductor of electricity.

140 RR What do you mean?

B It allows electricity to pass through.

RR Can we agree that (writes it on the board)?

[discussion about green plastic insulating plug]

S I put (on my drawing) a connector to connect one wire to another, perhaps negative to positive, I don’t know.

RR To connect them?

D Doesn’t it just hold them in place?

RR Hold them in place – let’s put both (on the drawing).

D (aside) I don’t know but there’s got to be a reason for it.

150 RR What can you see between the uprights?

S1 Coiled wire.

S2 Very fine.

S3 Not straight, like a bump ... goes up.

S1 Tiny little coils.

155 ..... 

9.16 RR What do you think might be in there (base)?

S1 Two pieces of metal from the filament both go down to the bottom ... down there (points to base).

S1 They can’t both go to there, one must go to the side.

160 RR Does it matter which one?

B I think it’s coiled inside.

RR Let’s take one idea and explore it.

Does it matter (which one)?

S1 No.

165 RR So shall I put one to the side?

S1 Yes.

RR So that’s idea 1 (both to bottom) and that’s idea 2 (one to the
side and one to the bottom).
B I can't see how it works.

RR What happens when a bulb works?
How do you explain (to Sa) ... if we're talking about
electricity passing through, what might that mean on this
drawing?

Sa It passes from this side of the battery and from the other to go
into the wire across the top.
RR So you've got electricity coming up from one side and up from
the other side and meeting in the filament.
S1 No, I don't agree.

RR Let's think about ... are you going for idea 1 or 2?
Sa Idea 2.
RR Whose was idea 1?
S1 Me.
RR In terms of Sarah's idea about electricity meeting in the middle
is her logic that idea 2 must be right acceptable to you?
S1 Yes, I guess it could be.
RR So would you like to come and explain. And we've just heard the
word circuit (aside comment overheard). What do you mean?
Me It would be like coming out and going right round. That's how I
would describe the flow of electricity.
RR That's a very different ideas to Sarah's.
Me It goes round (points). It comes in here (base), through there
(filament) and back down (through the base) ... No, through
there (side).

RR Which of those do you go for Stephanie?
S1 Melanie's.
B I don't think it goes anywhere, I think it goes round again.
RR OK, but you're going for Melanie's idea not Stephanie's?
B Yes.

RR But you said at the beginning ...
B I said about the anode and the cathode ..
RR So, you've changed you idea?
B Yes, I've changed.
RR What about you two?
S1 Me's idea.
RR So Sarah?
Sa I'm wrong, I know, I've just realised.
RR Why?
Sa 'Cos I can remember my physics now.
RR So you're going back to physics. But that learning in physics
you didn't really believe?
Sa No, I didn't understand it.
RR Can I say, and don't take this the wrong way because this isn't
a criticism of you (Sa) but you'll find a lot of adults and
children who hold that idea.

9.22 Now, I'm not convinced that Sa's actually changed her mind yet -
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I will come back to it 'cos I can provide you with a bit of evidence I hope that will help you agree with Melanies's as that is the accepted scientific idea at the present time.

Next question, if we've got this idea of a circuit. What causes the light?

Me: Is it heated up?
RR: Which bit?
S1: The filament, the coil.
S2: 'Cos it's thin.
RR: Because it's so thin?
S2: It's so scientific isn't it! [Ss laughing]
RR: That is so scientific 'cos all the words you get in physics don't help your understanding and it's so much better to do it in these kinds of terms. So if it's heated up because it is so thin, why might that be? What might be happening to cause it to heat up?
S1: Being absorbed by something. Like the energy in the battery has completely disappeared so it lights up.
RR: The energy being absorbed?
S1: By the wire.
RR: I find that hard. I can't make sense of what that might mean. Is it like soaking up in a sponge?
S1: It's because it is such thin material. It's almost as if it looses its own matter like it's completely taken over by the energy from the battery.
RR: Yes, that's fairly complicated, we might be able to find an easier solution. Imagine the electricity, what ever it is, coming up this wire. It suddenly gets to a very thin bit. What might that mean to the electricity?
S2: It's too .. 'cos it's a thicker bit there is more energy than is needed for the thin bit. The energy is dispersed somehow at the top.
S1: No, it can't be 'cos it's got to go down the other side.
S2: It's got to be in a smaller space. It's more condensed.
RR: Any parallels you can think of?
S3: Air pressure.
S4: Water pressure.
RR: If it was like water from a thick pipe to a thin pipe .. pressure increases.
B: You get a burst pipe.
RR: Yes, any other terms you could use to describe it? ... Let's test the idea about thinness.
S: We could see if the bulb gets hot.
RR: Ok try [students test and confirm]
S1: Yes, but that isn't testing the idea. It might be heat given off by light.
RR: Alright, but it is getting warm. If I were to give you some thin wire is there anything you could do with it?
B: Connect it up to the battery.
RR Alright, let’s try that (offers Brillo pad wire). If Beri was to connect that what do you think would happen?
Ss Nothing.
RR Try it.
270 S Will it not glow?
RR Try it. [B tests]
B Oh! (wire burns through)
RR Did you expect that?
B No.
RR What happens is it gets very hot and burns through. That is not only getting hot?
S It’s giving off light.
RR But it’s doing something else.
S Burning.
280 RR There’s a difference between heating up and giving off light and burning isn’t there. So it’s looking as if ’thin’ is OK but why doesn’t that (the filament) burn up?
S Because it’s coiled.
RR So if I could coil this it would glow?
[RR coils wire and tries it]
285 It glows longer but still burns through.
S ... some kind of coating to stop it burning. Keep all the heat in.
S1 Some sort of insulation around it.
290 RR That’s a nice idea. It isn’t actually the case I don’t think. Can we explore it further?
S2 Could it be those two things holding it. They kind of resist so much electricity going through.
S3 I think it ... a kind of rebound thing where electricity rebounds from one to the other.
RR That’s almost back to Sa’s idea. You know something about burning. Why does that burn (Brillo wire), what does it need to burn?
S1 Heat.
300 S2 Energy
S3 Air.
RR Things can’t burn without air.
B If you take away the air - that’s why there’s no air, there’s a vacuum in the bulb.
RR What’s a vacuum?
B A void with no air in it.
S Vacuum packed food.
RR OK, so what happens to it?
B They suck the air out and seal it.
310 RR So what would happen if I sucked the air out of that (the bulb)?
S You wouldn’t get the burning.
S1 It would break, ’cos the pressure outside is bigger than inside.
RR But, you’re on the right lines, there can’t be air in there.
S A gas.
It's an inert gas, it doesn't let anything burn.

RR It depends on the kind of bulb. But you know as well as I do that bulbs blow. What happens?

S The heat builds up.

RR The filament breaks.

S1 They don't go on forever, eventually ...

S The inert gas must run out.

B If it's inert it can't.

RR Imagine you're that wire, electricity goes through you every time you light. What happens to things when they get hot?

S1 They expand.

RR What about when they get cold?

S1 They contract.

RR Now surely that coil must be getting longer and shorter every time the bulb goes on and off. Could we accept an idea like it weakens the metal and eventually it gives up the chase. It gets tired. That's how I think we get an understanding of why a bulb blows.

9.40 It's taken 40 minutes to find out how a bulb works ...

[warning about rushing activities in the classroom]

S So you'd do this work with top juniors. Would you do it with younger?

RR I'd do it with 5 year olds.

S It would be harder though explaining it to them.

RR Five year olds are capable of making a bulb work and they will have an explanation in their own terms and I think a five year old (as we saw on the video) has some ideas and by the time they are 7 or so the idea of a circuit is one they can happily hold on to.

[ further points about dangers of bulb holders and plastic covered crocodile clips]

Your next task is to wire up a permanent circuit.

S That wire is too thick (to partner)

RR That's something we could come back to, thick and thin (wires).

[ informal discussion including comments about previous experience of electricity - I did a bit at primary school - and trying it with children - I'd like to do it and they (the children) would love it.]

RR I'm making this appear perhaps much more teacher intensive than it needs to be because I think in the classroom you can allow the children much more exploratory time, but because we've only got an hour and a half I'm trying to push you through much more quickly.
There's Beri running before she can walk again!
I want you to make a prediction... [re short circuit across battery terminals]
Put your left hand up if you think the bulb will go off, right if you think it will stay on. You might have to make a guess at this stage.

B It's a trick question!
RR No it's not.
Only Debri thinks it will go off.
As she is in the minority we'll let her try it/

De (tries it but makes a poor contact and bulb stays on) There it makes no difference. (tries again and bulb goes out) Oh, it does go off!

RR Now why might that be?
De Because the electricity decided to travel through the thin bit... the short bit, it looks thicker.
RR Let's try a thinner piece.
S 'Cos it's got a shorter distance to travel.
RR So if we went for a long piece of wire it would probably stay on? Let's see.

Sa I don't know. [RR demonstrates with a long piece of wire and the bulb goes out]
St But it's (the last piece tested) still shorter than those two (in the circuit) together.
RR OK, let's try a very long piece.

S Can I say what I don't understand. By putting the other wire there (across the terminals) you are still keeping the circuit going.

RR Has it gone out now?
S No, it's dim... it's shared.
RR What could we say about the sharing?
S If you had clips on the end it could make a difference.
RR We can try that in a minute.

S Also, there's a bulb causing some resistance.
RR Ah, that's a new word, what does it mean?
S It means it's got to push against something. It's not pushing as hard to get through that (short circuit).
RR In other words electricity is lazy and if you give it an easy route it will take it. Although that's a long way (long piece of wire) it's still easier for the electricity. Does that help me?
Me Would that be the case with any length of wire?
RR Well, what do you think?
Me I don't think that is long enough
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RR The bulb's still glowing a bit.
   [RR uses whole roll of wire]
   That's about 5 miles and no light!
Me Ah.
RR So are you happy - it makes sense doesn't it?
   ..
   Let's return to Sarah's idea.
   If I gave you a buzzer see if you can make it work (she does).
   Will it work like a bulb the other way round? (she tries it).
Sa No. Is it because its positive and negative?
S Why is it like that with the buzzer and not the bulb?
RR Does that provide evidence that the electricity must be going
   one way? If we look inside a buzzer it's much more complicated
   than a bulb. It's got lots of little bits. I don't know what
   they do but I think I can accept that some only work if
   electricity is going one way.
   [RR demonstrates a motor]
   ...
   [B lights 2 bulbs in series]
   ...
   [students encouraged to test materials to see which conduct
   electricity]
   ...
   Let's look at B's problem, she has made 2 bulbs light up but
   they're dim. If you take one out what happens to the other one?
B It goes out.
Sa That's because you have broken the circuit and there's a gap
   where it should come up and it goes into the earth.
B Yes, it's true, I've just tested it. It goes as far as there and
   couldn't go any further.
RR My problem is, I want a Xmas tree with two lights on it so that
   if one goes out the other stays on. I would prefer two wires to
   the battery.
S We need two batteries.
RR No, only one battery, he's tight!
   [discussion about problem]
   ..
B What makes fairy lights flash?
RR The little fairy inside!
   [students have problems trying to solve the problem]
   Go back to one bulb and try from there. You're locked into B's
   idea (series circuit) at the moment.
   ..
   ..
   [some succeed and are encouraged to make simple switches]
   ..
B I'm confused.
RR What about?
B All of it.
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RR If there is confusion let's share it. 'Cos you won't go away with understanding if you ...

St I think it's just the way we've been taught. We've got so many misconceptions now it's very difficult.

RR That's why we've been trying to do it very slowly, step by step. That's what worries me if Beri says it's very confusing. Are we going too quickly.

B A switch tho' . . . has it got to join both ends?

RR Let's think what a switch means, if I disconnect this what happens?

B You cut off the electricity.

RR So that's an acceptable switch, but not very useful. So how could we connect this (a simple pressure pad) into your circuit?

.. Are you saying (to B) that you don't understand the simple circuit?

B No.

RR Try and set it up, 'cos as you said a switch is just a way of stopping electricity from getting through.

[De/Ju succeed with parallel circuit and are very pleased]

RR Sarah, how happy are you about your idea being rejected?

Sa I'm happy now, I can see ....

.. [De/Ju succeed with parallel circuit and are very pleased]

RR (to De/Ju) Have you read the story Fox Busters .. [poses problem about an alarm in the context of book] ..

De Maybe we should have the buzzer at the end so that it (electricity) goes through the bulb first.

.. [B getting frustrated at her lack of success with a switch]

490 ..

B Yeah (laughing) we've got a switch. What do we have to do next? [DE/Ju make a series circuit with bulb and buzzer]

RR Do you remember Beri's circuit with two bulbs?

De Oh yes we need ...

RR (to Ju) Are you keeping up with her, she seems to be in overdrive?

.. RR (to De/Ju) Problem solved ...well done.

500 .. Will you all write down on your sheets your feelings about it (the session); the understanding you take away and the questions you still want answered.

505 B Stupid thing (still working on a circuit).
Case Study 2: BEd Yr.4 (Gp 2) Electricity

RR  What does stupid refer to?
B   Me!
RR  Go on, my impression is that you are more confident now than you were at the start.
510  B   Yea!
10.30

Immediate Evaluations (written)

Sa  Quite worried about the session initially due to my failure in physics lessons at school. Being taped didn't inhibit responses to questions. It was extremely useful starting at our level. Describing things in simple terms using everyday language and pointing to the diagram on the board clarified the points. I take away a clearer understanding of electricity and how it works - much happier - apprehension disappearing - misconceptions have gone.

Me   Very useful - something of which I had very little idea - I knew a circuit had to be made, but did not really know why or how. It was made into a manageable concept by looking first at the bulb (in our own terms) rather than jumping straight into the scientifics of a difficult concept. It gave an insight into how to tackle the concept with children because I now realise it can be understood on the level at which you are at. Brings home how important practical experience is.

De  A basic understanding of how it flows, therefore leading to the making of basic circuits, which when put in context could be brilliant problem solving activities both for us and children. I feel more confident now when dealing with electricity especially the section about making two bulbs work (remember not to break the flow). It jogged my memory from my own electricity sessions at primary school.

St  I found this work really interesting and very helpful. I didn't know much about electricity before the session and it really helped to clarify my understanding. I felt that starting where we were from helped our overall understanding at the end. We were given ideas about starting points for work with children which helped me as I wouldn't have known where to begin.

Ba  The session left me with a greater understanding of how electricity works. I knew electricity flowed around a circuit but was unaware of what happened on its journey. I never realised there was "inert gas" in the bulb, but how do you explain this to children? I found that I was trying to be more scientific in the explanation than was necessary and I found I was using vocabulary that I had used at 'O' level and never
actually really understood their relevance within the circuit.
Analysis of Case Study 2

Group 2: Later Years (working with 6 with little or no previous experience of electricity and 4 specialism students on extension activities because they had experienced a similar workshop recently).

Session: Weds 1.11.89, 9.00-10.30am

Data Collection: Tape of full group discussions
Students' annotated drawings
Students' evaluation notes

Aims for the session:

1. To develop students' confidence in introducing simple electricity experiences to Key Stage 2 children;

2. To develop students' background knowledge and understanding in science up to and including level 4 (AT11) of the National Curriculum;

3. To provide students' with an example of constructivism in action for adaption in their own teaching

4. To encourage the appreciation of the tentative and provisional nature of scientific knowledge.

For ease of reference each concern identified in Case Study 1 has been numbered. The concerns are listed, together with new ones from this case study at the end of this analysis.

The Nature of the approach

The orientation aspects of this session were even less than that in CS1 although this did not appear to have an adverse effect on the session. The nature of the approach was made explicit on a number of occasions (eg CS2: 9) and the evaluations provide evidence that students were aware of the process elements of the session (CS2: 517, 526, 543).

The fact that I "skipped" (CS2: 50) the first elicitation phase is of concern although their later responses appear to indicate this was not a problem as I gained considerable insight to their ideas as the session developed (ref. CS1 Concern 1).

Encouraging socially constructed understanding

The lack of confidence and concerns about the specific content were highlighted at the beginning of this session by Beri (CS2: 6) and this allowed me to introduce the session by reacting to her comment.
The social dimension of the activity was also addressed by my comment about the advantages of being in a small group (CS2: 19). I also used "we" when discussing the aim of the session with regard to understanding (CS2: 53). Throughout this case study there is evidence, within this small group, of socially constructed ideas. Students were prepared to question each others ideas (CS2: 179) and support and extend each others ideas (CS2: 151; 312). This provides evidence of students providing "scaffolding" for each other and enabling a better shared understanding than the individual may have been able to achieve working alone. Sarah and Stephanie both appear to have recognised this implicitly in their evaluation comments. The use of "our" (CS2: 518) and "we" (CS2: 544) indicate this.

There were several examples of me taking the students' existing ideas seriously and testing them (CS2: 374; 382) and this was made explicit to the students (CS2: 385). However, there were also several examples of students' ideas and suggestions which were not taken seriously enough (CS2: 351; 394).

The session also provided evidence of students using scientific words correctly, as in the case of resistance (CS2: 400) and "barking" words like "anode" (CS2: 86), offering a definition, but not using them to extend or clarify understanding. Beri referred to the use of language in her evaluation and stated that she was aware that she was using words that she "never really understood" (CS2: 554). All the students claimed to have a better understanding of electricity after the session.

The nature of science implicit in the session

Early in the session I reminded the group that science did not involve simple right and wrong answers (CS2: 23). I took the opportunity of Beri's claiming that the battery terminals touched the bottom of the bulb to introduce the notion of theory-laden observations (CS2: 120). However I do not think my approach through encouraging betting (CS2: 112) is the most desirable, although it is reasonable to suggest that the incident and the issue are more likely to be remembered by the group because of me treating it in this way. The approach was, in one sense, a focussing strategy.

When an individual claimed to be confused towards the end of the session (CS2: 454) I suggested it should be shared and another responded, "I think its just the way we've been taught. We've got so many misconceptions (that) now it is difficult" (CS2: 459).

Alternative frameworks held by individuals

Beri lacked an initial understanding of where a bulb needed to be touched to make a complete circuit (CS2: 118), although she was the
first to start using "scientific" words like 'anode' (CS2: 86) which she claimed was all she remembered from '0' level (CS2: 96). Sarah initially thought the insulator was where "the electricity is" (CS2: 87) and in discussion called it a "connector to connect one wire to another, perhaps negative to positive" (CS2: 144). Beri introduced the notion that "positive and negative electricity" met in the filament (CS2: 107). This idea was taken up and held firmly by Sarah (CS2: 175). The example of a buzzer (CS2: 415) was used later to counter this construct and there is evidence that this led to her restructuring her ideas (CS2: 479) (ref. CS1 Concern 5). She appears to have found the whole group discussion and the production of a "shared understanding" through the drawing valuable (CS2: 519). Stephanie suggested that the wires from the filament both connect to the bottom of the bulb (CS2: 157), although that was immediately contradicted by another student (CS2: 159). Stephanie soon appeared to change her mind (CS2: 186) but did not seem convinced. SI offered an explanation of (electricity) "Being absorbed by something. Like the energy in the battery has completely disappeared so it lights up." (CS2: 233). Although I probed this idea and the student offered a more detailed explanation in terms of "it looses its own matter like it's completely taken over by the energy of the battery", I was unable to gain sufficient insight into the alternative idea and offer a way of dealing with it and consequently suggested we looked for "an easier solution" (CS2: 241). This led to an interesting comment from another student, "'cos it's a thicker bit there is more energy than is needed for the thin bit. The energy is dispersed somehow on the top." This was responded to by another student suggesting, "No, it can't be 'cos its got to go down the other side.". This should have provided me with an opportunity to introduce the idea of "charge" and the "current" being the same both sides of the bulb. More background reading is necessary here for me to develop my own understanding (ref. CS1 Concern 2).

When explaining the reason the filament produced light, a student offered the idea that it "some kind of coating to stop it burning" (CS2: 287). I immediately dealt with that idea by stating that I didn't think that was the case (CS2: 290). On reflection, it probably deserved a more appropriate response that encouraged the student to explore the idea for themselves. Another student talked about "a kind of rebound thing" (CS2: 294) which might relate back to Beri's idea, or be confusing AC with DC. Beri, when referring to the gas in the bulb held the idea that it might "run out" (CS2: 323) although another student immediately countered this idea. She also explained a broken circuit in terms of, "it goes as far as there and couldn't go any further" (CS2: 436), which she claimed to have "tested". This is clear evidence to support a concern I held as a result of Case Study 1 (ref. CS1 Concern 11, see CS1 analysis p33-34).
Analysis of Case Study 2

Supporting students work in the primary classroom

Safety warnings were made near the beginning of the session (CS2: 25) as was a much stronger case for the need for an appropriate context for the work with children (CS2: 34). This was given a greater priority than in CS1 (ref. CS1 Concern 8, see CS1 analysis p33. Warnings about rushing work with electricity (CS2: 335) and using bulb holders and plastic covered clips (CS2: 346) were again offered (ref. CS1 Concern 13). The appropriateness of the activities to primary children was questioned by a student (CS2:337) and this allowed me to discuss work with the whole primary age-range. I also tackled the issue of how teacher-intensive the approach appears from the way I was working and stressed that in the classroom situation this would not need to be the case (CS2: 359). The problems I posed during the session were explicitly contextualised in a way that could easily be related to the primary classroom. I did this through an Xmas card (CS2: 438) and children's fiction (CS2: 482).

Melanie (CS2: 529), Debi (CS2: 534) and Stephanie (CS2: 544) all included positive comments in their evaluations about how it had helped them in terms of work with children. In particular, Debi's comment about "when put in a context could be brilliant problem solving activities" (CS2: 534) is encouraging (ref. CS1 Concern 8).

General issues (with reference back to Case Study 1)

Orientation opportunities (Concern 1) were not provided but there was no evidence of this causing difficulties for the students although they may have organised there ideas more usefully had those opportunities been offered. However, the interaction of the group appears to play a crucial part in supporting the individual's exploration of their own ideas (eg CS2: 150,).

I decided that it was not necessary to introduce any "scientific" words (Concern 2) into the discussion as key words like circuit, conducting, insulating and resistance were offered by students. However, as my comments earlier about "charge" and "current" suggest I may have missed an opportunity at one point to develop their understanding.

No new strategies were explored to elicit ideas (Concern 3) in this session.

The session was, like Case Study 1 fairly tightly structured (Concern 4). I did cover more ideas in this session and as these students are a later years group it was appropriate to extend the work into switches and an introduction to series and parallel circuits. This needs some further follow-up activities/reading if they are going to be able to use the ideas in the classroom. I have
explored the Shell computer simulation on "Circuits" and would like to explore its use with a group of students.

Can a computer simulation provide appropriate follow-up activities?

There was some evidence of restructuring (Concern 5) during this session but none to indicate that students used their restructured ideas in a problem solving situation. Julia and Debbie were the most successful problem solvers (CS2: 499) but there is no evidence to suggest they had restructured existing ideas in order to tackle the problems posed, although in view of their early contributions to the discussions in would seem likely that they did.

There is some evidence that this group took away an image of science (Concern 7) that reinforced it as an investigative activity that leads to tentative and provisional knowledge and understanding. Indeed, Melanie (CS2: 530) explicitly stated that the session "brings home how important practical experience is". There is evidence that the image of science offered contrasted with that they had during their experience of secondary science (CS2: 554). It is also reasonable to claim that they were offered a view of science that emphasised it was a human activity.

Could the students' view of science be elicited through interview before and after sessions?

The importance of context (Concern 8) in the primary classroom was given a greater priority in this session as indicated above.

I did not use the word "predict" as loosely in this session as the last time (CS2: 361) (Concern 9) and explained that it might be necessary to guess, although this did cause one student to suggest, "It's a trick question" (CS2: 366)!

The smaller group meant it was probably less threatening to ask students to expose their ideas (Concern 10) and most group members contributed to the discussion without prompting. A strong personality, like Beri, can obviously cause an imbalance in the group, but her confidence to say what she thought was probably an advantage in that it meant ideas were forthcoming.

Again I introduced or prompted the suggestion of numerous metaphors (Concern 12). For example the model of water to explain electricity (CS2:254). However, after some background reading I felt more confident with those that I used.
Analysis of Case Study 2

Concerns identified as a result of analysing Case Study 1

1. To what extent should I ensure an orientation period is provided for adult learners?

2. Should I introduce appropriate 'scientific' words if they do not come from the group?

3. What other strategies can I use to elicit students' existing ideas?

4. Should sessions be so tightly structured, paced and controlled and should this depend on the particular content involved?

5. How can I collect evidence of students restructuring their ideas?

6. How can I encourage students to apply their restructured ideas in novel situations?

7. What view of science do students take away from sessions like this?

8. How can I emphasise the importance of context for scientific activities with children?

9. When should I use the word "predict" - do I understand its meaning?

10. To what extent should I encourage individuals to expose their ideas?

11. Should I deal with every alternative framework identified or focus upon common ones?

12. To what extent do the metaphors I use foster misunderstanding in the students?

Concerns identified as a result of analysing case study 2

13. Do I allow students adequate time for practical exploration and investigation?

14. How can I use the relationship between adult and children's constructs to improve the adult's knowledge and understanding of science?
Case Study 3: BEd Yr.4 (Gp 3) Electricity

Group 3: Early Years (including 2 students from the Specialism Group working on differentiated tasks)

Session: Weds 10.11.90, 2.00 - 4.00pm

Data Collection: Tape of tutor input/full group discussions
Students' elicitation sheets
Students' evaluation notes

Aims for the session:

1. To develop students' confidence in introducing simple electricity experiences to Key Stage 1 children;

2. To develop students' background knowledge and understanding of science up to and including level 4 (AT 11) of the National Curriculum;

3. To provide students' with an example of constructivism in action for adaption in their own teaching

4. To encourage the appreciation of the tentative and provisional nature of scientific knowledge.

2.00 (Students were asked if they minded having the session taped for research purposes - all agreed. The reasons for the 2 students working on their own was explained. Reference back to last week's session on energy. Session put in context of other sessions related to forms of energy. Reasons for starting with electricity related to threat primary teachers feel. Warnings re safety and classroom application of session. Offered examples of context for using electricity. Reference to NC AT - provided. Reminder of constructivist approach and the threat that might imply - setting ground rules eg use of words. Intention is to reach a shared understanding.)

2.10 Although we are going to work in pairs most of the afternoon I would like to start by asking you to work individually and complete one of these sheets. It's not a test but I would like to take them in to have a look at at the end and then let you have them back. First of all it asks you, in your own words to explain what electricity is, you can begin thinking about it. There are some examples of children's ideas up on the wall, if you are interested. Then there's a drawing of a bulb and battery and it asks you how you would have to connect the two together and in particular to think where, if we had two wires, where do you touch it on the bulb and battery. It may be a guess because you've got no experience to draw on, that's fine. Don't do the next section or turn the sheet over. With children, there may be
Case Study 3: BEd Yr.4 (Gp 3) Electricity

a case at the outset, particularly with older children, to get them to express their ideas. It's our floorbook (introduced last week). I don't want a great heart search here just write down words you could use to express what you think electricity is.

... It's probably something you've not thought about before .. horrible isn't it.

... Written responses

Carol  A form of energy which provides power through a circuit
Liz    A form of energy. A circuit is needed using positive or negative somethings. It creates heat and/or light.
Rachel A form of energy which helps to provide heat and light
        (artificial)
Stuart A form of energy produced from a wide variety of sources ie solar/nuclear. A power source is used to drive a turbine/cogs which then produces energy/electricity.
Val    Electricity is one form of energy.
Ann    A source of power.
Annette Generated power.
Tresilla A source of energy which is generated at a power station.
Megan  A source of power - energy.
Kathy  An energy source that is generated from natural sources: water; coal etc. used extensively in most parts of the world.
Kate   An energy force which travels in pulses.

Connections of bulb
Correct:    Liz, Stuart, Ann, Tresilla
Both to bottom: Kathy, Meag, Carol, Rachel, Val
Both to side:  Kate, Annette

2.15 RR With children, a less threatening start may be to get them to draw what they think is in a torch. But one of the things I've been looking for and there is evidence that there is genuine uncertainty about where you touch the wires to the bulb. Some have wire to the side, some to the bottom and some to bottom and side. I'm going to give you all a bulb and battery and ask you to try and make it work. Do talk! Don't change your drawings - you might want to make notes at the side.

When you have got your's working talk to your partner about how it is working, try and come to a shared understanding and write that on your own sheet. Explain in as much detail as you can what is happening and why.

... S1 Mine doesn't work. What are you doing?
S2 Try touching it at the bottom and side.
S1 I think it's just me .... Ah I see!
(All make bulb work without wires)
Case Study 3: BEd Yr.4 (Gp 3) Electricity

Mine was working but doesn't any more

Let me see how you are connecting it (tries to touch both terminals to black insulating part of base). Try a different way. (success after several tries)

(Pairs move on to drawing - discussions informally about the filament, heating effect - close observation)

I've never been able to do this before (light a bulb). It's really good.

(to S2) The filament is the bit across the top 'cos that what breaks when the filament goes.

What is the green blob bit.

I asked my boss at work about electricity 'cos he's clever and has got a degree.

And what did he say?

He got all theoretical .. talked about different frequencies, something is a by-product of something else.

I see, well let's see where we get to this afternoon.

(Informal discussions about positive and negative)

When you have drawn what you can see can you try and predict what is inside that you can't see and draw that.

(to S2) How can we teach this if we don't even know it ourselves! When they ask questions ..

Say to them, "I don't know but how could we find out".

(informal discussion about wires inside bulb base)

Power from the battery passes up wire, is conducted from bottom of metal of bulb, inside bulb, up wires, across filament and down back to the battery - circuit. (nothing shown in base)

Positive and negative charge join in circuit to make electricity. (diagram shows both sides of filament connected to base of bulb)

(no explanation - diagram shows both sides of filament connected to base)

(no explanation - diagram shows filament wires to base and side)

From contact point at bottom one positive wire leads to filament. The metal on the sides of the bulb could be a negative. (both wires from filament go to base in diagram)

(no explanation or anything shown in base)

(no explanation - correct connections on diagram)

(no explanation - correct connections on diagram)

(no explanation - both wire from filament to base)
The electricity passes through the wires to the bulb and back again creating a circuit.

The discussion in pairs could go on a long time but can we try and draw this together. (drawing on whiteboard discussed - connection to bulb confirmed, origin of misunderstanding in the way domestic bulbs connect - purpose of insulator - nature of conductivity - filament, coiled and curved, thin - draws attention to solder blob - origins of light/heat - circuit - flow of electricity inside bulb)

Kathy: (correctly traces path of flow and confirms connections inside)

Kate: It doesn’t have to touch the solder, it doesn’t matter where it touches 'cos it’s metal.

RR: Any other explanations?

S3: It could go the other way.

Kate: It could be simultaneous, coming from both sides, does that make sense? It could cross over and go back out both sides.

RR: It is important for us to recognise that children hold different ideas. For example children often think electricity comes in from both sides but their explanations aren’t as sophisticated as Kate’s. You might have heard of alternating current (AC) and that is perhaps what you’re talking about. We’re talking about direct current and it does go in one direction. What happens in the filament?

S6: Is it something to do with being coiled?

S7: What it is made of?

S8: Because it’s thin?

Stuart: Is it just because it’s thin. Could it be that there is less resistance at that point?

RR: What do you mean by resistance?

Stuart: When electricity is conducted through a large wire and it’s all insulated, it’s all held in, so to speak ... it it just discharged ... like you get a spark? I can’t quite get my head round it?

RR: Let’s think about it as water in a pipe. if it got to a thin bit what is going to happen?

S2: It will be harder, it will use more energy and produce heat

RR: (demonstrates brillo pad wire across battery terminals - some predict nothing will happen)

S: How amazing!

Kate: Could it just be the soapy stuff burning? (general discussion, some ridiculing idea)

RR: Hang on, let’s just stop there because that is the kind of comment that we have to take seriously especially in the classroom (reference back to example used previous week). How could we get rid of any soap on the wire

Kate: Wash it

RR: (goes to wash it) I think I could probably convince her by just telling her but the message in the classroom would be it’s
important to test and challenge the idea. (washed wire burns). The filament doesn't burn .. why?

S2 'Cos it is coiled.
RR (coils a piece to test - still burns) .. So it's not the coiling.
S3 It is the kind of material.
RR If I broke the glass of the bulb we could see what happens (filament burns) ... why?

180 S6 Liz has got it!
Liz Is it 'cos there's no oxygen?
Stuart It is a vacuum.
S5 Brilliant
RR Is it - could they both be right? Can we agree things need oxygen to burn? So if there was no oxygen there it wouldn't burn. But if there's no oxygen ..Stuart was talking about a vacuum. What's a vacuum Stuart?
Stuart You not only take out oxygen, you take out all gases, everything.
RR What happens if you take everything out?
S2 It implodes
RR It collapses in .. did any of you in your secondary schools ever see the oil can experiment where the air is removed (some did). If there was nothing it would collapse in.
Kate (suggests another test with the Brillo pad wire using wires and crocodile clips which she does)
Stuart If you inject carbon dioxide into a fire it damps it down immediately so it could be carbon dioxide in there.

200 RR Let's just look at Kate's test (wire still burnt) .. Now let's return to the gas, it might not be oxygen, it might be carbon dioxide or another gas. (reference to neon lights and inert gases and explanation of why filament doesn't burn)

... It's taken nearly 50 minutes to discuss the bulb and I hope most of you are still with us! (Questions about fuses - review of ideas to date)
You have the idea of electricity trying to push its way through that thin wire where there is a lot of resistance and it is difficult. The push is coming from the battery, the battery is pushing something round. We also have the idea that heat and light is being produced - that's energy. The energy that is in the electricity is being changed into heat and light. Now, how do we deal with the idea of a current, which is the same coming into the bulb as going out. If we imagine carriages going around a circuit and being pushed around by a battery. When the carriages are at the battery they fill up with energy. This is taken to the filament and changed into heat and light. The carriages go back to the battery, but empty. There is still the same number. The current is how many carriages are going around
the circuit. The energy is changing when its offloaded at the filament because of how difficult it is to pass through the thin wire .... when the battery runs out its has lost all its useful energy.

Kate Why do they go back to the battery?

RR Imagine it as a continuous train of carriages .. if one moves they all move. If the battery is pushing because there is a route for the carriages to go round they have got to keep going.

If we break a circuit some children think the electricity moves to the break.

Kate On the way out you can get an electric shock. Are you still going to get one on the way back?

RR An excellent question - that exposes the weakness of the model. This is all happening so very quickly that the 'carriages' are effectively filled up immediately.

Stuart Does a battery pull as well?

RR Yes you can think of it as push and pull.

(encouraged to test which materials let electricity pass ... for the next 15 minutes try out some of the challenges in the booklet, 'A Challenge approach to Science')

Session continued in a similar way to the described in case study 2.

At the end each student was asked to complete the second side of the elicitation/evaluation sheet. The first section on side 2 asked them to chose one of four diagrams to explain what happens to the electric current in a simple circuit:

A - no current in 'return' wire
B - current towards bulb in both wires
C - current less in return wire
D - current the same in both wires

All who expressed a preference (11) selected D

Explanatory comments included:

Val Although I think it will be measurably the same I still think it loses something in the exchange.

Ann Diagram D is the best description of what happens to the electric current. The energy created by the battery passes along the wire, lights the bulb and passes back to the battery.

Evaluation comments written immediately:

Write down an evaluation of the session - What have you gained from it? What comments do you have about the approach used? What concerns do you still have about teaching electricity?
Case Study 3: BEd Yr.4 (Gp 3) Electricity

Kathy
I have gained a better understanding of how an electric circuit works - looking at the light bulb in detail was useful. I have been able to say vague ideas about how I think it works and sort out those ideas and see why they’re wrong or only half right! The hands-on experience is a good approach - far better to learn about the basics than be faced with problems of knowing what’s what in a bulb when you are actually in the middle of a session in class.

Megan
I feel I have a better understanding of electricity - though I’m not even going to attempt the above (explaining a circuit in terms of current). Having first hand experience is very useful. I did this on BSE 1 with Y2 and we all gained a lot from the activity and enjoyed it.

Liz
Very useful and clarified previously rather muddled thinking. Concerns - putting theory into practice. But I’m looking forward to trying it out.

Carol
Gained a basic understanding which I previously did not have. Liked the approach, made mistakes without being made to feel silly. Has given me lots of confidence.

Rachel
The session has been very valuable in helping my understanding of electricity. The approach allowed us to make mistakes and talk about them, which in turn helped to clarify ideas. Feeling a lot more confident towards the teaching of electricity although if approaching this topic I would probably need to do some more reading/practical work on my own.

Stuart
Although I have undertaken work with children using batteries and circuits and I deemed these successful this session exposed gaps in my own understanding. I feel the work undertaken in this session will enhance my work with children. The approach using hypotheses and then testing predictions worked well. I am eager to try out electricity problem solving in the classroom.

Kate
Fun. The approach was useful because the ideas came from us.

Tressila
Useful as we had very little experience of electricity. Have not really thought about how a bulb works before.

Annette
Enjoyed practical work in session - I feel more confident and familiar with using batteries and wires correctly. Also I would feel more confident experimenting in a class of children.

Ann
A greater understanding of how electricity passes through things. How a light bulb works and would feel more confident in relating this knowledge to other electricity work and attempting to introduce such activities to children, although I wouldn’t feel confident to attempt anything sophisticated.
Analysis of Case Study 3

Group 3: Early Years (working with 11 with little or no previous experience of electricity and 2 specialism students on extension activities because they had experienced a similar workshop recently).

Session: Weds 10.11.90, 2.00-4.00pm

Data Collection: Tape of full group discussions
Students' elicitation sheets
Students' evaluation notes

Analysis: 13.11.90

This analysis is directly linked to that relating to Case Studies 1 and 2. The sessions were very similar. A significant change was the use of elicitation sheets at the beginning, proposed as a technique for providing me with more detailed information about the existing ideas the students brought to the session. An example is provided at the end of this section.

The Nature of the approach

Students had been given several weeks notice of the session and this was intended to give them time to start thinking about their existing ideas. The notion of 'orientation' had been introduced to them in a session at the beginning of the autumn term. There is some evidence that individual students did take some action over this. For example, Kate had asked her "boss" for information (CS3: 93). It is interesting that she made numerous positive and interesting contributions to the session highlighting her involvement, perhaps indicating this self-directed orientation had been helpful (Concern 1).

The elicitation sheets were also intended to orientate the students but on reflection the individual nature of this activity was not the most appropriate way to start a session, even with my explicit rider that it was not a test (CS3: 16).

These sheets were used in the light of Concern 3. However, although they provided me with useful information it was not information that I could not have obtained in other ways and they did as noted provide a rather 'threatening' start to the session. On reflection I consider that they may have value during the DES 20-day Course, but not at the very start of cycles, particularly early on in the course.

Encouraging socially constructed understanding
Analysis of Case Study 3

There is more evidence in this case study than the previous two of students being encouraged to discuss their ideas in pairs (CS3: 127), despite the somewhat uncomfortable start to the session working individually. As with both previous case studies I am convinced that the students recognised the importance of this discussion and there was constant reinforcement of the significance of talk and activity to learning in science. The group dynamics were generally conducive to participation although certain individuals were far more involved in the discussion than others (Concern 10). Despite my attempts to draw in all students several seemed far happier listening than talking. This may not have been helped by the more 'threatening' start to the session. Generally the students took each others' ideas seriously, with one exception (CS3: 165) which I tackled immediately and turned into a teaching point.

The nature of science implicit in the session

The importance of practical activity as a route to developing understanding was recognised by the students (eg CS3: 305) and all were keen to handle and test out ideas. In particular Kate (CS3: 196) provided a good example of raising a question which she insisted upon testing, even though the discussion was moving on. She also provided evidence that my ideas were seen by the students as 'tentative' rather than right answers. Even after I had followed up her hypothesis about the soap causing the Brillo wire to burn (CS3: 165) and thought I had convinced her with evidence she wanted to follow-up her own ideas with a test. This I take to be a positive example of students valuing their own activity alongside tutor ideas. Stuart recognised the process of testing hypotheses as important in his evaluation (CS3: 297). This evidence related to Concern 7.

Alternative frameworks held by individuals

The elicitation sheets, referred to above, provided clear evidence that many students lacked understanding of simple circuits and brought alternative ideas to the session. In that sense the elicitation sheets were valuable, but in effect they only confirmed the insights I gained during Case Studies 1 and 2 in a less threatening way, using the drawings of the torch. The information related to the first question 'What is electricity?' provided evidence of the range of scientific language the students were using, but in most cases without evidence of understanding. They were short and basically uninformative responses. The initial drawings of connections showed only four out of eleven were aware of how to connect a bulb. This, however, is again of limited value to me as a teacher since the same information was easily elicited during the initial drawings and practical activity during Case Studies 1 and 2. The majority of students did not write explanatory
Analysis of Case Study 3

Common alternative ideas about there being a vacuum in a bulb were evident (CS3: 184) with evidence of 'imploding' being cited again. Stuart suggested a hypothesis that a bulb might contain carbon dioxide based upon his previous experience (CS3: 198). In terms of current flow Kate introduced a novel suggestion of 'cross-over' concept of 'clashing current' (CS3: 139). The case studies have enabled me to build up a set of common ideas students hold and Case Study 3 provided evidence of the diverse range of individual ideas students bring to or structure during sessions. Again, there are examples of how I tried to respond to and challenge these alternative ideas (CS3: 179). However, in terms of Concern 11, anticipating and confronting common alternative ideas may be more practical if working with a larger group.

Unlike the first two case studies this session dealt with the notion of current more explicitly (CS3: 215) resulting from student comments (not recorded) that current gets used up in the bulb. Time meant this could only be dealt with by exposition and I used an analogy from Osborne and Freeman (1989) based upon 'railway carriages'. This is linked to Concern 12, and I need to clarify in my own mind the differences between metaphors and analogies. It is clear that I have to prepare my use of models since I found Kate's simple question (CS3: 233) challenging and I am not convinced of my response, although the opportunity to highlight the weaknesses of models was important. It reminded me again of how, as a teacher an attempt to deal with a learner can cause you to reflect far more critically upon your own ideas. This is related to Concern 14 and making the point explicitly to students would help reinforce the significance of this. This issue must be made explicit if I use them on the DES 20-day courses. I was unhappy about the way I dealt with this part of the session and considered this needed to be approached differently, perhaps through the use of a simple quantitative approach using digital ammeters. This will be actioned during the DES Electricity cycles. In some respects, I was much too keen to demonstrate my own knowledge rather than take seriously the students' needs at that point.

Supporting students work in the primary classroom

This was tackled in a similar way to Case Studies 1 and 2 and did not raise further issues related to Concern 8.

General issues (with reference back to Case Study 1 and 2)

The session was not quite so tightly structured as those in Case Studies 1 and 2 (Concern 4). There were more opportunities for
Analysis of Case Study 3

paired discussion and exploratory work (Concern 13). This was partly due to the session lasting 2 hours rather than 90 minutes. This was a structural change to the course made in the light of tutor frustrations about organising workshops such as those covered by the earlier case studies for only an hour and a half. The slightly longer session allowed for more flexibility. The longer DES sessions, spread over a day will help considerably in this respect and should enable me to give much more attention to Concern 13.

Although I did not use the computer simulation during the session (see page 58) I had explored it myself, clarified its potential and introduced it to students during a Science Specialism Session. These students subsequently used it collaboratively with less confident students from this group in directed-time. Informal comments from students indicated they found it useful and helped them clarify ideas met during the session.

There may be some evidence of restructuring (Concern 5) in the final section of the elicitation sheet, related to the current in a circuit (CS3:250) but one comment (CS3: 260) indicates that the student's response is perhaps based upon recall and it is an idea that she does not 'believe' or is not clear about. The unstructured section of the session (CS3: 24) involved some problem solving challenges which required application of ideas from the earlier part of the session and evidence was collected of students being able to construct and explain simple circuits, in terms of flow and conductivity, using buzzers and motors.

The concerns I had about the section of the session where I tried to deal with ideas about 'current' caused me to consider the limitation of one-off content sessions. The different sessions during the autumn term have different themes such as light, heat, sound and electricity. Although they are all under the theme of energy the students perception seems to be of discrete sessions. This needs considering by the tutor group in terms of next year's course. The problem is less likely to occur on the DES courses as there are 4 days in each cycle and each cycle has one content theme, or focuses upon one conceptual area.
Explain in your own words which of these diagrams best describes what is happening to the electric current.

A battery is connected up to a torch bulb as shown in the diagram. The bulb is glowing.

In the way you think about it, the electric current in the wires is best described by which diagram?

- A: There will be no electric current in the wire attached to the base of the battery.
- B: The electric current will be in a direction toward the bulb in both wires.
- C: The direction of the electric current will be as shown. The current will be less in the 'return' wire.
- D: The direction of the electric current will be as shown. The current will be the same in both wires.

Write down an evaluation of this session - What have you gained from it? What comments do you have about the approach used? What concerns do you still have about teaching electricity?

Fun! Basically, it felt like a revision of 3rd year physics plus some extra information eg the workings of a bulb. The approach was useful because it came from us, not many questions and awkward questions yet asked.
Explain in your own words which of these diagrams best describes what is happening to the electric current.

A battery is connected up to a torch bulb as shown in the diagram. The bulb is glowing.

In the way you think about it, the electric current in the wires is best described by which diagram?

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Write down an evaluation of this session - What have you gained from it? What comments do you have about the approach used? What concerns do you still have about teaching electricity?

Fun! Basically it felt like a revision of 3rd year physics plus some extra information eg the things of a bulb. The approach was useful since it came from us. Not many concerns or awkward questions got asked.
Case Study 4: DES 20-day (Cohort 1) Materials

Group: 14 teachers from LEA X, Tutors: RR, ST, IS

Sessions: Monday 15.10.90 and Tuesday 16.10.90 9.15am - 4.00pm Friday 19.10.90 (Primary School A - Y1/2 class)

Data Collection: RR field notes
Other tutor's notes
Students' outcomes - Investigation records and elicitation sheets
Flip charts
Floor book
Students' evaluation notes

Aims for the sessions 1 & 2:

1. To develop students' background knowledge and understanding of materials;

2. To provide students' with an example of constructivism in action for adaption in their own teaching

Day 1

9.45 (After an introduction to the day's work RR asked pairs to select five items, with common aspects, from collections of materials provided and share the reasons for their choice. .....

9.55 Each pair was asked to report back to the whole group (the items chosen have not been listed below but the reasons given are transcribed from flip charts. Tutor (RR) probed each contribution for further amplification and clarification.)

Margaret They can all be changed by heat - heated and cooled ... regained
9 ...comes back ...used again ... reversible

Chris They are all biodegradable ... will disintegrate ... absorbed by earth ... breaks down into natural components ... rotting ...
9 decomposing

Caroline Same texture .. fairly rough
14 .... all have air spaces

Mary B All natural fibres

RR What are fibres?

Mary B not small pieces ... once living strands

Gill They can all have their shape changed ... its the effect of
19 pressure or heat

Ann They can all be identified by smell and they are all processed ...
... something has been done to them

Joy All translucent ... can see through them ... some are liquids

Phil Shape is the same ... all cylinders

James They all bounce ... springy

Barbara They are all mixtures ... fibres ... stone, glass, plastic and
26 metals

Lorna The papers are all processed in a particular way.

RR You have suggested lots of properties of materials, let's list
Case Study 4: DES 20-day (Cohort 1) Materials

them and brainstorm any others you can think of ...
(Flipchart -
liquids, solids and gases
changes - burn, stretch, processed, evaporate, absorbency
smell, transparency, strength, bounce, density, hard/soft -
compressibility, reflectivity, processed/natural, float/sink,
waterproof, weight, sounds when hit, insulate, conductivity
(electricity), magnetic, cold or warm to touch, texture, colour)
....
10.15
(Pairs were asked to explore one of the collections provided and
list questions that could be investigated (ST). A record sheet
was provided.)
....
11.15
(A report back was led by ST who began by reminding the course
member's about the nature of the scientific process.
The comments were recorded in a floor book and RR took notes.)
Barbara (Rock collection with James) Our questions were mainly factual
eg what does crystalline mean. We were surprised some rocks
smelt. Is it something to do with them being Ferris? Why are
some layered? Some are like stirred up mixtures. Will they
absorb water? What can they be used for? Why are they attracted
to a compass? ... sometimes it was, although not to single
rocks! How would the rocks break? .. into bits, powder or
layers?
Phil (Papers with Lorna) What is paper? When does paper become card?
What process is used to produce paper especially blotting paper
and tissue? Which papers are strongest and most durable?
What will the effect of heat be? ... warming and burning.
Which are see through? Which are greaseproof? How do they tear?
Joy (Balls with Ann) What are they like inside? ... layered,
solid/hollow? How areodynamic are they? ... How far do they
travel through the air? Does how easily they roll depend on
their surface? Which can take the most pressure (weight) without
distorting? Which is bounciest .. height of bounce and number of
bounces? What materials have been used? Why do things bounce?
Barbara If they bounce are they loosing energy? ... if it's moving it's
using energy
Lorna It could be the force
Joy Energy can't disappear
Phil Marbles make noise ... uses energy
Gill The pressure inside affects the bounce
Mary (Kitchen utensils with Gill) What is the knife handle made of?
Will they cut and what? What happens if they burn? Can they be
damaged by hot water or the detergents used in dish washers? Are
they potentially dangerous? Do they conduct heat or electricity?
Are they magnetic? What are the metals used? Why do handles
become loose? ... could be adhesive fails, metal rusting inside
or water damage to the bone.
Mary (Fibres with Caroline) Are they all made up of threads? Will
wool loose its strength in water? Will hot water affect the
plastic string? Is plaiting a method of making things strong? Is
Case Study 4: DES 20-day (Cohort 1) Materials

80 the strength something to do with the fibres structure? Are they fireproof or flammable?

Andrea (Powders with Christine) What are they? How do they change if mixed with water (hot and cold) or oil? Will they dissolve? What happens if exposed to air? ... could try a damp cloth over them.... need to measure the humidity of the air. What are some abrasive?

Lin (Candles with Margaret) What happens when you heat the candle? What happens to them in water? What if you put force on both ends (to test rigidity)? What happens to the wax when you burn the wick? Does the wick affect the time to burn? How can you make them burn brighter? Can the dye be separated from the wax? How do you perfume candles? How is paraffin and bees wax made?

12.15 Pairs then selected a question and devised an investigation (completing page two of a report form).

J&B set out to explore the meaning of crystalline

MP&G to investigate staining

A&C to investigate dissolving in water

L&M to find out what weight changes occur when candles burn and where has it gone?

J&A to investigate the distance balls travelled

P&L to test the strength of papers

.....

12.30 Lunch

1.45 Pairs worked on their chosen investigations and completed the third section of the report form, indicating generalised statements they had reached.

2.50 There was a review and the following statements were shared:

James Crystals have smooth surfaces, flat planes, sharp edges, shininess, regularity of shape, transparent and brittle (confirmed using books after observation and formulation).

Joy The lightest ball went furthest with the method of propulsion used. The ball's circumference seemed to make no difference.

Andrea Generally hot water dissolved "dissolvable" substances more easily than cold water. Generally the greater the volume of water the more easily the substances dissolved.

Phil Tentative ideas based on limited results: The thinner the paper the weaker it is; the more transparent the weaker it is;

120 blotted paper is incredibly strong.

Gill All droplets flattened out and spread. No metals stained after five minutes. Surgical spirit leaves a deposit on all surfaces and the wood absorbed it immediately. Nothing appeared to still have a stain after washing up apart from the wood.

Lin All (10) candles were 16-17g less in weight after 15 minutes burning. Therefore candles may burn at about 64g per hour. The night light may be made of denser wax. The size of wick does not affect the rate of burning. A thin candle appears to have a tall flame because the wax runs off quickly, a thick candle will give a small flame because a pool of wax forms and prevents a large
Caroline

Reached no generalised statement due to lack of time.

3.15 RR outlined the extent to which a constructivist model had been used during the day. He suggested course members try and produce a concept map of ideas based on their investigation to help them clarify any new ideas they have about materials. He then outlined the use of key themes for aiding the planning of science and the use of 'big ideas' especially in relation to materials.

Day 2

9.15 Andrea arrived having tested a number of household substances to see what happened when they dissolved. She had found a teaspoon in 25ml of water caused the level to rise in all cases except when coffee was used. She had noticed coffee settled on the surface and dissolved as it sank, the rest sank straight to the bottom and then dissolved.

James reported informally that he had already used the 'big ideas' he had read about in the course materials as the basis for a record keeping approach.

IS led the morning session. He explained that he was going to deal with the big idea concerning solids, liquids and gases. He asked the pairs (from yesterday with 2 changes - Phil/Caroline and Lorna/Mary) to complete elicitation sheets provided.

Course members were asked to retain these sheets for later reflection. Examples from Mary B, Gill, Margaret and Lin are included with this case study.

IS then asked the pairs to sort a collection of materials into solids, liquids and gases and don't knows. The collection included Blu Tac and shaving foam which caused considerable discussion. As pairs finished the sorting they were asked to write down their criteria for each state.

Caroline

The molecules in the table aren't moving.

10.25 IS What is a solid?

Gill The molecules are static.

James Fixed state

Lorna Fixed weight

Lin Can't be poured

Lorna Can alter the shape if you exert an energy or force but the mass stays the same

Andrea Shape can change, for example salt dissolved in water has changed its shape

Lorna State and shape are different. When you put sugar in water you are changing its state.

Joy Particles are held together less rigidly

Mary B Is molecular structure changing as you heat it?

Andrea Living things are solid and they are moving.
Case Study 4: DES 20-day (Cohort 1) Materials

Phil  Glass is still liquid, if left standing the bottom gets thicker than the top.

IS  What is a liquid?

Mary P  It can change shape.

Barbara  On its own

Ann  They are heavier than air

Andrea  They take the shape of their container from the bottom upwards.

Mary  The volume remains the same unless energy is applied.

Joy  Molecules are less firmly held together

Gill  Molecules only move when external force is applied.

Lin  Always finds its level

Andrea  It pours

Lorna  I don't think molecules only move when force is applied, they're moving about all the time. They're not held together (in a liquid) as they are in a solid.

Caroline  Substances are liquids at different temperatures according to what they are. Substances can be liquids, solids or gases.

Ann  They have different freezing points

Margaret  If you start with a solid and heat it it becomes a liquid except clay - you dry off water and it becomes solid

Lin  But is it a liquid when you apply heat?

Margaret  All liquids are solid particles in a liquid. (Discussion about clay)

Lin  Isn't it to do with the amount of molecules and how they are structured ... in solids there are more and they are more tightly structured, closer together

Lorna  Not more (molecules in a solid)

Andrea  Is that (more molecules) given equal volumes?

Joy  For the same volume gas is lighter than a liquid and a liquid is lighter than a solid.

IS  What is a gas?

Mary P  Molecules are moving all the time... normally invisible

Ann  Very light

Andrea  Spreads out to take the shape of entire container

Mary  (weight) can be measured if (gas is) collected

Barbara  Can be compressed

Ann  Spreads out if not in a container

Joy  Has had more energy applied to it to make it a gas

Andrea  What about naturally occurring gases?

Joy  It still has more energy in the gaseous state

Ann  Do all gases have to come from a solid?

Barbara  Do all substances have three states?

Lorna  They're more explosive.

Mary P  Do solids smell because they are giving off a gas?

Andrea  What is an empty container?

James  Are all gases manufactured? Naturally or otherwise?

IS  Can you measure the volume (of a gas)?

Phil  It takes up its entire container.

Andrea  You turn it into a liquid to measure its volume

Phil  What goes between molecules of a gas?
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Mary

Can you pour gas?

10.55
Coffee

235
.....

11.15
IS outlined the kinetic theory and used a computer simulation to illustrate solids, liquids and gases. He dealt with absolute zero, movement energy of particles, pressure increasing with temperature, compression or the addition of more gas and evaporation. Throughout the exposition he asked questions and was challenged by group members. He addressed most of the questions raised before coffee (referring to flip charts). He then dealt with physical and chemical changes and explored burning, especially in relation to a candle flame and explained how only gases burn.

245
.....

12.30
He ended the session by giving out a sheet on particle theory and inviting the course members to complete another elicitation sheet (identical to those used at the start) based on any new ideas they had about the phenomena described. ..... The afternoon was taken up with planning for the school-based day. Three pairs decided to work with fabrics, two pairs with papers and two with packages. ..... At the end of the afternoon course members were asked to write down an evaluation of the two days.

250
.....

Mary B

Day 2 was enlightening and very useful for clarifying one's own ideas. A lot of information was given quickly and would probably have been better over a longer period, particularly to ensure ideas had been digested and passed on to colleagues correctly. Day 1 made one think clearly about the meaning of the word 'material' and the numerous possibilities of sorting/classifying and hence the variety of tests that could be devised comparatively simply. Hands on experience was valid. Tests could possibly have been made after day two's output to test out some of the input.

Ann

Day 1 laid the foundations for thinking and finding out what I thought. I wanted some answers straight away but now realise I need to think things through rather than accepting a theory. Gave me more confidence in my own abilities especially working with a partner. Day 2 - enjoyed being stretched, hearing everyone's theories. Enjoyed answers to questions. Realised how little I had thought of basic theories. I think I need more technical input for basic ideas. Discussion in the morning helped group to work together as a whole.

Phil

Good balance between practical tasks and other bits as always time is the limiting constraint, bearing this in mind I feel the two days managed to address quite well the problems we can encounter. Day 2 am was too long sat still although very interesting and reminded me of lost information. I would have liked a practical session or at least something to break the morning up.

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Andrea Hands on is a must but inevitably it leads to a large number of questions which remained unanswered at the end of the day. So I found day 2 valuable as it helped me, not so much answer all the questions, but come some way towards a greater understanding which it would have been very frustrating not to have had. Having said that today would not have been so valuable if we had not been doing yesterday. A long way round of saying the balance seemed right. This has been the first occasion when I have been fully convinced that working at our own level was right - partly to demonstrate that we could question long held beliefs without oversimplification and partly because when we came to plan for children the relevance of what we had done could be transferred to our planning for the children - we did not assume too much for them having questioned ourselves so much already.

Margaret Good points - stimulus of being made to think about seemingly simple questions; discussion; review of question sheets - seeing how far my knowledge has been built on/changed/reinforced; being shown how this process can be translated into classroom practice ie constructivist approach. Could be expanded - activities, learning and discussion at own level (this highlighted preconceptions, helped me to question them and also helped me to accept that not all questions can be answered).

Joy Both days worthwhile, the open-endeness of day 1 prepared us for day 2. The contrast between the two days helps clarify different approaches used in the classroom. I found it especially useful to have ideas of solid/liquid/gas explained. It helped clarify thoughts which I was somewhat confused by - having dim recollections from my own school education. I would find it interesting to have more sessions like that covering other areas. Opportunity to discuss with partner and ask questions as necessary is very valuable.

Gill A rally fascinating two days. I really enjoyed working at my own level, no experiences of this nature for many years. This morning a lot of ideas and information were exchanged in a short time and I needed more time for reflection and digesting.

Lin I think the balance of first hand experience and input from Ian is about right. The variety of approaches has held my interest. Too much practical experience would be counter productive in the time schedule we have. Sometimes it is necessary to be told the answers! So far, I think the course is excellent though it makes me realise how little time we have and how much we have yet to learn. I like working in pairs and having problems posed, without feeling threatened. I hope we'll be looking into the science coordinator's role in more detail.

James Day 1 - really enjoyed working at my own level, collaboratively learnt a great deal and obviously had a lot of satisfaction from results. Certainly learnt a good deal about processes of learning on this day. Day 2 - am again enjoyable, Ian's input excellent - lots of my own alternative views nicely eased into mainstream thinking.
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Mary
336 I found today very good and it made me think more carefully about the ideas I already hold. Day 1 - I found very interesting in the approach used but at first I didn't quite understand what was exactly wanted.

Lorna
340 I found both days very interesting. I particularly enjoyed the discussion sessions on the second morning. It was good to have a workshop and I liked the open-ended approach at the beginning. It was interesting to actually devise a test and it made me think about how children react in a similar situation.

Barbara
345 I found both days very useful - I found day 1’s open-ended type approach good, because it put me in the child's position and helped me to understand the processes I need to encourage in following this through. I enjoyed - found helpful - this morning's teaching session, because my ideas need a lot of background. The balance seems about right - too much information might be hard to take! Practical workshop sessions seem slightly more helpful when followed by factual back-up.

Chris
355 Day 1 - enjoyed the investigative approach. Hands on experience is useful and helps to clarify own thinking. Balance between listening/doing about right. Gave a lot of food for thought and enabled a more questioning approach. Some questions were left unanswered, but I feel I can go away and find some of the answers myself. Day 2 - am mind-blowing!! - clarified a lot of thoughts from day 1, own inadequacies in basic knowledge of science highlighted - feeling out of my own depth at times. Good explanations helped sort out some of the confusions. Questions raised helped by molecular discussion/computer simulation. Need to go away and think through clearly at a slower pace to absorb what has been said.

360 Day 3 - Work in Primary School A with a Y1/2 class. This was recorded in Assessment in Science Project Teachers' Notebooks.

8.45 am Arrival
371 9.30 am First teaching session (6 groups with 4 children, 1 with 3) ... most groups soon had children practically involved in activities although all remained seated around the tables where they had started. Lots of teacher talk and the children were in some groups reluctant to contribute more than answers to direct questions.

10.15am Evaluation session ... pairs discussed first impressions of session, response of children, teacher's role etc. Some expressed concern about not knowing the children

10.45am Using skills sheet pairs attempted to identify skills used by children during the session. Most pairs confidently identified most of the exploratory skills (except recording) and
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Some felt their group were already using investigational skills such as planning an investigation. It was apparent that most pairs felt there was an expectation to move the children on to a 'fair' test in the second session. RR stressed this was not expected and indeed was unlikely to be appropriate for most of the class who would need further exploration. Only one or two pairs had time to look for evidence of children's ideas.

11.45am Pairs started planning afternoon teaching session.

12.00 Lunch

1.00pm Further planning.

1.30pm Second teaching session with pairs reversing roles.

The children were more relaxed during this session and several groups moved on to the floor or to a more spacious area. Lots of handling of materials was evident and in some groups the children apparently had greater 'control' of the work and were more enthusiastic in their responses. Most groups tackled some form of investigation although in several this basically involved exploration in a slightly more systematic way.

2.15 Further evaluation session.

Again pairs wrote down initial impressions of the activity, children's responses and the teacher's role. They were then asked to focus on one child and note (without reference to data) the achievements in terms of skills and ideas. They analysed the data to find evidence to support reject or extend their first impressions. This led to fascinating discussions about the nature of 'hypothesising' and other skills and in at least two pairs revelations about the extent to which first impressions considerably underestimated the extent of the individual's contribution. One pair felt there had been little achievement in the forty five minutes. However, more careful analysis indicated numerous evidence of skills being demonstrated. The teacher involved had been particularly concerned that the children had stuck sticky paper on to a sheet using glue. However, analysis of the data indicated an earlier conversation in which a child had remembered using sticky paper before and reported that although they had licked and stuck it, it had soon fallen off the display. Another pair identified several key ideas about materials in their data for the chosen individual and were able to assess the child's knowledge and understanding in three attainment targets (AT6 Materials, AT13 Energy and AT9 Earth and atmosphere). They claimed the child had achieved level 2 in each.

3.30 A plenary discussion took place. RR suggested that each pair further analyse their data and provide the class teacher with written feedback of the achievements of each child, particularly in AT 1. Course members were positive about the
value of the day. At least two indicated that they intended to take back the idea of collecting careful data on a limited number of children for close analysis into their own classrooms. RR questioned the extent to which they could see the purpose of such detailed data collection. The response indicated that all could see the need to do this, although earlier in the day one or two had suggested taping the children would be easier. The disadvantage of this in terms of not being able to share an immediate evaluation was apparent to all by the end of the day. They were also questioned about the extent to which the first three days had been coherent. All felt that the third day had been a very valuable development of the work done on the first two days.
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Day 4

Aims: To look at the nature of investigations
To review work students have tried out in school
To revisit some of the ideas explored on day 1 & 2.

9.15 (RR introduced the day and outlined the programme:
9.30 Approaches to investigations - sherbert lemon (ST)
10.30 The nature of variables (IS)
12.00 Revisiting candles
1.30 Approaches to a collection of rubbish (ST)
3.15 Review of school work
4.00 Question time)

9.30 (ST introduced a task on dissolving, two groups of 3 (Andrea, Chris & Mary, Caroline, Lin & Margaret) were given a worksheet detailing an investigation and two groups of 4 (Ann, Joy, Mary B & Gill, James, Phil, Barbara & Lorna) were invited to find out how long it takes a sweet to dissolve. Each group was unaware of what the other groups had been told. Each group was asked to appoint an observer to note down what happened)

10.00 ST Will the observers outline the approach of their groups.
Caroline (Read out worksheet) The decisions concerned which container we would use and which stick to stir with. One person said, "We'll use this one" and the rest went along with it....(group) were drawing on previous experience. We questioned whether to time it, whether to change the direction of the stirring, how and what the sweet can be crushed with. We found we should have done things eg take the temperature of the water.

What levels in ATI were you working at?
Margaret 1 and 2
Lin We were fair testing
Andrea We were going to split the activity (one person doing each test) but decided that would mean no joint decisions. We decided to use hot water and measure the volume. We agreed the state of the dissolved sweet since there were bits of kettle as well! We didn't need to test the temperature since we decided to use just-boiled water. We decided, after the first test, to keep the stirring the same.....
We felt we could do the investigation with infants.
Margaret We were directed without having to think
Mary A child would follow the instructions as written down, we were thinking more about it. Children would rush in and not think ahead.
Lin Some get on and do, some ponder. I want to know why Lorna is still stirring.
Lorna It's our experiment
ST The other groups had less guidance.
Phil We first went to see what was available. We decided to recreate the mouth, use body temperature. we thought about saliva - is it
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acid or alkaline? We thought about using vinegar with water. We chose to use a small container - mouth size. After our first test we realised there were too many variables. We changed the water every few stirs to represent swallowing. Then we split up, I acted as a control and chewed and sucked a sweet. We crushed two and stirred one of them, and we had whole sweets stirred and not stirred. We could narrow down our test if we had more time. Lorna is testing the whole one! We think we were working at level 6+ in ATL.

Mary B It was very interesting. We tested two crushed and uncrushed. We weighed the sweets accurately to check if they were the same. We crushed them with paper wrapped round and the paper split.

We then tried giving them a gentle tap - that worked.... we used 200ml of water at a time and it was very hot water, we took the temperature, using two thermometers and poured (them out) at the same time. We stirred them. Somebody decided to crush one finer and it dissolved more quickly. We were working at level 4 since we constructed a fair test.

(discussion about different approaches and their advantages)

IS I would suggest that those using the work sheet were making low level decisions - which stick etc.

Mary But it can become too open-ended.

Barabara You generally have a point you want to reach.

Lorna It's not what they arrive at, but how they get there (that is important)

ST The problem (of too many different lines of enquiry) can be overcome by getting the children to report back to you before they start to investigate.

IS Worksheets can be a starting point.

RR But it is important that the children are 'hooked' by an activity and this can be a problem if a worksheet is used.

10.50 IS Variables have been mentioned this morning and we are going to explore them further now. I want you to work in the groups you are in and brainstorm the factors that affect dissolving.

11.00 Contributions included (later clarification, when probed is indicated): size of object, volume of fluid/liquid, source of heat (Ann: whether hot water on on a source), type of liquid (Lorna: eg acid), density of liquid, density of object, size of container, agitation, state of solid (Mary B: no, I've used the wrong word), time (Lorna: that not to do with dissolving but testing), energy source (Mary: energy has to be provided, shaking, whisking etc.), nature of substance, shape of container, stirring instrument used, pressure (James: whether you press on it with the stirrer), speed of stirring, surface of object (Phil: porous or waterproof), surface area.

Mary We could be dissolving a liquid in a liquid.

11.10 IS Select three factors, and in your groups come up with a
hypothesis, based on particle theory and a way to investigate it. (provided a sheet for recording ideas)

11.30 (feedback discussion)
Lorna Keep the substance the same, don’t agitate it and change the size of particles and measure how quickly each dissolves.
Joy We decided it would be hard to vary the agitation regularly.
Andrea Keep the volume and temperature the same, independent variable - surface area. Dependent variable - time or number of stirs.

IS What about the problem of deciding when it had all gone, especially if you are stirring it?
Mary B You could weigh what is left after a certain time.
IS Or measure how much you can get to dissolve me, have both boiling on a cooker. When you make jam you stir as well.
Lorna That’s to do with the volume of liquid and solid involved.

... Joy
How do you prevent children going away with the wrong idea (if you use their investigations and results)?
(discussion about tentative nature of science, teachers challenging children’s ideas and finding example of contrary evidence)

11.50 IS We would like you to complete this candle sheet individually to give us an idea of how much of day 2’s input you are able to apply.

... (there was an apparent need for further discussion of points about change of state and burning which RR led up until lunch). The candle sheets were analysed in terms of the ideas used to explain a candle burning. A * indicates the term or idea was included in an individual’s response:

589 Name  melts  wax>wick  liq>gas  particles  wax burns  wick burns

Lorna  * Oxygen  *
Barbara  * * * * *
Mary B  * * * *
Caroline  * * *
Lin  * gives off a * *
gas water evaporates
Margaret  *
Andrea  *
Mary  *
Christine  *
Ann  * burnt off as a *
gas
Gill  *
Joy  * * * *
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Phil * * * * * 
James * * *

Examples:

Joy Wax (solid) melts (liquid) as heat from match applied. Wax travels up wick. Wax turns to gas and ignites. Heat from flame continues to melt wax. the top of the wick is burnt. Candles molecules are becoming less strongly held and they have more energy and are moving more quickly. The energy is being applied by the flame.

Margaret Wax is drawn up into the wick through capillary action. It feeds the wick and slows down the rate of burning. The heat from the flame melts the wax below the wick. Some of the wax, ie that in the wick, is 'burnt'. I'm not sure if this is a chemical reaction or if the wax molecules are heated sufficiently to become a gas and disperse in the atmosphere. What is a flame?

2.00 (ST used a collection of rubbish to introduce a range of strategies for introducing sorting and classifying - volunteers sorted the collection and other tried to guess; someone chose an object and others tried to guess by asking questions that could be answered with a yes or no; a paired activity with partners sitting back to back - one chooses an object the other asks questions, one describes it (without labelling) and the other draws it; Carroll diagrams; domino game - each person writes a card indicating how their object is the same as (or different) to the one already placed; identification trees (on paper and using Branch on the computer).

3.20 (group split into 2 and shared experiences of activities tried in school with their own classes - the following notes were taken as they talked about their work)

Chris (had done little science before) As part of a Three Bears topic with her Y2 class she had worked with a group of 4 children and used a floor book to record their ideas - How could we keep porridge hot? If the sun is out leave it on a shelf; put a towel over it; put a plate on it. What does the plate do? Keeps the air in; heat in; warm in; cold out. What kind of lid could we use? Solid one; thick one; tight one, otherwise the air will get out. They explored a variety of 'insulating' materials, ordered them according to predictions, described them, at which point one child said, "It doesn't matter if it's nice and soft, it's whether it's going to keep it warm". How could we test which is best? (probed what they thought test meant - trying something out, and what 'fair' meant - if it's like that for one time, it's got to be like that after) One child suggested using a thermometer (C surprised since they had not met them in school before). They tried a test.

Andrea Worked with a collection of fabrics (with her Y1/2 class). She
felt all the science she had done previously had been with a clear purpose as far as the children were concerned (testing to find out which is best etc). But on this occasion she tried to find out what the children wanted to find out about. She used a floor book with a group of 10. They did some sorting and then tests based on the children's ideas. She probed their ideas about fairness - "to do the same to each". They were testing for waterproofness and she found one child was confusing ideas about sinking with waterproofness and although the child concerned went along with the rest of the group's ideas for a test she hung on to her original idea when asked to record the test. She contextualised the work in a story about Mrs. plug for another group. One child when they started testing said, "Everybody's doing something different, it's not fair!". She felt the context based task involved the children in using more process skills but a more open approach provided opportunities for more question-raising. Both approaches have there place.

Mary Y5 class had worked with a collection of waste materials and devised their own criteria for sorting, they had looked closely and used criteria such as metals, plastic and glass; dangerous and safe. She asked them to choose 3 to 5 items with a 'connection', they used terms like recycled, corroded. The first group chose to do some observational drawings. Another group chose to use the collection when working with a supply teacher and reported their findings to Mary when she returned. They had been discussing similarities and differences. They went on to investigate the materials' properties.

Caroline Tried out work on dissolving with the whole class in groups of 7. The topic for her Y5/6 class was water. The children had sugar, salt, orange juice and other foods to explore. They talked about which were powders and crystals. They tried dissolving tests, making predictions and then testing to see if they were right. Only one group chose to test with hot water and the rest 'copied'. The solutions were left over half term and when they returned some had recrystallised and others had gone mouldy which prompted some useful discussions.

Lin Talked about the difficulties she had had with her special class when trying work on floating and sinking. They had talked about what would float and she found some of their predictions were obviously wrong, although hypotheses like 'heavy things sink and light things float' were made. She challenged these. They tested objects and then went on to make boats. Difficulties with manipulative skills led to some frustration.

Margaret Her Y2 class of 30 children had looked at fabrics. They were posed problems, 'If you had to make a hat which would you use?', 'If you were making night clothes which would you use?'. This led to testing which materials were flammable. There were some who raised questions about the fairness of the tests they
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did. They were curious about what was left when things burnt. The whole class were involved and enthusiastic, waiting turns etc. She had found recording a slight problem, some can write, some can't. (all course members had done some work with their classes linked to the materials theme).
Record your ideas in a simple concept map. Put the name of your investigative focus in the main box and aspects of that into the smaller boxes. Link boxes with lines in any order, but only if you can write the nature of the link along the line.

1. What did you find out?
   Collection of powders and liquids - visual observation
   Identification by smell & previous experience - discovered
   range of food, cleaning materials, lubricants (some toxic).
   Glass containers made identification of substances easier.
   Need for safety considerations.

2. Note questions raised that could be answered by further investigation.
   Would the substances mix with water?
   Would each other.
   What changes would occur?
   Could change occur in another way e.g. leaving exposed to the air, covering with a damp cloth.
   Does the abrasive nature of substances have the same cleaning effect as the known abrasiveness of cleaning materials.

3. What clarification or explanation would you like?
   Confirmation of our identification of substances (especially toxic ones).

Note: Process skills in action.
DESIGNING AN INVESTIGATION
(Structuring - Restructuring)

1. What question will your investigation seek to answer?
(or what statement will it seek to disprove?)
Will substances remain dissolved in hot water?
Will substances not dissolve in cold water and separate out over a time span of 5 minutes?

2. Note possible approaches to the investigation.

UN ITED PEACE ALLIANCE

EXTENSION
Use 3rd substance
Use 4th substance (another salt)
Use for both
Use for 10 mins
Stand for 5 minutes

3. Note approach taken and variables considered.

INVESTIGATION
(Restructuring - Applying)
RAISING QUESTIONS

1. What did you find out?
Can you make a generalised statement?
Generally, generally, hot water dissolved "dissolvable" substances more easily than cold water.
We thought we found generally that the greater the volume of water, the more easily
those substances dissolved.

2. Note further questions raised during the investigation.
How long would a substance left in a beaker make any difference?
Does the water level in a beaker remain water? (and why?)

QUESTIONS FOR THE SCIENTIST

3. What clarification or explanation would you like?
Why did the level of water rise when 25ml hot water was mixed with
5ml unsaturated sugar?
Will sugar dissolve in cold water if left over a longer period of time?
— or will any other substance dissolve eventually?

4. Note PROCESS skills in action during the activity.
Press down the plunger of each syringe.
Write down what you notice.

Sand: The plunger can be pressed down to the sand level.
Air: The plunger moves freely up and down to the level of compressed air.
Water: The plunger will not move in either direction very easily.

What are your explanations for what you notice?
Discuss your ideas with your partner before writing down what you think.

Water: Much greater force had to be used to move the plunger. A few air bubbles were released not compatible with the space created. Most of the space must have been a vacuum. This is confirmed by the fact that the plunger immediately returned to its former position.
This saucepan of cold water is on an electric ring which has been turned to high. If the saucepan is left there what will happen to the water? What will happen to the temperature of the water throughout this time?

The temperature will begin to rise. Bubbles of air will appear on the bottom inside of the saucepan. As the temperature continues to rise, the water will bubble and its temperature will reach 100°C. At this point, water will eventually evaporate completely.

Write down an explanation for what happens.

The molecules of water are given energy to move by heat. Faster moving molecules escape. Continuous heat causes all molecules to eventually escape. Air in water escapes first.
What do you notice when the cover of the air freshener is open?

A strong perfume is smelled.

What are your explanations for what you notice? Discuss your ideas with your partner before writing down what you think.

The scent is removed rapidly and steady until all the liquid has evaporated. The speed increases as the liquid is absorbed quickly. The liquid turns to a gas. Pad...possibly sprayed foam.

PLEASE CLOSE THE AIR FRESHENER
What will happen if these ice cubes are left out on a kitchen work surface for several days?

The ice-cubes will have melted and the water will have evaporated and left a water-mark around all sides of the dish.

Explain in as much detail as you can why you think this happens.

The ice-cubes revert to its former state (water) when the surrounding temp > 0°C and then over a period of time it evaporates. The warmth of the atmosphere causes the molecules in the water to speed up their action and escape. The ring left in the dish is the deposit left by the impurities, possibly calcium + lime.
Press down the plunger of each syringe.
Write down what you notice.

Air: ...80 ml at 15 ml. There is...moisture...The...syringe...Stops at 5 ml.
Water: ...No...movement...reading...Stops...the...same...15 ml...Water doesn't...
A small air bubble is formed. Should it be there?
Sand: ...3 ml...in...increased...to...15 ml...Sand...is...compressed...

What are your explanations for what you notice?
Discuss your ideas with your partner before writing down what you think.

Air: ...The...air...is...compressed...from...13 ml...to...5 ml...Air...density...

Water: ...Water...density...cannot...change...Water...contains...air...

Sand: ...Some...air...was...forced...into...sand...and...so...increased...volume...
What will happen to the bar of chocolate if the saucepan is put on a source of heat? What will happen if the saucepan is then left to cool?

It will melt from the outside in. If the saucepan is too great a heat it will burn eventually. If it must be stirred to prevent uneven melting when cooled it changes to a firm and slowly solidifies. It forms a crust and no longer has its shiny texture.

What are your explanations for this?

When heated slowly the water lets turn into a liquid form. Water evaporates during heating. After heating, cooling turns it proportionally more fluid. The water in the chocolate appears heavier. We assume if you weighed the shore of water it would weigh less. Perhaps air is also released. This gives a denser composition after cooling. If heated in a microwave water is heated but not driven off.
Analysis of Case Study 4

Group: Cohort 1
1st analysis: 19.10.90
2nd analysis: 11.11.90

The nature of the teaching approach

This session resulted from collaborative planning with the tutor team involved in cycle 1 of the course and co-tutors were responsible for several key inputs. The data draws upon their work with the group as well as my own. The insights gained as a result of observing their interactions and the teachers responses to them together with the ongoing discussions with them during and after sessions informed this analysis, which was discussed with them in some detail. There was an attempt to offer teachers an approach that emphasised an exploratory phase prior to investigation. There was little time for orientation during the session although the teachers had prior warning of the science content from a pre-course meeting held two weeks before the session. The first activity (CS4: 1) obviously provided some orientation for those that needed it. The importance of exploration was made explicit during the day (CS4: 38, 134) and the school-based work during day 3 provided evidence that this was seen as important by the course members since all pairs began their work with children in an exploratory manner (CS4: 372). This directly addresses Concern 13 (resulting from Case Study 2) and suggests that adults do need time for exploration themselves if they are to recognise its importance when working with children. The fact that most then moved the children on to investigations with undue haste (CS4: 386) may be due to the structure of day 1 and the implicit expectation that as adults they could move fairly quickly from exploration to investigation. There is also a difficulty about allowing adults to pursue any interest that arises from exploration that reflects that met by teachers in the classroom. In this case study the students were directed towards particular collections and pushed very quickly into identifying a question for investigation. Whilst this was successful for most there were exceptions (CS4: 132) and it is reasonable to suggest that this was due to inadequate time for exploration and consequent lack of commitment to a particular investigation. This issue requires more discussion with the tutor group prior to the detailed planning of cycle 2.

How can course members be given more 'ownership' of investigations? (new concern 15).

Elicitation of students' existing ideas was given a priority throughout the day. The first activity yielded considerable evidence of their ideas about properties (CS4: 31) and the review of potential areas for investigation provided evidence of their
understanding of science processes, control of variables etc (CS4: 46-93). This also elicited more of their existing ideas, for example about energy (CS4: 64-67). However, I did not probe the students' understanding of some of the words used to describe properties in the way that IS did during Case Study 5 (CS5: 36). This provided an indication of some alternative frameworks. The review of investigative work (CS4: 109) added to our insights about students' ideas. The use of a floorbook (by ST) was successful at this point of the day and together with the use of flip charts provided some evidence to address Concern 3 (resulting from Case Study 1). The morning of day 2 was also organised to provide more evidence of their ideas. Elicitation sheets were used at the start of the day (CS4: 155). Although these were intended to be used as a means of course members reflecting back on their initial ideas they provided the us with valuable insights into course members' ideas (see examples at the end of the case study) which are analysed later. This again provides a method of eliciting that addresses Concern 3, and was more successful than the use of elicitation sheets during Case Study 3.

Course members were introduced to the idea of a concept map (see page 4 of investigation record sheet) at the end of day 1 (CS4: 136) and encouraged to produce one for the investigation they had conducted. By day 3 none had done this and so it requires more careful introduction during day 4 or cycle 2 since it was identified during my review of concerns as a suitable strategy to address Concern 3 discussed above.

The second day included a substantial input when IS provided an introduction to particulate theory. His treatment was based on existing ideas shared by the group and developed from comments made by students about molecules (CS4: 168). The student evaluations were generally positive about this exposition and the use of a computer simulation (eg CS4: 287, 310) although several considered it too much to be given in one treatment (CS4: 260, 280).

The balance between input and student initiated practical work is a key question to address in future cycles (of the course). The present evaluation seem to suggest that the students consider the balance offered to be about right (CS4: 291). However, whether this balance is most successful in terms of leading to restructured ideas that can be used to improve the quality of science experiences for children in the classroom remains unanswered. The timing of tutor inputs is also worthy of consideration. Should it always come after practical exploration and investigation or, as one student suggested (CS4: 265), before to allow the practical to test out the ideas offered?

Which part of a cycle should include tutor input of accepted

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scientific ideas? (new Concern 16).

The particular input on this cycle required students to have a concept of "energy" which was not really probed by the tutor and could have led to some students reinforcing existing alternative frameworks that they held.

The nature of science implicit in the session

The students showed some evidence of recognising the importance of processes in science and of accepting that science is essentially about tentative understanding. There were numerous examples of question raising that indicated the students were distinguishing between factual and investigational questions, most clearly in the case of James (CS4: 46) who articulated the point. Although he and Barbara went on to provide an example of how even factual questions can be used as a starting point for good investigational work. Their question (CS4: 46) "What does crystalline mean?" could have been answered by reference to an appropriate text. However, before looking up an answer they chose to decide on their own criteria through observation and investigation. Their findings (CS4: 110) were accurate and confirmed by reference at the end of the afternoon. They gained a tremendous amount (CS4: 331, 346) from their activity which would not have resulted from using a book immediately.

The nature of the questions raised is cause for some concern. Few questions raised were initially worded in a way that would lead to an explanation. There was a tendency for questions of the "Which is best .....?" or "What will happen if ....? kind (CS4: 71-) rather than Why? questions that could lead to more generalised statements of explanation. This could reflect an approach to science in primary schools which is typified by "fair" testing for a particular purpose rather than attempts to explain and understand.

How can course members be encouraged to raise 'scientific' questions? (new Concern 17).

Later in the day there were more incidental questions raised that were attempts to understand and explain. "Is the molecular structure changing?" (CS4: 182), "Do all gases have to come from a solid?" (CS4:223), "What goes between molecules of a gas?" (CS4: 332).

Andrea, in her evaluation (CS4: 284), raises an interesting view about wanting answers and the extent to which the two days helped her understand her questions and the nature of the response she needed (rather than wanted). There is evidence here and in Ann's comments (CS4: 269) that the students realised that they were wrong to expect a set of "right answers" as a result of being on the
course. Indeed, the students are paraphrasing a constructivist approach when they say things like "Day 1 laid the foundations for thinking and finding out what I thought." (CS4: 268) and "This helped me highlight preconceptions and helped me question them." (CS4: 305).

The students' understanding of the tentative nature of scientific knowledge is clearly shown in the way they described their findings at the end of day 1. Terms like "generally" (CS4: 115, 116), "seemed" (CS4: 114), "tentative" (CS4: 124) and "may" (CS4: 126) were used in nearly every case.

The process of science was in evidence in a number of ways on day 1. There were examples of hypothesising, some of which (like the possible explanations for the handles of knives becoming loose (CS4: 75)) were never tested. Close observations were apparent in several cases (CS4: 121). The investigations themselves were generally carried out with care and appropriate measuring skills were used (CS4: 125). Several groups (during informal discussion that was not recorded) showed awareness of variables involved in their investigations. Other comments about control of variables were recorded (CS4: 85, 128 and investigation record sheets). The results were critically interpreted and all but one pair were able to reach some form of generalised statement at the end of the investigation. Andrea (CS4: 143) was clearly motivated by her investigation and the subsequent discussion of findings since she went home and carried out further investigations, bring the results in the following morning. Her actions seemed to result from critical interpretation of the previous day's findings.

What view of science do students take away from sessions like this?

The above discussion would suggest that the students' have taken a view of science from the first cycle of the course which is in line with that intended (see Case Study 1 and the main thesis, Chapter 1) and this foundation needs to be built on over subsequent cycles.

Alternative frameworks held by individuals

There was evidence of a considerable number of ideas held by the students which do not match accepted scientific ideas. Gill clearly considered molecules to be static in solids (CS4: 168) at the start of day 2 and restated this later in the context of gases (CS4: 191). However, she was challenged by Lorna (CS4: 194) and the following exchanges provide an example of the way in which ideas in the group were discussed and the extent to which shared meanings were socially constructed. A little later Andrea enters the conversation (CS4: 210) looking for clarification and providing another example of
Analysis of Case Study 4

Students' supporting each other as they attempted to organise and restructure their ideas. Mary B (CS4: 214) introduces the idea that molecules are travelling all the time. This idea was apparently accepted by the whole group at the end of the morning when SS dealt with questions that had been raised (CS4: 242) and Gill was specifically asked if she accepted the idea (not recorded). Her response was positive and can be taken as evidence of restructuring although it would be necessary to find other examples of the idea in use to confirm the new construct had been accommodated.

The discussion about particles led to an alternative framework that solids contained more particles than liquids (CS4: 206). Lorna provides another challenge (CS4: 209) and Andrea clarifies the possible problem Lin might have (CS4: 210).

Another alternative framework concerned what happened to salt when it dissolved (CS4: 174). Andrea here suggested salt "changed its shape" in water. Lorna (as she did with Gill and Lin above) offers a challenge by suggesting "shape" and "state" (to which she assumed Andrea was actually referring) are different (CS4: 176).

Phil raised an interesting point that glass "is still a liquid" and flowing (CS4: 182) although he did not amplify in terms of timescale etc. even though several other students expressed considerable surprise at his comment eg "Does that mean my Victorian windows are thicker at the bottom" (not recorded).

Margaret said, "all liquids are solid particles in a liquid" (CS4: 203) but as this was not probed further it is difficult to decide whether this idea is acceptable (does her use of particles refers to molecules).

There were examples of words which were misused. Pressure (CS4: 61) was used to mean weight.

There were also comments which indicated acceptable frameworks. Barbara questioned whether the balls were loosing energy as they bounced (CS4: 64) and Joy stated that "energy cannot disappear" (CS4: 67). Phil, in the same conversation seems to accept sound as a form of energy, "marbles make a sound (when they bounce and) use energy." (CS4: 68). Joy had an apparently acceptable model of particles before IS's input since she said, "molecules are less firmly held together (in a gas)" (CS4: 190) and "it still has more energy in the gaseous state" (CS4: 220). Lorna implies an understanding of mass and weight being different (CS4: 172), has an understanding of state (CS4: 176) and particulate theory (CS4: 194). Caroline also articulated a difference between states (CS4: 197).

The elicitation sheets provided useful evidence of existing ideas.
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Mary B provided sound explanations for the saucepan, in terms of particulate theory and energy. She used particulate theory to explain the air freshener in terms of evaporation. Her explanation of the ice included acceptable ideas about heat and temperature and again used a particulate model. The only "partial" problem she had was in explaining the syringes. In these explanations she talked about a "vacuum" being created, rather than a partial vacuum. Gill also talked about "the space being a vacuum". She used the term "diffusion" to explain the airfreshner and "molecular theory" to explain ice melting. She talked about "the warmth in the atmosphere causes the molecules in the water to speed up their action and escape" although she was adamant later that "molecules in a solid were static" (CS4: 168) and in a liquid "only move when a force is applied". It would seem she has accepted aspects of molecular theory but perhaps does not "believe it" in the case of solids and regards the atmosphere's warmth as a force.

Lin and Margaret worked together and their elicitation sheets include several alternative ideas - that the air freshener works because of "capillary action", that the "vacuum is important" and "the liquid is drawn up by vacuum pressure". They provided a good explanation of chocolate melting and explained it had "a denser composition after cooling" because air and water is released.

General Concerns/Issues

This case study contrasts with the previous ones on electricity in that it was less structured and students had time to explore and pursue their "own" investigations within constraints outlined above. This resulted from the discussions with co-tutors during which my earlier work with the B.Ed. students was compared with sessions run by a colleague at Bristol Polytechnic who provided more opportunities for exploration and student-initiated investigations. This considerably influenced the structure used on day 1 of the course. It is an area that will remain under scrutiny in this enquiry.

The methods used to elicit existing ideas were broader than in the previous cases and I consider that Concern 3 has been addressed and that I can pursue that focus further by specifically exploring the use of concept maps (during cycle 2 of the course). I will also explore the use of posters since these proved very successful with a group of B.Ed Year 4 students during a session on sound (24.10.90, Group F, not written up as a case study). They provided an excellent tool for paired discussion and a review discussion with the whole group.

Evidence of restructuring, Concern 5, even over two days is
difficult to obtain. This remains a concern that needs further thought although I anticipate finding out more on day 4 of each cycle and in later cycles the school-based days should provide more evidence of this – the first cycle's focus on process meant limited opportunities existed. More structured directed activities at the end of day 2 are worth considering. The cycle's process focus also meant that this case study did not yield evidence related to Concern 14 about child/adult constructs. However, it is hoped students will bring in examples of elicitation work from school which may be helpful in exploring this concern further.

I consider this case study is further evidence that Concern 1 about orientation time with adults is not problematic as long as exploratory time (Concern 13) is available. The extent to which adequate exploratory time was available in this case study remains to be seen in terms of subsequent evidence of ideas in action and applied, both later in the course and in students' classrooms.

Paired work was used to address Concern 10 and there is no evidence in the evaluations that individuals felt threatened in any way by the approach used and so this would seem to be an appropriate strategy for eliciting ideas, when complemented by strategies that allow tutors to elicit individual ideas as well. This was not the case however with the Cohort 2 since several of them indicated that they felt 'threatened' at the end of day 1 (CS5: 290, 318).

2nd Analysis (after Day 4)

The nature of the teaching approach

The final day of the cycle included a review of work carried out in school (CS4: 635). All of the course members had implemented some work based on the theme of materials. This provided evidence that several course members had started using the approach illustrated during days 1 and 2. Chris claimed she had done little science with her class prior to the course but outlined an example of classroom work indicating that she had clearly elicited the children's ideas through the effective use of a floorbook (CS4: 640) and based activities on those ideas (CS4: 653). There is clear evidence that at least one of her group was committed to the investigation (CS4: 648). Andrea had also worked from the children's ideas (CS4: 658) using a floorbook. She had elicited the children's existing ideas about investigations and was pleased that the concept of 'fairness' was already evident (CS4: 661). She discovered a child's alternative ideas about 'sinking' (CS4: 665) was retained even when contradicted by evidence. A particularly interesting aspect of Andrea's work was the extent to which she was testing out her own hypothesis about a concern ie the best approach – an obvious context or starting from the child's interests- (CS4: 658) and came to a tentative conclusion
Analysis of Case Study 4

(CS4: 672). This action learning approach, evident so early in the course is encouraging. Mary had also adopted a more open-ended approach than usual (according to a Wiltshire advisory teacher, who had worked in her class previously and had observed this activity and commented on the changes). It is encouraging that she adapted a strategy used on day 1 (CS4: 675) and found it successful. Other course members had used more teacher-directed approaches (CS4: 683, 695), but most had spent time talking to the children and eliciting existing ideas. There is little evidence of orientation activities and a worrying lack of time for exploration prior to investigation. This may be due to the teachers themselves not appreciating the part exploration had to play in their own work on day 1 and this needs revisiting in cycle 2. It suggests that the point made after the school-based day, explaining the undue haste with which most pairs moved the children on to investigation, was not only due to the artificial nature of the work.

Caroline had found the children raising questions about orange juice dissolving in water (CS4: 685) and was unsure about whether a liquid can dissolve in water. This is the first example of a teacher relating their own constructs to those of the children (Concern 14). On this occasion it was dealt with by IS at the end of the morning by giving a direct answer.

There was an interesting discussion earlier on day 4 when the open-endedness of activities was explored (CS4: 530) and a number of course members countered Mary's claim that using children's ideas for tests is too problematic (CS4: 532 and other comments not recorded).

Day 4, provided more evidence of the course members' own ideas about process (CS4: 561,) and concepts (CS4:508, 542) being elicited.

The morning's sherbert lemon activity raised a number of interesting points about approaches (CS4: 480-540) and the evidence of the observers about the levels at which the groups were working (in terms of AT 1) provided considerable support for an open-ended approach starting from student-centred explorations. The work of the group that set about 'modelling' the mouth was particularly impressive in terms of this (CS4: 506). Ian's contribution about low and high level decisions (CS4: 528) was crucial to the discussion that occurred since there were several course members who considered both approaches had led to decision-making.

The nature of science implicit in the session

Day 4 included a considerable amount of time dealing with the nature of investigations and variables and this reinforced the nature of science as a process that leads to better understanding.
Evidence of restructuring of ideas

The candle sheet (not used on day 2) provided evidence of the extent to which individuals had been able to use ideas introduced on day 2 to explain the way a candle burns (CS4: 242). At that point none of the course member’s offered any explanation of a candle burning in terms of particle theory and none knew that solids and liquids could not burn. The analysis of the day 4 sheets indicates that all include the change of state, solid to liquid, in their explanations. The extent to which other terms or ideas were included is listed below:

- a. the wax goes up the wick 64%
- b. liquid wax changes to gas 71% (another 14% mentioned gas but not the change)
- c. particle theory 43%
- d. wax burning 93%
- e. wick burning 57%

This is encouraging, although it would be valuable to interview those that did not mention particle theory to probe their understanding further (Concern 5). Gill’s restructured ideas in this area would be interesting in terms of her original ideas about static molecules (CS4: 168). Informal discussion with course members about the analysis, as their sheets were returned, indicated several (eg James and Phil) said they would have explained the candle burning in terms of particle theory if they had had more time. There first ‘level’ explanations, they claimed, did not need to include mention of particles to be coherent. Some explanations were excellent (CS4: 610) and indicate that some course members would be capable of dealing with more sophisticated ideas -

How can this be catered for on the course? (new Concern 18)

Future action:

1. Interview several course members (including Gill and Margaret) in 3 months time to investigate extent to which ideas have been retained and applied (Concern 5).
2. Use posters during cycle 2 as an elicitation tool (Concern 3).
3. Develop the use of concept maps further in cycle 2 (Concern 3).
4. Make the place of exploration more explicit during cycle 2 (Concern 13)
5. Consider strategies to give course members more ‘ownership’ of investigations – such as a prioritising exercise (Concern 15).
Analysis of Case Study 4

6. Consider which part of a cycle should include tutor input of accepted scientific ideas (Concern 16).

7. Consider how course members can be encouraged to raise scientific questions - use strategies to get them to analyse questions (Concern 17).

8. Consider how course members' individual needs can be met (Concern 18)
Case Study 5: DES 20-day (Cohort 2) Materials

Group: 16 teachers from LEA B
Tutors: RR, IS (Day 1 & 2), ST (Day 4)
HMI D.Stockdale present on day 2

Sessions: Thursday 18.10.90, Thursday & Friday 1/2.11.90
Thursday 15.11.90

Data Collection: RR field notes
Other tutor's notes
Students' outcomes - Investigation records
Flip charts
Elicitation sheets

Aims for the session:

1. To develop students' background knowledge and understanding of materials:

2. To provide students' with an example of constructivism in action for adoption in their own teaching

Day 1

9.15 After an introduction to the day's work RR asked pairs to select five items, with common aspects, from collections of materials provided and share the reasons for their choice. ....

9.35 Each pair was asked to report back to the whole group (the items chosen have not been listed below but the reasons given are transcribed from flip charts).

Kay/Jenny Role in a straight line (when tested one didn't)
Neil/Dave Capacity to hold something
Becci/Barbara Containers
Anne/Caroline Texture - rough
Pauline/Andrew Elastic - stretchable
Adrian/Rick When force is applied they return to original shape
13 (when tested this wasn't the case)
Frances/Debbi Things you can bend
Mark/Trisha Can produce energy (battery, magnet, copper and glass)
Jill/Julia Reflectors

RR What are materials?
Debbi Things
Tony Substances

Adrian Objects

21 RR What are properties?
Frances Qualities
Andrew Characteristicss
Julia Perculiarities
Tony Potentialities

26 RR What properties can we brainstorm?
Strength, weight, man-made/natural, solubility, float, absorbency, texture, hardness, sound, elasticity, flammable, degradable, malleability, metallic, reflective, colour, conductivity, durability, transparent/opaque, waterproof, size, volume, shape, symmetry, smell, taste, use, source, liquid, manufactured, goo/bad conductor, magnetic, pliability, acidity/alkalinity, insulate.

... IS probed meanings of these terms:
Mark Strength - ability to stand up to stress
Trisha Natural - occurring in its original state
Dave Solubility - whether it dissolves in a liquid
Debbi It might dissolve in air
Rick Absorbency - takes up water
Rick Hardness - withstands scratching
Pauline Flammable - does it burn?
Mark Degradable - rots
Dave Malleability - changes its shape
Rick Pliability is not the same as malleability - if its pliable it should return to its shape
Pauline Insulator - keeps heat in
Mark and keeps electricity out, its a barrier
Rick Conductivity - can carry electricity or heat
Dave Volume - the space it fills
Mark displaces
Rick Its (volume) very tricky
Trisha Metallic - could look like a metal but be something else
Rick You would have to use other tests (to decide)
Debbi Acidity - linked to taste and pH value

Choose a collection and explore it - what can you find out? What questions can you raise?

Please complete the first section of the record sheet.

Bottles (Kay and Jenny)
First question - which is the most efficient pourer?
Involved too many things to overcome ... how do you measure it?
Why do some bottles empty more quickly than others?
Ideas - its the width of opening,

length of neck,
capacity
Case Study 5: DES 20-day (Cohort 2) Materials

We found width of neck was significant and a long neck took a shorter time to empty.

Threads (Rebecca and Barbara)
Is cotton thread stronger than polyester thread?
Unable to produce a generalised statement.

Papers (Caroline and Anne)
Which paper is most absorbent?
Layered papers seemed to be most absorbent.

Candles (Pauline and Andrew)
Why does a candle have a wick?
Can a wick be any string-like material?
Which threads burn?
Which work as a wick?
A candle is like a paraffin lamp - the wick absorbs wax and the wax burns.
Are the wax and wick burning together?

Rocks (Neil and Dave)
Are crystalline rocks heavier per unit volume?
Crystalline rock have angular pieces, reflect light and you can chip pieces off easily.
Non-crystalline rocks absorbed more water.
Before absorbing water non-crystalline rocks had a greater volume per unit weight. After absorbing all rocks had about the same volume per unit weight (density).

Metals (Frances and Debbie)
What makes a metal a metal?
metals are cold to the touch
sink
withstand burning/melting longer
conduct heat
conduct electricity (except a magnet)
smell metallic
are strong

Liquids (Rick and Adrian)
Is there a link between density and viscosity?
Thought the thickest fluid would be most viscous - not the case.

Powders (Mark and Trish)
Are crystalline powders the most soluble?
Found apparent increases and decreases in weight when some substances dissolved.
Most crystalline powders dissolve more easily than other powders.
Case Study 5: DES 20-day (Cohort 2) Materials

Fabrics (Julia and Jill)
Which would be best for absorbing liquids?
Thought thicker fibres absorbed most - found the most absorbent was in fact made up of thin fibres.

3.30 RR (Outlined the extent to which a constructivist approach had been used during the day and introduced the notion of big ideas and invited course members to produce a concept map based on their investigation)

Day 2

9.15 RR (Introduction to day 2, reminder of day 1 [data circulated])

10.15 IS I have noticed some people changing their ideas (as they complete the sheets) as a result of discussion and others have been apologetic, saying things like, I’m more confused now that when I arrived. This is because you haven’t been asked to explain before, you haven’t been challenged to think about these phenomena before.

Anne (relating an experience she had had when asking children where the water had gone from a saucer left on a cupboard) ... one boy said he thought it had leaked through into the cupboard below. I suggested we had a look.

11.00 IS (reminded course members about the 'big ideas' and that materials can be solid, liquid or gas) We would like you to sort the materials we have put out into solids, liquids and gases and those that you are not sure about.

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... (As pairs finished they were asked to list their criteria for each state)

11.30 IS (Plenary) I would like you to tell me what makes a solid a solid (ideas listed on flip chart)

Mark They retain their shape ... some do
Jill Less subjected to external force or pressure
Fran Don’t run or flow
Anne Can’t be poured
Rick Something that can be felt ... innate, but don’t ask me what that means!

IS 'Some' is a problematic word
Dave You can heat metals, they melt and then reform...
(discussion about flowing, rolling, pouring)
Dave A marble rolls
Pat I was thinking about the oil advert (and how liquids hold their shape but flow).
IS Isn't salt more similar to water than a marble (in terms of pouring/rolling)?
Adrian Solids can be scratched
Mark A solid has a hardness
Kay It can be rough or smooth
Anne Liquids are wet, solids are dry
(IS challenged this with an example of a solid just removed from water)
IS What about a solid?
Caroline They can be absorbed by some materials
Rick Flows or runs
Mark Will take the shape of its container... will fill the space
Dave Without leaving any spaces
Mark At the bottom (of the container) ... it displaces .. replaces the air. Salt flows but it still contains air when in a container
Jill Do viscous liquids push out air?
Neil Does it (liquid) take up the volume?
Caroline It covers the bottom
Dave It spreads out
Caroline It doesn't take up the whole space, it spreads out
Mark That's why I tried to differentiate between shape and space
Julia It will fill the space if you have enough
Pat It fills the space at the bottom
Julia Liquids find their own level
Dave Is that to do with gravity, it will try to be parallel with the surface of the Earth
Neil Is that also to do with air pressure on it?
Mark Do all liquids have a surface tension ... a skin?
Jill Liquids allow things to float
IS What about gases?
Fran Often invisible
Neil Intangible - can't touch it
Dave Usually constrained .. it's freely mobile
Mark It can be frozen
Adrian They can't be stretched.

11.10 IS (Introduced idea of particles, drawing on Rebecca's elicitation sheet [the only mention of particles], and accepted scientific ideas about solids, liquids and gases, he introduced absolute zero and used the computer simulation)

Andy What happens to a solid like wood when you heat it (referring to
changes of state described)?

Mark Why do some gases sink?

... Why do some gases sink?

Neil Do the number of particles increase (when change of state occurs)?

... What happens to the volume of a solid when it is heated?

Neil It should increase, but that doesn't apply to water (discussion about particular characteristics of water)

... (talks about boiling points, evaporation, movement energy of particles)

Andy Do all liquids evaporate?

IS The particles are bonded, this helps retain a liquid's shape ... if particles break away it evaporates ... they evaporate quicker

Rick if the boiling point is lower ... What do you think the bonds might be like in a liquid like oil or shampoo?

IS Stronger bonds ... needs more energy to break them (dealt with pressure in a gas)

What happens if we increase the temperature of the gas (in the simulation)

Mark Raises the pressure

Rick The walls (of the container) heats, because of the energy ... energy is transferred at the walls

IS How else could you increase the pressure?

? Put more particles in.

IS (talked about the number of particles not increasing or decreasing)

Mark If you increase the pressure can you turn a gas into a liquid?

IS Andy, tell us about your ideas about the candle

Andy When you light it, the wax melts, it's drawn up the wick and burns ... (discussion about burning)

Mark Is it (how it burns) because the wax vaporizes?

IS That's right, liquids and solids don't burn (goes on to describe chemical and physical changes)

(Course members were asked to try elicitation sheets again - see analysis below)

IS (dealt with changes of state gas > liquid > solid)

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IS (dealt with changes of state gas > liquid > solid)
Quotes from evaluation comments made at the end of day 2 (open format):

Pauline
... enjoyed both days ... somewhat threatened after day 1, perhaps by my own lack of knowledge - not being a scientist ... day 2 more reassuring, realising that many of my though processes were infact quite logical and that not being a scientist probably helps when trying to understand the way children think and form ideas ... I'm slightly worried at the thought of the teaching day, but found the time spent on preparation extremely valuable.

Jill
Good to have 'hands on' experience ... not too threatening ... amazed at difficulty of explaining such a simple concept as 'solid'.

Jenny
Enjoyed the workshop ... very challenging and confusing ... made you think carefully about your own questioning in the classroom ... did find it hard to relate to science at an adult level ... found day 2 much more relaxed and less threatening ... I'm worried about tomorrow (school day) although today has helped increase my confidence and awareness.

Anne
Day 1 I felt overwhelmed and slightly inadequate ... however, by probing and questioning myself I found my open and honest view of myself was not sneered at. I left feeling I needed to know much more and indeed had to make enquiries about candles at home ... I felt more relaxed on day 2 and enjoyed 'learning' in Ian's session. Completely felt at home when preparing for work in school.

Trish
Gap between day 1 & 2 wasn't a problem ... interesting exploring at our own level ... I did feel unsure until this afternoon where we were going.

Dave
First day a little drawn out, although idea of free investigation at our own level very worthwhile ... Day 2 very worthwhile, made us think a lot more.

Becchi
I feel day 2 has been much more relevant to my classroom situation. Day 1 was too much based on adult experiences and I didn't feel I could really use this. The idea of going into school is really good.

Caroline
I found day 1 challenging ... found it hard to draw away from the children and thinking about how they think ... I can appreciate how the children feel and the need they have to pursue their own questions ... day 2 was informative and felt my own knowledge was expanded.

Kay
Somewhat confused at the end of day 1 ... I needed to be guided more about how to ask questions and formulate them to get the most out of an activity ... day 2 should have followed straight on ... I spent two weeks worrying inbetween. I feel much less threatened now.

Mark
Have found the theoretical ideas useful and the probing of my own inadequacies.
Case Study 5: DES 20-day (Cohort 2) Materials

Andy
I found it hard working at my own level. Interesting... I feel I have gained ideas useful in my classroom situation... I still find it frustrating at school that many children are still at the exploratory stage and do not move on to investigations.

Julia
Like the format today of revisiting investigations armed with more knowledge - found this reassuring... didn't feel I gained much from investigation on day 1 - wished I'd selected a different collection... exchange of ideas interesting.

Rick
Quite intense but informative and stimulating... would have liked more feedback on day 1 questions.

Adrian
Quite happy with the 2 days... found the exploratory aspect challenging, enjoyable and rewarding. Ian's input very useful... developed my own thinking and use of language.

Barbara
Would have liked day 1 & 2 together... I felt more unsure of my direction in day 1... day 2 light at the end of the tunnel, but still quite hard to discuss things I've never thought of before - challenging and stimulating.

Frances
Day 1 was challenging... made me think carefully about my own preconceptions... bit frustrating, wanted answers. I learnt a lot from day 2... my knowledge suddenly blossomed. The computer model was the key - it illustrated it so well... a very full day but worthwhile.

Debbi
Exploration was fun, providing the realisation that I prefer to have a final answer - obviously a personal fault... Day 2 a long gap, some ideas no longer fresh, but did reoccur. Ian's talk very interesting... I understood 'secondary science' for the first time - an amazing feat. I like the fact that reports were given of the last session. The tasks in the morning and going back to them were very thought-provoking.

Neil
First day thought provoking and interesting but I wonder if more time could have been given to discussing out cognitive processes and those of children. I wander if some of the ways we are motivated and the way our children are motivated were left unexplored. The 2nd day addressed these questions more thoroughly and extensively and helped to explain the place and importance of teacher-implanted information - when it is appropriate and inappropriate.

Day 3 (2.11.90)
Similar format to CS 4. Y2 class (5 groups in Barbara's classroom, 4 groups in spare classroom that was also used for evaluation sessions)
Pairs worked with fabrics, bottles, foods (liquids and solids), papers, threads.

Day 4 (25.11.90)
(ST introduced the day (in RR's absence) and set up the sherbert lemon activity (see CS4)).
9.50 ST Will each group now tell us what happened?
Caroline We worked from a worksheet and found that the one that was crushed dissolved quicker than the other. We were working at levels 1 & 2 of AT1.
Dave (same group) I think we covered some aspects of levels 3 and 4.
Kaye We raised questions in a form that could be investigated
Adrian For example, how would rate of stirring affect dissolving?
Kaye We constructed a fair test
Rick We weighed the sweets to see they were the same and used the same container
Andy (observer of a worksheet group) It was a boring response, two people I was observing were more interested in what was going on elsewhere
Rick It was pretty tedious!
380 ST What about the other groups who had an open-ended task?
Mike We did a fair test using cold and hot water, one was stirred, one wasn't. We weighed them for weight loss or gain and were surprised to find that yet again (as happened on day 1) some weighed more after the sweet dissolved. The two in hot water went down which we can explain by evaporation. We were operating at level 7 or 8. We selected measuring instruments, decided on methods of recording etc. There were discussions about why things happened and we had things we wanted to develop.
390 Pauline I put one in my mouth to see what happened
Barbara And we put one in very hot water, one at body temperature and one in cold water. At first we had to add more water to cover the sweet. We weighed them to check they were the same and we considered the problem of body temperature being constant and the water in the beaker cooling down....

400 ST I don't want to suggest we abandon all workcards but this exercise points out the limitations of structured sheets. The more structured the less chance of making decisions...
Mike We were dissolving in school and my class was following instructions but they raised variables and suggested how to make the test fair
ST That depends, in part, on their previous experience...
Andy There is more interaction in an open-ended situation, much more
Mike We looked across and they (the worksheet groups) were all writing....
412 (They were given a sheet for analysing the advantages of different approaches)

10.05 RR We've been looking at variables. Now I would like you to brainstorm with a partner all the factors that affect dissolving...
Case Study 5: DES 20-day (Cohort 2) Materials

10.10 (Results drawn together on a flip chart and were very similar to those in CS4 - small groups were then asked to select one or two, develop a hypothesis based on particle theory and devise a model investigation, listing independent and dependent variables on a sheet provided. They were also given a list defining different kinds of variables. RR & ST joined in the discussions and RR drew this together at 11.15)

11.30 RR In pairs, working with someone new, spend five minutes each sharing the work you have tried in school on the materials theme.

11.40 (in 2 groups, RR & ST invited course members to share their school work, indicating: approaches used (was there opportunities for orientation, elicitation etc); evidence collected; existing ideas about investigating; existing ideas about materials) The following were noted during the discussions.

Rebecca had worked with a collection of threads with her Y2/3 class. They had had two days orientation during which the collection was available for free-play and exploration. She then posed the problem of which might be best for making a handle for a bag. Some suggested the thicker threads were stronger, others that twisted threads were. She collected evidence in a notebook. They predicted which would be strongest and talked about experiments they could do - this was a whole class (15) discussion. It was suggested that weights were tied on the threads and this was tested and the results recorded. They then made bags but lack of resources and the children's limited experience was a problem.

Dave His Y6 class had looked at candles as part of a light and colour topic. They had worked in groups of 4 & 5 and he had asked probing questions but not recorded their ideas at this stage. However, at the end of the day he recorded all their ideas on a large sheet on the wall. He discovered several alternative ideas, such as 'the wax is there to hold the wick up'. They all seemed to have the idea of solids turning to liquids, the term 'evaporation' was used but not defined by the children. One child suggested 'all solids have to be hard' and classified bendy things like wire as 'liquid'. A plastic film canister was 'liquid' because 'it was different to a plastic ruler and to change its shape it must have been liquid'.

Jenny Her 7 and 8 year olds had worked with fabrics. She had had the opportunity to work with two small groups from her own class and one group from another class. They had sorted a collection using their own criteria but found it difficult. They had talked about winter/summer clothes. She asked them to order them according to which would be best at keeping you warm. The children were then asked to devise a test using the limited equipment available (cans, thermometers). This they managed with some success and
recorded their work using the 'shape system' adopted by the whole school - triangle - prediction, rectangle - what we used, square - what we did, circle - results, hexagon - 'hypothesis'.

The term hypothesis was discussed and Jenny agreed this shape actually came at the end of the work and recorded 'what we found out' or a generalised statement.

Kay Also worked with fabrics with her 34 reception children. She had them in groups of 8 or 9 and they did a lot of sorting. They started with a pile and the children were invited to tell her about them. They sorted using their own criteria and all the groups were recorded in a large book. They thought about ways of using the fabrics and this led to ideas about absorbency. They were asked to choose a fabric that they would wear in the rain and they all chose pretty cottons.

Jill She outlined a school inservice day that was identical to the school-based day and reported it had been very successful. In her own class she had discovered a child who thought leaves turned red at this time of the year because of the 'blood' in them. This idea proved very resistant to change even though she tried to challenge it and provide evidence such as cutting a red leaf.

Rick His Y6 class had been working on a 'Think Green' topic and had brought in collections of rubbish to work with. Each group produced a large format book of their work which was a new idea to them but worked well. They had brainstormed in small groups the things they throw away. They had sorted using their own criteria, which included inorganic and organic. Even though they were top juniors he found they still need time for 'free-play'. After their investigations, they had gone back to their original ideas, recorded in their books, and changed them in the light of what they had found out. One group had tried shrinking crisp bags in the oven, at home, and this had led to interesting discussion. Some investigated which containers were waterproof and this led to them rubbing the wax off milk containers and discovering that they then let water through. There are long term investigations involving items buried in the school's conservation area.

Neil Work on the Roman Baths had led to things that dissolve in water and small groups had investigated materials that dissolve in water. They devised their own test eg used the same amount of water. He had elicited their ideas and discovered views like, 'different chemicals is why some things don't dissolve', 'salt dissolves 'cos it's used to doing it', 'milk powder goes cloudy to look like milk'. The plenary discussion he held raised even more questions.

Andy As part of work on volcanoes, his class had been exploring liquids and looking at viscosity in an attempt to find out whether a thick liquid flows as far as a thin liquid. They found this quite difficult and he found some got fed up easily.
Case Study 5: DES 20-day (Cohort 2) Materials

Caroline Here 7 and 8 year olds worked with paper, sorting relatively well but they were not good at devising their own tests. They couldn’t decide whether all the samples were indeed paper e.g. sandpaper and wallpaper confused them. When asked how they could decide if they were papers they suggested if they soaked up water then they were papers. They carried out the test and squeezed each sample, after it had been in water, to see if it had soaked any up. The sand in fact came off the sandpaper and they decided all the samples were indeed paper.

2.30 (ST led a session on approaches to a collection of rubbish - see CS4)

3.10 (RR asked them to write down an explanation of how a candle burns, and why a copper rod gets hot quickly using ideas from the first two days. The results of these were discussed and individuals asked to analyse their own explanations)

The following ideas were included in individual’s responses:

<table>
<thead>
<tr>
<th>Burns</th>
<th>melt</th>
<th>up wick</th>
<th>liq&gt;gas</th>
<th>particles</th>
<th>gas</th>
<th>wick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caroline</td>
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<td>Dave</td>
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<td>Jenny</td>
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<td>Kay</td>
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<td>Rick</td>
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<td>Barbara</td>
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<td>Debbi</td>
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<td>Anne</td>
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<td>Mark</td>
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<td>Pauline</td>
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<td>Frances</td>
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<td>Julia</td>
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<td>Andy</td>
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<td>Jill</td>
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<td>Adrian</td>
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<tr>
<td>Becci</td>
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</table>

Examples:

Becci

When lit, it’s the wax on the candle which burns to form a liquid (the particles in wax start moving so wax goes from solid>liquid [1]). The liquid wax is absorbed up by the wick and so the flame keeps burning. The excess collects and runs down the candle.

Andy

Candle is a solid material which has its particles close
together. When the wick is lit the heat begins to change the state of the wax to liquid by the particles spreading out. At the same time the liquid passes up the wick a short distance and it begins to burn off in the form of a gas which has the particles wider apart. When this happens it is the gas that is burning not the liquid wax.

Debbi Wick initially catches alight. Wax begins to melt as particles turn solid to liquid (moving around more randomly). Liquid wax moves up the wick and catches light. It turns to vapour (as particles escape into air) and this burns. Wax needs a wick to begin burning under these circumstances. This explains why less melted wax is collected than there was originally.

Course members' own analysis of their responses, in terms of key ideas included, were more generous than the above and several suggested the ideas were 'implicit' in their explanations. ... Analysis of the explanations of why the metal rod gets hot quickly indicated all used a particle explanation and 17 out of 18 included mention of the particles moving more quickly. Debbi talked about "the gaps in the particles are made bigger". Becci said, "the particles move around more quickly (in the metal)".

Analysis of some of the elicitation sheets completed at start of the morning on day 2 and, in some cases, revisited after SS's input:

Neil Before .. ice OK; saucepan OK; sugar - suggests sugar changes to liquid sugar
Rick Before .. saucepan - heat causes molecules to vibrate .. heat caused by friction
After .. in cold water particles are only vibrating .. heat increase leads to more interaction
Adrian Before .. saucepan - energy transfer causes molecules in water to move rapidly
After .. cold water particles vibrating slowly
Before .. sugar - absorbed by the tea; ice - molecular structure altered
Frances Before and after .. candle - no particle explanation or ideas about liquid > gas
Before .. sugar - level the same .. sugar crystals 'suspended' in liquid molecules
After .. level will go down due to evaporation
Anne/ Before .. chocolate - no particle explanation
Pauline After .. particle theory used
together. When the wick is lit the heat begins to change the state of the wax to liquid by the particles spreading out. At the same time the liquid passes up the wick a short distance and it begins to burn off in the form of a gas which has the particles wider apart. When this happens it is the gas that is burning not the liquid wax.

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After .. cold water particles vibrating slowly
Before .. sugar - absorbed by the tea; ice - molecular structure altered
Frances Before and after .. candle - no particle explanation or ideas about liquid > gas
Before .. sugar - level the same .. sugar crystals ‘suspended’ in liquid molecules
After .. level will go down due to evaporation
610 Before .. air freshner - evaporates .. releases oil that gives off smell
After .. particle explanation
Ann/ Pauline Before .. chocolate - no particle explanation
After .. particle theory used
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Kay
Before . . . chocolate - when heated the particles are broken down when it cools particles harden and join together
After . . . particle explanation OK
Before . . . air freshener - air circulates and blows out a more noticeable smell

620
After . . . particle explanation OK

Dave
Before . . . chocolate - as temperature rises, bonds between particles are broken and they move freely
After . . . particles 'excited' and bonds break down . . . particles charged with heat energy . . . need more space and liquid state is then induced
Before . . . air freshener - particle explanation OK
Before . . . candle - no particle explanation

Becci
Before . . . saucepan - particles in water when cold remain quite still but when heated they vibrate; chocolate - in solids the particles are locked together but when heated they break so forming a fluid state; sugar - level will go up as sugar is still there in a liquid state

630
Before and after . . . candle - no particle explanation
Before . . . air freshener - it evaporates and slowly oil is released
After . . . particle explanation OK
Before . . . sugar - level the same . . . crystals suspended in liquid molecules

Debbi
Before . . . level goes down due to evaporation

Jenny
Before . . . air freshener - air circulates and blows a smell
After . . . particle explanation OK
Before . . . chocolate - particles move around more (when heated) and take up a greater volume

Andy
After . . . sugar - energy transferred as moving energy to sugar crystals thus turning them to liquid

Barbara
After . . . saucepan - included particle theory and conduction

Caroline
Before . . . air freshener - smells due to liquid . . . smell carried by air

650
After . . . evaporates
Before . . . chocolate - included particle ideas; candle - no particle ideas

Trish
After . . . ice - particle ideas
Before . . . chocolate - those (particles) at the top stay static
Analysis of Case Study 5

Group: Cohort 2

1st analysis: 20.11.90

This analysis covers similar sessions to those analysed in Case Study 4. Consequently, it should be seen as extending and developing points raised in that analysis.

The nature of the teaching approach

The extent to which the teaching approach used during the cycle was based on constructivism and reflected that which the course members could adopt as a sound model for their own classroom work was a key feature of the course that was positively evaluated by HMI Stockdale as a result of his visit.

The timing of the sessions were similar to Case Study 4 and so little time was offered for orientation. However, there is evidence that in some cases the teachers appreciated the importance of this for children and when reporting back what they had done with their class, during the cycle, emphasised this. For example, Becci had given her class the opportunity to handle a collection of threads for two days prior to any structured work (CS5: 438).

Time for exploration was provided and with most pairs this led to questions which could be investigated. The extent to which the need for an exploratory phase with children is appreciated is not clear from the evidence of Case Study 5 although several pairs did plan the day 3 session with children around this approach and Andy, when reporting back on work with his own class expressed frustration at not being able to get beyond an exploratory phase (CS5: 325). Other reports suggested that opportunities for children to explore, by for example, sorting materials according to their own criteria (CS5: 476 & 498) were offered to infant and junior aged children. Some of the other reports about work with their own classes suggest that the exploratory phase is not recognised as being crucial to successful investigations (eg CS5: 507).

The need elicit existing ideas and take them seriously, implicitly evident during the cycle and made explicit on occasions with statements like, 'If you suppress ideas they are not available to challenge' (CS5: 153), does seem to have been accepted by all of the group. The co-tutor also reassured them at this stage that the fact that they felt 'more confused than before' was not due to less understanding but to being challenged to think about things that they had not tried to explain before. The extent to which this threatened course members is reflected in some evaluations. Some evidently felt uncomfortable on day 1 (CS5: 276 and 296) although others obviously did not (CS5: 284 and 289). One of the most
encouraging comments came from Ann, "... I found my open and honest view of myself was not sneered at." (CS5: 295).

In terms of the course members using strategies to elicit their children's ideas, there are examples of floorbooks being used (CS5: 492) and wall posters (CS5: 455) to record children's ideas. Caroline provides a sound example of accepting children's ideas and encouraging them to seek their own clarification, in this case, about the nature of paper (CS5: 522).

The methods used to elicit student ideas were similar to Case Study 4 except on day 2 when more time was made available for completion of the elicitation sheets before and after the input by IS. This was recognised as valuable by some course members (CS5: 326 and 350) and provided more evidence of the extent to which students restructured their ideas as a result of the ideas offered. This is analysed later.

The cycle offered the course members a variety of teaching strategies such as paired work (CS5: 4), small group (CS5: 371), whole group discussion (CS5: 26) and individual work (CS5: 531). The role of the teacher offered through example also varied during the cycle and included work with individuals and pairs (during investigatory work), leading discussions (CS5: 26-) and exposition (CS5: 218). These different roles were not made explicit to course members in the same way as the constructivist model was made explicit (CS5: 131). This may need addressing in later cycles, perhaps by asking course members to identify roles using their own terms to describe them. There were a variety of teaching aids evident during the cycle such as flip charts (CS5: 6), OHTs (CS5: 132) and computers (CS5: 221). These three aspects were all commented on very positively by HMI Stockdale in his debriefing.

The extent to which IS was able to use questions asked by course members, during his exposition of accepted ideas, as a means of linking one idea with another was encouraging and considerably helped by individuals like Mark who managed to 'ask the right question at the right time' (CS5: 237 and 254). In these instances the questions provided the means of moving on to evaporation and pressure.

The sherbert lemon activity on day 4 (CS5: 368) allowed the tutors to deal with a key issue concerning teaching approaches - how useful are worksheets? This session resulted in a similar discussion to that during Case Study 4 (CS4: 479-) and provided ample evidence that those working on the open-ended task were operating at a much higher level in terms of ATI (CS5: 391) and course members offered advantages for such approaches (CS5: 410).
Analysis of Case Study 5

The nature of science implicit in the session

The first activity indicated that some course members did not recognise the need to base statements, in a scientific context, on evidence. Two of the criteria chosen to group objects did not stand up to very simple tests (CS5: 7 and 12). The need to collect evidence did however become accepted when they began investigations (CS5: 70-).

The nature of the questions raised is interesting since many of the initial questions were, like those in case study 4, of the 'Which is best?' kind (CS5: 71, 85 and 123) and the initial exploration led to few 'Why?' questions. However, during the session and as a result of tutor support (addressing Concern 17) there were more questions requiring answers of an explanatory nature (CS5: 73 and 89). During day 2's exposition of accepted scientific ideas there were more examples of this (CS5: 223, 226, 237). The nature of scientific questions was also discussed during day 4 (CS5: 422).

The case study provides another example of students using a factual question (What makes a metal a metal?) as a starting point for investigational work (CS5: 106) which is similar to the work on crystalline rocks (CS4: 46).

There is less evidence in the data of students appreciating the tentative nature of the ideas they came to as a result of their investigations although in part this is due to the field notes at this point being less detailed than they were in case study 4.

The role of discussion in the formulation of ideas and the aspect of socially constructed meaning is well illustrated by the attempt to clarify the properties of liquids (CS5: 194-).

The issue raised in Case Study 4 about the course members coming to terms with not always getting the answers they want was again evident (CS5: 345).

The relationship between process and knowledge and understanding was not discussed explicitly during this cycle although some course members who had begun to think about the first assignment (which deals with this) were informally discussing and exploring these links. The school-based day indicated that most course members were aware of the nature of process skills and some were confidently identifying those skills being demonstrated by children. There was some confusion about the differences between predicting and hypothesising (not helped by the poor example of hypothesising in the National Curriculum). This was explored through the use of examples of children's utterances.
Alternative frameworks held by individuals

There were numerous examples of the elicitation aspects of the cycle revealing alternative ideas. Some, such as the idea that solids and liquids burn were held by all course members (CS5: 261) and were challenged. Others were less commonly held and not always challenged. For example, very early on in the cycle Mark and Trisha sorted a battery, magnet, a piece of copper and glass as things that could "produce energy" (CS5: 15). This was not probed further at the time. Dave (CS5: 40) thought things "might dissolve in air". The elicitation sheets indicated some examples, although generally they indicated sound understanding within accepted scientific frameworks as a fairly basic level. Exceptions included "sugar is absorbed by tea" (CS5: 603) and "particles in water when cold remain quite still" (CS5: 629). Before IS's input few course members explained phenomena in terms of particles apart from Becci's example just cited and a few others including Kay who said, ".. when heated the particles are broken down .. when it cools particles harden and join together" (CS5: 615).

Reports from school during day 4 provided some examples of children's alternative ideas including one from Jill which proved remarkably resistant to change. She discovered a child who thought leaves turned red in Autumn because they contained blood (CS5: 485).

Evidence of restructuring of ideas

The use of elicitation sheets before and after IS's input allowed some evidence (CS5: 591-) to be collected of restructuring and indicates that numerous course members could explain phenomena in terms of particle theory after the input. In particular the air freshner (CS5: 610) was only explained by Dave in terms of particles before the input (CS5: 628). More significant evidence of restructuring is apparent through the analysis of the course member's explanations of candles written on day 4 (some time after the discussion on day 2 about candles). This indicates, as did the similar analysis linked to Case Study 4, an encouraging number of individuals who were able to use ideas introduced to explain a candle burning.

<table>
<thead>
<tr>
<th>Idea</th>
<th>CS4 evidence</th>
<th>CS5 evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wax goes up wick</td>
<td>64</td>
<td>50 Liquid wax</td>
</tr>
<tr>
<td>changes to gas</td>
<td>71</td>
<td>78</td>
</tr>
<tr>
<td>Particle theory</td>
<td>43</td>
<td>89</td>
</tr>
<tr>
<td>Wax burning</td>
<td>93</td>
<td>56</td>
</tr>
<tr>
<td>Wick burning</td>
<td>57</td>
<td>44</td>
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</tbody>
</table>

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Of the two individuals who investigated candles on day 1, Andy included all aspects in his explanation and Pauline only omitted one (wax travelling up the wick) (CS5: 551 and 554). An interesting extension of this activity compared to Case Study 4 was that course members, having written down an explanation were asked to evaluate their outcomes in terms of key ideas which RR listed. Their analysis of their own explanations tended to be overgenerous because they claimed the key idea was implicit in their explanation.

The course members were also asked to try and explain why a metal rod gets hot when held and heated, before a wooden splint (CS5: 532). This required them to recognise that particle theory could be used in an explanation and apply ideas about particles in a new area since IS had not discussed conduction or heat travelling during day 2. The outcomes indicated 94% (17 out of 18) used particle theory in their explanation and all referred to the particles move more quickly when heated.

Consequently there was considerable evidence of restructured ideas on day 4 (Concern 5) and an indication that the strategy used to evaluate this has some potential.

General Concerns/Issues

The role of the teacher demonstrated through example is generally sound although the extent to which the tutor is being seen as an 'expert' is of some concern since it may adversely affect teachers confidence as they appreciate during the course the amount they do not know! Neil (CS5: 357) suggests in his evaluation sheet that he has assumed a place for 'teacher-implanted' information. This may indicate a worrying misunderstanding about the teacher's role which in his terms seems to include a 'transmissionist' element. This may be due to the way in which the expositional elements are being perceived.

Unlike Case Study 4, more of this cohort felt threatened by day 1 and this may have been due to too much reassurance at the beginning (from a co-tutor, not included in the data) that they wouldn't find it threatening! They also seemed to find it more difficult to relate to the purpose of tackling science at their own level (CS5: 289, 307 and 322) and this needs to be more openly addressed in cycle 2, perhaps indicating more clearly which aspects relate to science at their own level and which to the implementation of science with children.

The gap between day 1 and day 2 proved a problem for some (CS5: 335) and not for others (CS5: 300). The fact that course members were offered data from day 1 at the start of day 2 seems to have helped (CS5: 348). A provided me with feed-back upon the nature of my data.
Analysis of Case Study 5

collection and presentation - none requested changes and all were surprised at the detail, which helped reorientate them to the second day. However, returning to the timing, the tutors evaluation was that it was better, as in Case Study 4, to have day 1 and 2 happening consequently.

The need for differentiation according to individual needs should take into account, not only individuals scientific knowledge but also their understanding of how that knowledge can be used with children in the classroom. Those confidently dealing with scientific ideas in a formal setting can sometimes find it difficult to adapt and apply those ideas in a more informal classroom context. It also requires considerable 'creativity' to identify a range of potentially useful experiences for children related to a specific scientific idea. Course members' individual needs in this area needs consideration and should be addressed during school-based days. This point was made strongly by HMI Stockdale in his informal feedback.

Future action:

1. Look for further evidence of the best pattern of days.
2. Anticipate the problem of day 1 being "threatening" on future courses and handle the introduction sensitively.
3. Consider the teaching role model offered during exposition. Encourage course members to identify different teaching roles used during the course and to reflect on the suitability of each.
4. Reflect further on the ways in which individuals' needs can be met by the course.
Case Study 6: DES 20-day (Cohort 1) Forces

Group: 14 teachers from LEA X, Tutors: RR, ST, TD

Sessions: Monday 13.11.90 and Tuesday 14.11.90 9.15am - 4.00pm
Friday 17.11.90 (Junior School C) Weds 5.12.90

Data Collection: RR field notes
Other tutor's notes
Students' outcomes and notes
Floorbooks
Students' evaluation notes

Aims for the session 1 & 2:

1. To develop students' background knowledge and understanding of forces;

2. To provide students' with an example of constructivism in action for adaption in their own teaching

Day 1

9.15 RR
(Introduction to 2nd cycle. Course members were invited to form new pairs and explore the objects out noting, in their own terms what they had to do with forces. The collection included a bike, toys, springs, newton meters, clay and plasticine, lever tools, simple construction and a tank with objects floating. They were asked to feedback their ideas in larger groups with a course member using a floorbook to record ideas)

New pairs: Lorna/Barbara; Margaret/James; Phil/Lin; Joy/Caroline; Andrea/Mary B; Ann/Mary; Chris/Gill.

10.00 Feedback. The following comments are from field notes and a floorbook from one group of 6 with James using the floor book. (looking an an elastic band powered vehicle with a propeller)

Lorna Is it stored energy
Ann It's pushing on the air
Barbara You have to put a force in and it's stored in the elastic band
Ann There is a release of tension

17 Lorna Energy means movement or heat is produced
You apply a force and get heat or movement
Mary Potential energy is there (in the elastic band)
Barbara Sometimes you apply a force and it is not always stored

Mary As we're twisting it (the elastic) we're stretching it
The elastic grows in length and creates tension and energy

25 ... potential energy is stored energy
Lorna Kinetic energy is movement energy, like when something rolls down an inclined slope
Mary We're changing the state of the elastic band ... no that's the
Case Study 6: DES 20-day (Cohort 1) Forces

wrong word, we're not changing its state

30  ...  
Lorna  As something moves down a slope it gathers energy and momentum it gets faster
Barbara  Would it use kinetic energy?
Ann  Gravity is pulling it down ... the weight
Mary  Aren't we spending too much time talking about energy and not forces?
(move on to look at a roundabout suspended on strings)
Barbara  The weight of the wood acts like a flywheel
Ann  Is there tension in the string?
Mary  Gravity pulls it down
Margaret  Why should twisting increase impulse?
Ann  Gravity is untwisting it, is there a difference between twisting and turning?

43  ...  
James  Let's look at the bike and its pushes and pulls
Lorna  You apply a pressure to the pedals
Mary  I can push it along
Barbara  You're making the pedals go round
(Lorna was asked about 'pressure')
Lorna  It's a force or push not pressure
51  Weight makes the pedals go down ... you push on the pedal and that turns the cogwheel and that turns the chain
...
Margaret  Friction is a force
James  How do you know?
Margaret  It's in the handbook! Friction causes things to stop
Lorna  And cause them to heat up
James  Is friction a force or a by-product?
Ann  A by-product
Mary  When a space capsule comes down it slows down by friction, so
61  friction must be a force
James  So what is friction?
Ann  It causes heat and slows movement, it's when two things are rubbing
James  How can you make the bike go faster?
Barbara  Apply more force, press down harder
Lorna  Pedal faster
...
James  How do you stop it?
Barbara  Put on the brakes
Margaret  If you're going on the level you just stop pedalling but to stop quickly you have to exert an extra force by friction, using the lever of the brake
Ann  How do brakes work?
Barbara  Brake blocks are on a lever (demonstrates) ... you operate a lever (brake lever)
...

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Case Study 6: DES 20-day (Cohort 1) Forces

(look at magnetic frogs)

Lorna Opposite poles attract and like poles repel
James Is attraction a pull? Its a force
Mary Margaret Magnetic force can be created into energy by impulse

Comments from other two groups:
1. Lin as scribe (comments not attributed)
   Could be the weight or density which is forcing down, which in
   turn forces the colourless liquid up.
   The pink droplets are falling downwards because of gravitational
   pull.
   Is it something to do with surface tension - the surface tension
   exerts a force. (waterwheel toy)
   It's attraction and repulsion (magnetic blocks)
   It's a friction toy with levers. You just wind the spring up -
   it is geared up - energy is stored in the spring, slowly
   released thro' the gearing mechanism etc. It moves in water, it
   floats. The two legs are pivoted together. (clockwork frog)
   Twisting, pushing, screwing. As you twist it down the arms come
   up. As you press the levers down it forces cogs into the rack
   which pulls the cork out. (corkscrew)
2. Mary B scribe.
Caroline Certain structures are stronger than others

Joy With a strong structure you can exert a greater force before it
   collapses
Andrea Resistance . . forces within the structure . . determined by the
   composition of the structure and materials (used)

Mary B Water exerts a force upwards. Object will sink by weight until
   equal forces are exerted
Andrea How much force is required to make a rugby ball sink? How do you
   measure a constant force?

Andrea Equal and opposite creating an equilibrium. Have to overcome
   this to create movement. The way you overcome it varies -
   different forms of energy
Caroline Mechanical energy is created in the clockwork fish. Stored
   energy is then changed into movement energy.

(Mechanical energy is created in the clockwork fish. Stored
energy is then changed into movement energy.)

... (Friction - unattributed)
Reaction between two surfaces, surface area is proportionate to
friction. Does friction act in space?
(Levers and balances)
Depends on fulcrum position - relationship of load, pivot and
Case Study 6: DES 20-day (Cohort 1) Forces

movement
...
(Equal and opposite)
Andrea If you bounce a ball it will bounce equal to the force with
131 which it hits the ground
Joy It creates energy, but not from nothing
... Boats in water have equal forces up and down. When moving
force is applied horizontally the boat rises.
Caroline You can change one form of energy to another by applying a force
Andrea Every movement has a force involved
...
(Ball)
Joy Gravity pulls it down
Andrea Is the bounce a combination of the force with which it is
141 dropped and what is going on inside? If the ball is deflated it
will not bounce
Joy When it hits the ground the air pressure inside is greater
because the air is squashed so the ball is pushed to its
original shape to regain equilibrium and forces it against floor
to go back up.
...
Force on object on the floor will make floor bend slightly ...
springs back up, forces object to come back up
Andrea Grass gives more than concrete.. is the ground absorbing the
151 force? A surface that absorbs the force will create less bounce
...
Joy Bouncy balls must have a greater potential and hold energy
Andrea Stored energy
...
(Each pair was then asked to prioritise the following areas -
pushing and pulling, starting and stopping, levers and balance,
friction, structures, Floating and sinking - in terms of
interest and need to know more. They were then asked to explore
their chosen area and identify an investigation. The following
were selected:
160 Mary/James - Starting and stopping
Mary/Ann - Friction
Lorna/Barbara - Pushing and pulling
Phil/Lin - Starting and stopping
Andrea/Mary B - Floating and sinking
Gill/Chris - Levers
Joy/Caroline - Structures.
The investigations went on until 2.45 at which time they
reviewed the work in the original three groups with the tutors
maintaining a floorbook.
....
2.45 Review of investigations (in original 3 groups, tutors
maintaining a floorbook). Comments from floor books.
Mary/Ann Investigated 6 blocks on 3 surfaces at different inclines.
Case Study 6: DES 20-day (Cohort 1) Forces

Predicted accurately, tried timing blocks but found it inaccurate. They found that the way the block was placed affected whether it moved. The block surfaces were irregular and the surfaces, especially the chipboard, were inconsistent. Found the investigation unsatisfactory - did not help understanding of friction.

Ann Heat is caused by two surfaces moving - the moving force causes the heat not friction.
Mary Friction is when the surfaces are stationary
Barbara It's when two surfaces are rubbing
Mary It is the force between two surfaces in contact
Margaret It involves minute pushes and pulls on surfaces
Marg Investigated a moving vehicle hitting a wall. The variables were: weight of vehicle; size of starting force; friction between surface and wheels; the drag (air resistance); material the wall is made from. The investigation was limited to size of starting force. It was measured using a spring balance in Newtons and was the independent variable. The dependent variable was the rebound, because it was considered easy to measure. The problem they met included the angle of rebound - it was not always straight. They found the greater the starting force the greater the rebound. However, the relationship is not direct. They think this is to do with the vehicles increasing acceleration.

Lorna They had set out to measure pushes and pulls. They did not know what newtons were but found out they were a measure of force.
Barbara 10N is the force required to lift 1kg (approx). They discovered that there wasn't a push meter and made one using a spring. They calibrated it and found 1cm compression was equivalent to about 10 newtons. They questioned whether the push or pull needed to move chairs was the same. They measured the forces needed to pull and push 1, 2 and 3 chairs. They found the force needed to push was considerably greater in each case. They found the speed of pull makes a difference and a slow pull measured less. They were not sure if their results are due to the accuracy of their measurer. They also explored mass and weight, discovering mass is constant everywhere and weight varies - it is less on the moon - as it is the pull of gravity on something.

Phil/Lin They tested vehicles in an attempt to find out what difference the size of wheels made. They considered other variables like: thickness of wheels; surface of wheels; surface of slope; mass; distribution of mass; angle of slope; means of propulsion; number of wheels. They constructed identical vehicles with varying wheel sizes and discovered the big wheels went further. They decided this was as a result of friction, since friction would have a greater effect on small wheels (they turn more times).

Gill Explored levers and after making up some simple lever systems on softboard went on to investigate balancing. They had practical
problems setting up a balance accurate enough to investigate the relationship between the load on each side and its distance from the pivot or fulcrum. The found out from other sources that the load multiplied by the distance from the pivot must be the same on each side for the beam to balance.

Andrea They began by exploring bath toys and how they float. They then used a computer simulation to investigate factors involved in floating. How do you describe what's happening in terms of displacement? The programme allowed them to investigate 8cm³ cubes in water. They found any cubes with a mass over 8gm would sink. This is because that volume of water has a mass of 8gm. The density of water is 1 and everything else has a relative density, compare to water. They discovered glycerine is 1.26 times denser than water. 8ml of glycerine has a mass of 8 x 1.26 or 10.08gm. Hence any block under this mass floats in glycerine. The upthrust in a liquid is equal to the weight of water displaced. The next investigation involved looking at floating containers. They found a small box sank faster than a large box when weights were added.

Joy Is it because it's denser?
Andrea No it's surface area.

....

After a discussion about displacement Joy was convinced the volume of liquid displaced by a container will be the volume of the container's material and the air inside, therefore the upthrust will be greater and the container can be loaded. Others were not convinced of this.

Caroline /Joy had investigated solid structures - pyramid, cylinder and cuboid. They had begun from the premise that certain structures will support more weight. They felt whether something was strong or not depends on the pressure you apply to it. They found there are so many ways of applying a force and you get different results according to the kind of force applied.

ST What is the difference between pressure and force?
Joy If the same force is applied to different surfaces it results in a different pressure. Same force, smaller area - greater pressure.

....

They questioned why a cuboid was less strong than cylinder or pyramid.

Joy Because it's folded and scored and has more joining edges.

Caroline It's nearer the force
Joy But there is an equal force from the table supporting the cube, therefore the cube is a sandwich in the middle and should crumple symmetrically.

....

Day 2 - 13th November

RR (Introduction to day 2, outlining draft plans. Raised issue of
Case Study 6: DES 20-day (Cohort 1) Forces

time taken yesterday to get into an investigation - a concern in his research and paralleled in the classroom)

9.25 TD Complete one of the elicitation cards (asking what forces are acting on a stone thrown in the air as it moves upwards - Response a - force downwards, response b - force upwards) individually.

280 Comments from sheets
Mary b - force comes from muscular energy in the arm and returns due to the pull of gravity
Margaret a/b - ... the gravity force overcomes the upward force and the object returns
Lin b (changed to a) The force is exerted by the hand vertically for the stone to be thrown. This is greater than air pressure or gravity. Friction slows it down.
Lorna a - the force is coming from the person's hand as he moves his hand to fire the stone. There is also the force of moving air.
Caroline no choice initially - gravitational force, kinetic energy.
Mary B no choice - the stone is given movement (kinetic) energy by the movement of the hand. The force is directed upwards so the stone rises. The force is gradually affected by gravitational pull.
Ann b - the force is coming from underneath to go against the force of gravity
James b - ball is 'pushed' upwards with a given force. At the top of its path gravity is greater than the force of the push.
Joy b - force from hand pushes the stone up, overcoming the force of gravity ...
Phil a - which force? the gravitational force or the force given to the stone from the thrower?
Andrea a - force of movement of hand in throwing the stone upwards overcoming force of air/gravity pushing stone downwards.
Barbara b - to carry on up it must still have impetus from the throw, gravity hasn't started to work against thrown yet.
Gill a - the stone had to work against air resistance on the way up and gravity pulling it down.
Chris b - the stone thrown in the air using energy from the person's arm. It reaches a certain height and gravity helps to bring down the stone.

TD Compare your ideas with your neighbour.

... Many of you have chosen b, some are split between a and b. The first is correct - gravity is the only force acting on the way up.
Lorna But air pressure is pushing it up

TD (holds a ball out) What forces are acting on this? all Gravity

320 ... TD Why is force difficult to understand? You can't see them, you can only see their effects. It is an abstract concept. If you
are worried about forces don’t worry, so am I and so are scientists - they can only study the effects.

... mass/weight - mass is the amount of substance and is constant, it will not change wherever you are... in everyday life we use weight to mean mass, to a physicist weight is a force - gravitational attraction. The units of mass and weight are different. the unit of force is a newton... 1kg is approximately 10 Newtons... when we weigh something we are measuring the force of gravity. There is a problem because kitchen spring balances are usually calibrated in gms or kgs. There is a tension between mass and weight in terms of what we use in the classroom ....

Gravitational pull is the least understood force. Contact forces like pushes, friction etc are easier to understand than a force like gravity. Gravity is independent of mass (demonstrates with 5p and £1, 5p and kg, introduces plastic weigh and effect of air resistance, hammer and feather on moon - MIST module)

Newton’s laws (refers to OU article given out on day 1)
To understand the first law think about an object in space being given a small push ....
The second law links force, mass and acceleration... as you push an object in space its velocity will increase ... acceleration is the rate at which velocity changes ... speed and velocity are different ... velocity is concerned with speed and direction, it is a vector ... acceleration is measured in ms-2... Force equals mass multiplied by acceleration .. 1N = 1 kg x 1 ms-2

... Gravity F = m x g, F = m x 9.8

Acceleration is constant irrespective of mass ie weight and mass are related - weight = mass x 9.8

... Third law - equal and opposite forces, think about hitting a ball with a bat, stepping off a boat or holding a weight - equal forces are involved as they are when you stand on the floor. There is an upthrust - something pushing up. This applies between bodies not in contact, there is an attraction between any two bodies .. the moon affects the Earth’s tides. Gravity is only one side of the interaction between a ball and the Earth.

... 

11.15 (TD tackled flight, starting from what happens when you blow over a piece of paper, looking at aerofoils and what happens when air passes over them. He used MIST modules. Ideas about pressure were introduced and explored. As a consolidation exercise pairs were asked to draw all the forces acting on an aeroplane)

....

Analysis of the drawings produced showed the following forces or terms were included:

Lift  Gravity  Thrust  Drag  Pressure  Others
Case Study 6: DES 20-day (Cohort 1) Forces

Ann/Mary * * * * *
James/Chris * * * * * streamlined shape
Barabara * * engines friction *
Gill * * * air resist *
Margaret v ^ * * *
Lorna/Lin * * * *

2.00 (RR indicated resources to support IT work in science, discussed assignment 1 and other support material available. The school-based day was outlined, stressing the focus of analysis would be the existing ideas about forces that the children hold and how they might be dealt with. Course members spent the afternoon planning in pairs and at 3.30 the plans were reviewed).

380 Day 3 - 16th November
(The group worked with a Y6 class at Junior School C. Due to illness no tutor support was available and the following notes were made by Andrea)

Morning evaluation session:
Margaret One child was using vocabulary that showed screwed up ideas. He was very articulate but thought that all wheels on vehicles go at different speeds and this makes the car go faster - his basic understanding was wrong.

James We thought we could put yellow sticky paper on the wheels and let him observe them going round.

Margaret He doesn't feel wheels on the same axle are the same - he's sure they develop individual speeds.

Gill Has he heard the expression 4-wheel drive and interpreted it himself?

Joy In toys the wheels can spin independently

James We can test it by showing him wheels with sticky paper on and show him the wheels turning together.

Mary He could make his own wheels, paint them and observe them move over a given time

James He will get there

Margaret We felt young children would have the correct concept and it makes us wonder how many others are wrong

Gill On an uneven surface, he might be right

Mary B Were there any other strange ideas?

Mary Not exactly a strange idea - but do they understand what they are expressing? Do they use the language without understanding what they are saying?

Joy Like we do! (general agreement)

Mary B You mean they have the words and use them without understanding?

Margaret On use friction, like in friction cars. Equating friction with
friction cars - by pulling back it has more power, the power is used up very quickly and that is friction. Other children talked about the idea of bumps on the surface and carpet.

Mary B Do we use these words too early?
Lorna Can't stop them
Mary B So do we focus in and help them?
Andrea We should concentrate on helping children observe properly - the words come afterwards.
Mary B We should use the correct words from the beginning.
Lorna We all use words incorrectly
Andrea They need a lot of practical work to focus their ideas, and fair testing
Mary B Our child, Michael said, "Put something in it and it wouldn't sink, don't put something in it, it will float" - we're not sure if it was poor understanding or poor expression.
Margaret We interpret what they say
Andrea It comes back to knowing the children. We are being presumptuous when we tell the class teacher where the children are "at".
Gill It happens each time - the first session we get to know the children
Mary B In our classrooms we do it all the time
Margaret There is a place for outsiders coming in
Andrea Our children know push/pull - at the stage of seeing if each person's pull is different
Mary We introduced Newton's third law. Our fair test will aim to measure the force needed to pull. They have a good idea of push force / pull force - they are working on how to measure it.
Mary B Ours seem to have some good ideas about horizontal push / pull force but seem to have no idea of vertical forces.
Andrea Afternoon Report back
Joy/Caroline We looked at toys and levers. The development in their knowledge of levers was zero therefore it is difficult to comment - they were confused. They had no concept of gravity at all.
Phil/Lin Neither did ours
Lorna They may not be ready for it
Caroline They had never heard the word gravity - one thought he had on TV
Lorna/Barbara We had one bright boy. In the morning he sorted toys by push / pull and talked about what makes toys go down. He knew of gravity, other had heard of it / knew of it - they recognised the yo-yo used gravity. He explained the Earth was like a magnet and things were attracted down to Earth. The afternoon plan was too complicated, so we tried a simple tug of war looking at strengths of pull and different effects - horizontal and vertical forces.
Andrea Did they accept that both were involved?
Barbara No
Lorna We asked them to think of a toy seen in the morning that used push / pull but across a surface. The bright boy remembered the
yo-yo and talked about gravity again.

Mary B
How did he explain it going up?

Lorna
You (the person) are using force to make it go up and gravity makes it go down. Also he talked about taking strain - the elastic may snap because it can't take the strain.

Barbara
We tested to see if increasing weights and then pulling would produce regular results - we asked them to predict and they could. The pattern then changed and we were discussing that at the end.

Lorna
The bright boy understood variables - he didn't use that word.

In the tug of war he said we should use the same finger to make it fair.

Barbara
The next stage would have been a graph but there was no time.

Lorna
He realised the same person should pull each time because others have different strengths.

Gill/
They had the concept of push or pull, some had both
Chris
Suction was grasped

They had an idea that one toy (the water hippo) would sink because it was heavy. This was a digression but we needed to explore it immediately.

Andrea
Do we need to do this with concepts? (general consent)

James
We discussed springs

Ann/Mary
All understood push / pull, but when thinking about a fair test they didn't have much experience - they only thought about being fair to each other. They spent a long time on rubber bands and string.

Mary
They were starting to get there but didn't have enough concrete understanding of fair testing.

Andrea
They were getting frustrated because they knew they were not accurate. We introduced the idea of a Newton scale and they enjoyed it. They understood there could be a big pull or a small pull and that you can measure it. They started to work out a fair test for using it - they suggested we use the floor not the carpet. We asked for the name of the units at the end and got "neutrons" and "neutrals" for newtons. They worked out it would be fair to use the same number each time on the newton scale. Their predicting and estimating was good.

Mary
If we were to introduce fair testing it wouldn't be with forces - materials would be better - you'd need something more concrete.

Andrea
They were ready for fair testing but hadn't any practice. Their language around "pull" was good - wide ranging with good examples. Their interest was kept all the time.

James/
They knew "fair", one had some idea of variables. We set a
Margaret
problem of fairness - I challenged each child for a Mars bar to see if I could push my car further than their's. Mine always won. I varied the positions and asked if it was fair - they said yes because "we all voted for the challenge". We repeated this as a race in the playground, discussed variable length of legs
and they still felt it was fair. Children wanted to push cars but our aim to show that we don't all push the same was not grasped. Not much idea of fair testing. Despite observation often what they say is not what they mean - because we don't know the children, can we make valid judgements to the teacher? We now think we misunderstood our earlier child and that he had greater understanding than adults. The two girls played a servicing role all the way through.

Chris
We had two of each and the boys dominated.

Phil/Lin
They were not ready to do the things we had set up. They needed time to play with the cars (especially Tyrone!!) We were trying to test the size of wheels.

Lorna
What was your hypothesis?

Phil
That bigger wheels go further – we couldn’t get that far so we looked at comparing weight – would the heavier one go further? They were good at measuring but not good at working as a small group.

Mary/Andrea
We looked at whether you can make things that float heavier and observe how they sink. The children had poor ideas about fair testing.

At the end of the morning session the children were talking about forces working horizontally. They had suggested we weigh down something (containers) watch it sink and weigh how much extra weight made it sink. The afternoon showed they had a clear idea of what to observe but a poor concept of fair testing – it took a lot of time and prompting and 'hands-on' before they realised and accepted the need for uniformity. They were good at actually carrying out the test and during it had a lot of discussion about how/why the water level changed including the idea that in a bath the water goes up because there is not enough room for it. In this discussion we also got the idea of pushing down and up and as weights (masses!) were added they decided if they were dropped rather than put in the force downwards would be stronger. Right at the end one child observed that his container (which had the largest base area) had more room for weights and he thought it stayed floating the longest because there was less pressure on certain points. It was a smashing session with lots of evidence and I would like to feel all the children moved forward in their understanding a little.

Day 4 – 5.12.90

(HMI Stockdale attended – Tutors RR all day, ST am, TD pm

Until morning coffee the course members feedback in two groups what they had tried in school since day 3. All had elicited some examples of children’s existing ideas. Most of these were in the area of forces. For example Andrea had discovered several of her children thought floating required "forward movement". Reference were made to day 3 and several had followed up the work tried then with their own classes and two had explored the idea with
Case Study 6: DES 20-day (Cohort 1) Forces

different age groups for comparison. At 10.30 RR asked them to review their ideas about forces by using the forces elicitation cards from the PSTS project. In pairs they were asked to consider the forces acting each each situation. After about 15 minutes during which time ST and RR visited each pair there was a few minutes general discussion. Several pairs had concluded that all the cards were similar in terms of gravity acting in all situations. No one suggested a force was acting in the direction of movement. There was some discussion about whether the moving car had a constant force acting on it and it was agreed that it had.

RR then asked course members to produce a concept map about forces individually and then to discuss their ideas.

The following is an analysis of the maps given in straight after the session. KEY - M mentioned U indicates understanding S indicates some understanding X indicates misunderstanding

<table>
<thead>
<tr>
<th>IDEA</th>
<th>Mary B</th>
<th>Marg Joy Ann Andrea Lorna Chris Barb Phil Carol Lin</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORCE</td>
<td>U</td>
<td>U U U U U U X1 U U U U U</td>
</tr>
<tr>
<td>GRAVITY</td>
<td>U</td>
<td>M M U U U X1 U U U U M</td>
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<td>RESISTANCE</td>
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<td>MOMENTUM</td>
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X1 - gravity comes from above (corrected on 2nd draft)
X2 - density depends on pressure operating on the material
X3 - mass is measured in Newtons

Some of the key ideas on these maps and the potential uses of concept maps were discussed.

After lunch RR brainstormed words used concerning 'energy'.

All the conventional 'types' were offered along with sources
such as sun, water, wind etc. These were grouped according to 'types' and 'sources' without any difficulties. The significance of the two main types ie stored and movement was discussed. PD then introduced the idea of energy transfers and course members were asked, in pairs, to consider the energy transfers involved in one of the objects available (including toys etc. from day 1, a tape-recorder, plant in pot, hairdryer candle etc.) Their ideas were displayed as posters. PD then explained some key ideas about energy conservation and the relationship between forces, work, energy and power.

The afternoon finished with a open discussion which included Hooke's law in response to the experience of Barbara and Lorna (see L 278).

Informal evaluations of the cycle were all positive and course members were asked to put in writing any comments they had and include them with their assignments.

The HMI provided detailed feedback which will be discussed in a later analysis, but overall his comments were extremely positive and highlighted no concerns which the tutors were not already aware of (eg related to differentiation).
Analysis of Case Study 6

Group: Cohort 1

1st analysis: 12.12.90

The nature of the teaching approach

This cycle of the DES course provided a further example for the course members of constructivism in action. I have decided that previous case studies indicate that specific orientation activities at the start of cycles are unnecessary if course members already have prior notice of the content involved. Consequently, the first session started with an elicitation activity that provided orientation time for any who needed it. In terms of elicitation strategies, a development from the previous cycle was the control of floorbooks within sessions by a group member (CS6: 8). This individual was then responsible for questioning and prompting other group members about their ideas. In this instance, about what each of the objects had to do with forces. This worked well in most groups and the detailed evidence at the start of the case study (CS6: 11,) indicates the effectiveness of this strategy. There was an exception (CS6: 85) when one 'scribe' did not attribute individual utterances. This implies a poor understanding of the purpose of the floor (or in this situation table) books. The use of floorbooks by course members was complemented later in the day (CS6: 175) by another example of tutor produced floorbooks during the review of investigations. The benefits of there being three tutors (RR, ST and TD) available at this stage of the session were considerable.

Another example of an elicitation strategy involved the use of elicitation cards (based on Kruger et al.(1990b) interviews about instances cards). The use of these (CS6: 276 and 571) proved valuable both before an input (CS6: 276) and to indicate retained and restructured ideas (CS6: 571).

Concept maps were used more effectively during this cycle (CS6: 579) than during Case Studies 4 and 5 (Concern 3) and analysis later will indicate their usefulness. In this instance they were used to provide evidence of the extent to which individuals had been able to restructure their ideas as the result of investigations and exposition. The opportunity was taken during day 4 (CS6: 615) to discuss the use of concept maps with children and it is hoped that some evidence will be found during later cycles to indicate whether any course members try them out with their classes. There is still some difficulty in encouraging course members to expose their individual ideas using strategies like this and informal comments indicate that some still find committing their existing ideas to paper quite threatening. This was identified early in my research as
Analysis of Case Study 6

a concern (Concern 10). My intention then was to try paired work and this was explored after individual work on the maps. Course members seemed more comfortable working with a partner but this makes it much more difficult to identify individual constructs.

This case study provided further evidence that course members recognised the importance of the elicitation phase with children. Numerous examples of elicitation activities were evident during the school-based day of the cycle and perhaps more significantly in the reports of work from their own classrooms offered during day 4 (CS6: 563). Margaret seems to have found the children's ideas (CS6: 401) during day 3 unexpected (CS6: 411) and clearly recognises the need to start from elicitation. This same example also shows that course members are appreciating the need to challenge children's existing ideas through activities rather than exposition (CS6: 408). Another encouraging aspect of this exchange concerns Gill's attempt to explore the child's logic and reasons for offering alternative ideas (CS6: 403, 413). The crucial importance of language during this phase is identified by Mary (CS6: 415) who questions whether the use of the word indicates understanding and Joy reminds the group (CS6: 418) that they as adults can also end up using words without understanding.

The need for exploration before investigation was again made explicit during this case study (CS6: 159) since this remains a concern of tutors (Concern 13). The time needed for exploration by course members during this cycle varied from pair to pair. They were helped to focus in on one content area using a prioritising activity (CS6: 155). This was intended to give them more ownership of the exploration (Concern 15) and overcome the problem of complete tutor identified content. The motivation of participants during the investigational phase would suggest this was reasonably successful although there were exceptions that are discussed later.

Nearly three hours (10.45 - 2.45, including lunch) were available for exploration and investigation. It took some pairs over an hour (not recorded) to move from unstructured exploration to a more systematic investigation addressing a question that had arisen. This proved a difficult time for the tutors whose role in terms of when to intervene is problematic. It is particularly difficult when conversations seem to indicate pairs are off task although it would seem that this may be an important part of exploration. Time to chat more generally during exploration may give the individual opportunities to reflect and 'think around' ideas more explicitly related to the task. At this stage in my own 'exploration' of teaching strategies I consider the most appropriate tutor role to be non-interventionist during the course members' explorations unless specific requests are made or a pair has obviously lost interest in the materials they are exploring.
When the investigations were reviewed one pair, Mary and Ann said they had found their practical work unsatisfactory since it had not helped their understanding of friction (CS6: 180). This may have been due to the nature of the content area, the nature of the questions they raised, the nature of the investigation they carried out or the quality of tutor support. However, the later sections on alternative ideas and restructuring discuss Ann's initial ideas that friction is not a force but a 'by product' (CS6: 59) and her restructured ideas about friction and heat (CS6: 183). This would suggest the practical work and related discussions had some influence on her understanding.

Other pairs engaged in fairly 'low level' investigations on levers (CS6: 223), measuring forces (CS6: 201) and structures (CS6: 250). In several cases the technological problems of making something such as the vehicles (CS6: 218), structures to test (CS6: 251) and accurate balance (CS6: 224). These activities consumed time that could have been more efficiently used on the investigative aspects. This problem also arose during Case Study 7 and suggests that during future cycles on forces it would be desirable to have more suitable equipment available although some course members gained from the opportunity to work with resistant materials and use tools and construction equipment (CS6: 219).

There were also some sophisticated and very successful investigations that led to improved understandings. In particular Andrea and Mary B's work on floating and sinking (CS6: 230) was impressive and illustrated the extent to which a computer simulation can support practical work (raised in the analysis of Case Study 2 but not identified as a key concern). This pair also worked with children on day 3 in this content area (CS6: 536) and Andrea covered the same area with her own class (CS6: 566).

Returning to issues related to the teaching approach used in the case study, there were examples of individual work (CS6: 279, 579), paired work (CS6: 1, 155), small groups (CS6: 11) and large group work (CS6: 294). The tutor's role varied from support of individuals, pairs and small groups (CS6: 162) to exposition (CS6: 321) and facilitating whole group discussion (CS6: 616). A variety of resources were used and more effective use was made of MIST (CS6: 363) although the material has greater potential which should be explored in Case Study 7. The resources available to support the use of IT in science were also outlined (CS6: 382).

Finally, in this section, there was a more structured attempt during this cycle to consolidate the ideas offered during the exposition session (CS: 321). The course members were invited to apply ideas
about forces to identify the forces acting on an aeroplane in level flight (CS6: 368) which indicated a sound understanding of those forces.

The nature of science implicit in the session

The scientific questions raised by course members as the basis for investigation and discussion were generally more appropriate than those raised during Case Study 4. They indicated a clearer understanding of variables (eg CS6: 194) which suggests the work done on variables during Case Study 4 (CS4: 540) was understood and was now being applied.

The course members' understanding of the tentative nature of scientific is less apparent from the evidence collected during this case study but informal discussions and conversations during practical sessions indicated that it was now 'accepted' that the findings and generalizations made from them were indeed tentative. However, it is probably necessary to make this more explicit during a later cycle to reinforce this fundamental aspect of the nature of scientific knowledge and understanding.

Andrea and Mary were one of several pairs whose investigations were more quantitative this time than during Case Study 4. There are numerous examples of course members making a variety of accurate measurements during their investigations (length (CS6: 190), time (CS6: 214), mass (CS6: 230), volume (CS6: 230) and force (CS6: 193, 200, 231, 250). The latter measurements are significant since none of the group had previously heard of Newtons or appreciated how forces could be measured. Anecdotal evidence suggests that the inclusion of Newtons and Newton meters in Key Stage 2 of the National Curriculum has caused primary teachers considerable worries and it is therefore important that a course like the present one introduces this aspect of measurement. There is evidence that course members felt confident to introduce Newton meters to children on day 3 (eg CS6: 446 and 501).

The links between science processes and knowledge and understanding continue to be appreciated by course members and there is evidence that although the focus of the school work on day three had been children's ideas about forces some of the evaluation session appropriately dealt with the processes involved in developing understanding (CS6: 479, 510). There was a encouraging amount of practical investigation structured into the work with children (eg CS6: 540). The course members' first assignments (completed after this cycle) dealt with the issue of the inextricable links between process and knowledge and understanding and indicated that all of the group had been able to find examples of these in their work with children both on the school-based days and back in their own
Analysis of Case Study 6

The discussions that took place during the case study, especially those during days 1 and 2 and the afternoon of day 4 provided yet more examples of the extent to which adult's scientific ideas are socially constructed. The initial small group discussions, recorded in floorbooks, (CS6:13-82) provide the best examples of this which are analysed in the next section. The importance of discussion in pairs, small and large groups is constantly reinforced by the teaching strategies used on the course and examples from the course members own classrooms in feedback on day 4 and in their assignments show that this is influencing the way they work with children.

Course members' knowledge and understanding of science

There was considerable evidence of acceptable scientific ideas being held by course members during this cycle. The relationship between energy and forces was dealt with at the end of the cycle but early comments from course members indicate that some already held ideas about energy (CS6: 13, 19, 26). In particular, Lorna seems to be expressing her ideas about energy confidently. She refers to 'stored energy' (CS6: 13), 'movement energy' (CS6: 18 and 26) and introduces 'momentum' (CS6: 31). Later she illustrates a sound understanding of magnetic attraction (CS6: 78). She used 'pressure' (CS6: 46) but changed her terminology when challenged (CS6: 49) to 'force'. It was disappointing that this confident start led to a low level activity (CS6: 201) although there is evidence that sound scientific questions were raised during this activity (C6: 205) which were investigated. The differences between pressure and force were clarified by Joy later in the day (CS6: 259). Joy was one of the few course members to articulate Newton's third law in the context of day 1's activities (CS6: 268). Ann and others held acceptable ideas about gravity and weight (eg CS6: 34). Margaret recognised friction was a force (CS6: 54) although cited the handbook as the source of her knowledge. Andrea described the forces within a structure appropriately (CS6: 106) and Mary B began the cycle with acceptable ideas about floating (CS6: 110) although her later work (CS6: 230) indicated that this initial comment was not evidence of sophisticated understanding of upthrust in water. Andrea seems to have an understanding of equilibrium of forces (CS6: 115) and also appreciated the need for a force to produce movement (CS6: 136).

Alternative frameworks held by individuals

There is also evidence, as in previous cycles, of ideas being held which do not correspond to acceptable scientific ideas. Examples of these include Barbara's idea that 'force can be stored' (CS6: 15) which she holds on to (CS6: 21) even when potential energy is discussed (CS6: 20). Mary's idea the 'state' of the elastic band is
being changed (CS6:28) may suggest an alternative framework, although she corrects herself immediately, hopefully as a result of her work during cycle 1 (CS4: 176). Margaret seems to hold some idea about impulse (CS6: 41) which is not clarified. On numerous previous occasions Margaret has tried out 'scientific' words without pursuing its meaning. She uses the same term in a different context later (CS6: 82). The issue about the use of language without meaning was raised in the group discussion on the school-based day (CS6: 415) and Joy expressed the view that adults often use words without understanding and this met with general agreement (CS6: 418). Lorna provides evidence of some alternative ideas such as 'friction causes things to heat up' (CS6: 57). Friction was not understood as a force by several course members. James questioned whether it is a force of a by product (CS6: 58) and Ann seems convinced it is the latter (CS6: 59) and causes heat (CS6: 63) although she accurately explains that it slows movement and is 'when two things are rubbing' (CS6: 59). Caroline suggests 'mechanical energy is created' in a toy (CS6: 119) and Joy also talks about creating energy (CS6: 132) but states this cannot be from nothing. During Case Study 4 she stated it could not 'disappear' (CS4: 67).

Perhaps the most significant alternative idea that was held generally concerned the idea of 'impulse force' whenever movement occurs. When asked to consider the forces acting on a stone in the middle of its upward path only 4 out of 14 gave the acceptable response that gravity is the only force acting. 8 stated there was a force in the direction of movement (CS6: 280). Lorna defended her alternative idea with 'but air pressure is pushing it up' (CS6: 316).

There is limited evidence that the course members elicited evidence of children alternative ideas. Examples include ideas about the 'fairness' of tests (CS6: 512) and concepts of floating depending upon forward movement (CS6: 565).

**Evidence of restructuring of ideas**

Crucially, the general alternative idea of 'impulse force' seems to have been successfully addressed by day 4 (CS6: 575). This needs confirming by probing their understanding at a later date. Other specific examples of restructuring include Ann's ideas about friction (CS6: 183) which is particularly interesting in the light of her comments about the value of the practical investigations (CS6: 180) discussed earlier. James has begun to appreciate the relationship between force and acceleration (CS6: 198) which was a development of his existing ideas about forces.

The concept maps proved successful in providing evidence of ideas held (CS6: 579) but for evidence of restructuring it would have been
desirable to have asked them to produce concept maps at an earlier stage of the cycle for comparison. This will be done with the Cohort 2 (see Case Study 7).

General Concerns/Issues

The input on forces during day 2 was more expositional than the approach used during the materials cycle. This was identified as a concern during Case Study 5 (Concern 19) and needs further reflection.

There was some confusion (not recorded in field notes) about working at an adult level on day 1 and 2. Teachers still find it difficult to tackle activities at their own level, perhaps because they feel more confident and secure looking at practical activities from a child's perspective. The course model is dependent on scientific work at an adult level and this needs to be made explicit at the start of each cycle. The evidence to date confirms my original views on the appropriateness of the course model (reinforced by HMI's view after visits) and the response of course members to exploration and investigations in terms of lack of curiosity and question raising suggest more experience in this area is essential.

This case study provides further evidence concerning the question about the pattern of the days raised at the end of Case Study 5. Consecutive days have proved successful and the continuity over the two days seems particularly beneficial in terms of relating the exposition to the previous day's practical activities.

The content area covered in this case study proved problematic in terms of the breadth of the topic. Certain areas such as structures were unproductive in the time available and have less obvious links with the orientation/elicit activities. It is therefore preferable to delete that theme from the options in Case Study 7. The overlap between forces and energy is also problematic and needs discussing with the planning team before next year. The decision to cover energy types and transfers on day 4 was as a direct result of the course members' response to the elicitation phase when so many expressed ideas about energy as opposed to forces. It would have been productive to have linked the work during this cycle more explicitly to the big ideas introduced in cycle 1.

Many course members found the concepts involved in forces very difficult and two or three expressed the view that the exposition had gone into too much depth, especially in terms of velocity and acceleration (James). TD started his input by explaining why forces are difficult to understand this view was reflected back later in the cycle when Mary stated that she would be much happier introducing children to fair-testing through the use of materials,
Analysis of Case Study 6

because they’re more concrete than forces (CS6: 508).

However, the case study produced examples of some teachers eg Andrea using the same theme (floating and sinking) at their own level on day 1, with children on the school-based day and in their own classes between day 3 and 4 (CS6: 230, 565, 568). This is encouraging and will hopefully occur more in later cycles to allow more reflection on children’s alternative ideas and their relationship to the teachers’ initial and restructured ideas.

Future action:

1. Discuss the difficulties of the content area with the planning team and course members during cycle 4.

2. Remind course members about the ‘big ideas’ framework.

3. Consider how better use can be made of the course handbooks. question course members about how they are using them.
Case Study 7: DES 20-day (Cohort 2) Forces

Group: 17 teachers from LEA Y, Tutor: RR, DW (pm Day 2 and Day 3)

Sessions: Thursday 22.11.90, Friday 23.11.90, Thursday 29.11.90 and Thursday 13.12.90

Data Collection: RR field notes Students’ outcomes - concept maps Floorbooks Students’ evaluation notes

Aims for the session 1 & 2:

1. To develop students' background knowledge and understanding of forces;

2. To provide students' with an example of constructivism in action for adaption in their own teaching

Day 1

9.15 RR (Introduction to 2nd cycle. Course members were invited to form new pairs and explore the objects out noting, in their own terms what they had to do with forces. The collection included a bike, toys, springs, newton meters, clay and plasticine, lever tools, simple construction and a tank with objects floating. They were asked to feedback their ideas in larger groups with a course member using a floor book to record ideas)

The following comments are taken from those floor books:

Group 1 (Barbara + Trish, Frances + Debbi, Pauline + Anne)

Frances (Hippo) It's like a spring
Debbi It works quicker out of water
12 Force is pulling .. contracting the spring ...
Anne The spring closed up tight, storing energy
Debbi Water pressure slows it down
Pauline There's resistance
Barbara Friction
Debbi It's got a hinged jaw
Pauline There's a pivot ...
20 (nutcracker) There's a lever .. you exert force at the base of the lever .. there are two pivots
Debbi And a spring inside to make it ping back
Frances (the) Spring is at the base
Debbi There is only one pivot .. the spring is depressed with force on the lever
Pauline The smaller the nut the nearer it must be to the spring - where force is applied ...

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Case Study 7: DES 20-day (Cohort 2) Forces

Group 2 (Kay + Caroline, Dave + Becki + Mark) - Caroline took notes.

Becki (spring balance) This has got pressure put on it by the person pulling the spring down. The tension in the spring causes it to go back to its normal state.

Dave (syringes and tube) When one is pushed down, the air is forced along the tube because the other one (syringe) is smaller it can't take all the air and so is forced out.

Mark (magnetic frogs) Because there is some force that makes them turn around.

Kay The should attract each other put paper between them they should attract (tries it) Oh, you can.

Mark Weak magnets the magnets are moving around inside, look (demonstrates). They are now the other way.

Caroline (pecking chickens) When the ball at the bottom is pulled it makes the chicken move their necks. Why does the head spring up? When the string is tight it pulls it up it's gravity

Becki On all of them there has to be an external force.

Mark There is a force there all the time, but someone has to make it respond there is a force within the magnet all the time but they're loose.

Kay How does that affect them?

Mark Sometimes they attract, sometimes they repel how is this (clockwork mouse) so balanced? the tail is a counterbalance.

Kay It has got a wider base.

Mark How is the energy stored up?

Dave Like that spring.

Group 3 (Julia + Jill, Rick and Adrian, Andy and Neil) Julia took notes.

Jill (2 magnetic discs on a rod) There's a magnetic force working here, -ve > +ve attracting and like repelling. I don't know whether (it's) 2 -ve or 2 +ve gravity is forcing them down.

Rick My clockwork toy moves forward by a series of cogs and wheels.

Andy Surely there's a spring in there. Is it the spring unwinds?

Adrian It's a vehicle worked with a spring (laboratory trolley) You can roll it against a hard surface and it will make the spring compress. Then it will release making the vehicle roll away from the surface. The wheels have bearings which make them move more freely. It needs somebody to provide the energy to make it start (acrobat) when I squeeze it goes boinggg tension of the strings.

Andy What happens when you squeeze one?

Adrian It releases tension on one which causes the string to slacken when I apply force from either side it forces two bits apart spring?
Case Study 7: DES 20-day (Cohort 2) Forces

Neil

A lever?

Andy

tension of wire .. pushes sides out, bottom in

Adrian

Creates tension at the top .. when you push the button in it

pushes plastic in at the bottom forcing plastic out at the top

which tightens the wire.

Julia

Is she (acrobat) normally hanging because of gravity?

....

10.00

(RR showed MIST module from disc 6 on Forces. He suggested it is

helpful to use the noun 'force' rather than the verb 'forcing'

and referred to a handout explaining this. He then outlined the

areas that course members could investigate - pushing and

pulling, starting and stopping, levers and balance, floating and

sinking, friction, structures. He invited course members to form

new pairs, if they wished, and prioritise the focus for their

work. They were asked to explore their area, identify questions

for investigation and record their progress in a floor book.)

...

10.20

(Neil and Julia, Andy and Jill were the only changes of pairing

- all pairs selected their focus within 5 minutes and proceeded

to explore their chosen areas)

The following comments are taken from floorbooks produced by the

pairs as they worked:

Kay/ Caroline

Measuring the rebound on the trolley against various materials

(sponge, polystyrene, hardboard and carpet)

Measured starting force on trolley (at top of a ramp) was 1.2N

(they tested the trolley with the sprung rod extended and not

extended, repeated each test three times and calculated a mean

value - found the first created more rebound but the order of

materials was the same)

Decided to investigate the effect of the surface area (of the

front of the trolley)

(they added a plate to the end of the spring the same are as the

end of the trolley and found that the rebound was less if the

surface area of contact with the wall was greater)

Dave/Mark

Decided to investigate the effect of length of lever

from fulcrum on force needed to balance a weight on the other

end (fixed weight, fixed distance from fulcrum).

Decided to use newton meter at 5cm intervals.

(also used masses needed to balance at different points, decided

weight of wood was significant, tried to calculate its effect.

Plotted results on a graph - found newton meter results least

accurate compared to their 'ideal' curve based on calculated

moments.

Rick/ Adrian

Chose selection of lever devices (pliers, scissors, wire

stripers and garlic crush)

Applied effort to each until a sponge piece (in the load

position) began to be squashed.

(after discussion applied ideas about moments to calculate

forces being exerted)
Case Study 7: DES 20-day (Cohort 2) Forces

Discovered that the longer the lever, i.e., distance between pivot and end of handle, the more force that is applied at the cutting/crushing end.

(went on to explore the different effects of lever length and fulcrum position)

Andy/Jill

Does the size of wheel affect the force needed to stop it?

Idea - The bigger the wheel the greater the pressure needed to stop it, therefore larger wheels need stronger brake systems.

Decided to design and make a machine to test this.

Discovered that a small pulley (on motor) to a large pulley makes the wheel go slower.

Small to large gears do the same

Large to small gears makes the axle spin faster therefore less energy is needed to turn the wheel so it would be easier to stop.

Driving a car uphill - axle faster but wheel goes slower which helps it go up hill.

We made 4 different size wheels all weighing 18g as we decided weight may affect the speed of wheel turn.

Brake pads were made from lego bricks, applying equal weight each time.

(test rig was motorised)

Timed how long it took each wheel to stop.

(results inconsistent and inconclusive - discussion with RR led to varying load on brake block until wheel stopped - not long available enough to complete tests)

Frances/Debbi

Investigation into factors affecting floating and sinking

What substances float or sink?

Predictions - clay > sinks .. correct
lead > sinks .. correct
Aluminium > sinks .. correct
Wax > sink (D), might float (F) .. floats low in water
Polystyrene > floats high .. correct
Soft wood > floats .. at an angle

Hypothesis - grain is closer at the end that is lower in the water therefore (the wood is) denser at the lower end > prediction that hardwood will float level .. result - floated low in water at an angle from one side.

Discovered grain was wider at end that floats lower in the water.

Hypothesis (D) - heavier objects float lower in water (F) not true of ships

(D) these are blocks.

Next step - weigh objects to test hypothesis

(results recorded)

Therefore hypothesis was right

Next step - measure blocks with a newton meter in air and in water.
Case Study 7: DES 20-day (Cohort 2) Forces

Clay - in air 125g in water 60g
Predict on above evidence that all blocks will be lighter in water because of water pressure's upthrust

Aluminium - 150g  90g
Lead - 460g  400g
Therefore we think the ratio in > out will always be the same for the same size block eg 60g
Wax - 40g  0g
Next step - used different size blocks
Slate - 95g  60g
Prediction - there will be a 35g difference in ratio in > out in this shape object.
Marble - 100g  70g
Aluminium - 100g  70g
Next step - used computer simulation to look for correlations between ml of water displaced and weight of object displacing water.
Found the upthrust was always the same as the volume of water displaced.
Predicted upthrusts on different blocks to confirm.
Next step - tried different liquids (on computer)
Found 1ml of glycerine is heavier than 1ml water, 1ml of oil is lighter than 1ml of water.
Displacement is less with floaters in more viscous liquids.
Hypothesis - water is more dense than oil therefore objects of the same weight will be held up more in water.
Tested and found to be correct (results recorded in a table)
Discovery - you can calculate what an object will weigh in a liquid relative to water by subtracting the weight of the volume of cube from original weight out of the liquid.
Relative density of glycerine = 1.26g
~ ~ ~ oil = 0.73g
Prediction - 8cm³ of iron will weigh in glycerine - 62.96 - (8 x 1.26) = 52.88g (correct when tested)
Barbara
Investigated lifting, dragging and pulling a load
Trish
Force needed to lift load (a stone) = 9.5N
Force needed to drag - Why does force lessen as load gets nearer to us (standing still to pull)
Suggestion - grit at beginning of pull (on paper) - friction? the way we are pulling?
Tried moving and pulling load steadily
Set a distance of 1m
Force of 3N on floor, 3.5N on paper
But force lessened as we got going - is more force needed to set a load in motion?
Load on a pan reduced force to 2.5N
Load on runners reduced force to 2N but grit on paper obstructed runner and it stopped completely - would a larger area of pan-sledge have compensated ie slid straight over?
Case Study 7: DES 20-day (Cohort 2) Forces

Investigate whether more force is needed to set load in motion:
To lift the load with one pulley wheel took 10N - why more to
lift using the pulley than by hand?  
Found that using a pulley to drag a load produced a reading
higher than without a pulley.
Does it change reading if we use a longer string?
Does direction of pull make any difference?
Tried a different and heavier load - still apparently needs more
initial pull with a pulley
Would two pulleys make any difference?
Would the reading be the same if the pull using a pulley was in
the same direction?

Pauline/

Investigated starting/stopping forces - looked at the
relationship between speed of car and distance an object is
thrown when car stops suddenly.
We selected a car/vehicle, made a ramp with sides to prevent the
car coming off course, constructed a barrier at end of ramp to
provide a fixed point of impact.
In our initial explorations we encountered two major problems -
vehicle selected had a deep cavity in which to put the person
and this proved to be too secure a position;
when we used a brick, it moved!
(results recorded in a table with a diagram of set up -
inconsistent results explained using careful observation)

Decided toy car involved too many variables so used a Duplo
buggy with a corriflute platform
(results recorded showing gradient of slope proportionate to
distance figure thrown)
Could perhaps take two measurements - where figure first hits
ground and where it ends up.

(Investigations were reviewed in original three groups and then
RR drew out some key ideas about levers and factors affecting
floating and sinking - gave out OU information on Energy and
Forces)

Day 2 23.11.90
(am RR only tutor)

(RR introduced day 2 and revisited ideas about floating and
sinking - explaining how the upthrust was due to differences in
pressure. He then asked course members to consider the forces
acting on a thrown stone at the midpoint of its upwards flight
.. individuals chose from 4 options - a. downwards, b. upwards,
c. no force and d. forces in both directions and wrote an
explanatory paragraph on a sheet)
All 16 present opted for d (forces in both directions)
Examples of explanations:

Mark
Pressure both ways, stronger pressure upwards (kinetic energy)
but gravitational potential energy pushing down.
Case Study 7: DES 20-day (Cohort 2) Forces

Caroline Because there is force from the throwing action which pushes up. But there is also a force from gravity that is pulling it down.

Dave Both an upthrust and a downward pull because the force upwards is against the "natural" force but has been exerted by the hand. the downward force of gravity and pressure is acting as natural.

Rick For every action there is an equal and opposite reaction.

Neil Stone moving up as a result of propulsion from hand. Friction caused by air forcing marble down, also force of gravity slowing it down.

Barbara Pressure of air pushing down on the marble and equal force of air pushing up.

Debbi Friction downwards, muscular energy upwards, gravity downwards. You have made it move upwards but gravity and friction are also acting on it.

Pauline There is always a force (gravitational) pulling down, but because the stone is travelling upwards there is probably a certain amount of force being exerted upwards, this continues until gravitational pull becomes greater than the force exerted upwards.

Anne The force exerted on the marble by you began the upward motion. However, the force of gravity acting on the marble is pulling downwards.

Frances The force from below is slightly more because it has been pushed from the hand. Force down - gravity.

Trish The push upwards from the act of throwing marble up is greater than the push down of the air (gravity).

Jill Upward thrust - force has changed from thrown energy (the thrust) to kinetic energy but gravitational energy is beginning to push down.

Andy Upward movement still in motion but effects of gravity has a bearing on the marble in beginning to pull marble down.

Adrian The pressure exerted on it is equal on all sides.

Julia Gravity is always present but as the stone is still in the middle of its path upwards it still has kinetic energy transferred from person (throwing).

9.40 RR Will somebody share their ideas?

Mark There's kinetic energy and gravitational energy

312 RR But I asked about the forces on the stone

Pauline There is gravitational force all the time. You've thrown it up an exerted a force

RR I agree with that but what forces does that mean are acting at on the way up?

Neil You only exert a force when you set it in motion.

RR That's right - the only force acting is a downwards force due to gravity

320 ... (RR then outlined a number of key ideas, demonstrating as appropriate, using MIST modules and drawing ideas from course members. The input covered: mass and weight and the units of
Case Study 7: DES 20-day (Cohort 2) Forces

both; gravitational force [when asked to predict whether 100g or 20g mass of similar size when dropped would hit the ground first, 5 predicted the 100g and 11 predicted at the same time]; Newtonian physics; First Law; Second Law; speed, velocity and acceleration; acceleration due to gravity; relationship between mass and weight; Third Law. Course members were then asked to produce a concept map, in pairs or individually, covering the ideas introduced. These were collected and checked over the lunch break in order to identify any problems)

... 12.00 (As a consolidation exercise RR introduced ideas about lift (using MIST modules and demonstration) and asked course members in pairs to illustrate all the forces acting on an aeroplane in level flight - all pairs showed lift, thrust, gravity and drag, although the words used to describe them included friction, air resistance (drag), propulsion, forward push and engines (thrust)).

... The following were the only comments of concern on the concept maps (and were clarified acceptably by the individuals who wrote them):

Frances Gravity is independent of mass but affected by air resistance
Becki Gravity on an object is affected by air resistance.

... 2.15 (RR introduced the second school-day. Outlined work done with infants using a floorbook, brainstorming, word spurs etc - case study included in handbook, and stressed the need for orientation and elicitation when working with the children. He explained that the focus of analysis on this cycle was the children's existing ideas and how they might be challenged or developed. Pairs then planned their work, supported by RR and DW who joined the group for the afternoon)

... 3.30 (Each pair reported back on their plans)
Pauline/ To use a collection of balls and a floor book - looking at Anne bouncing and rolling, what makes a ball stop?
Frances/ Floating and sinking, brainstorming and possibly leading to the Debbi children making a boat
Barbara/ Thing that move or have moving parts - sorting activity. How can Trish you move a brick? Using a floorbook
Rick/ How do things fall? Using a collection - predicting which will Adrian fall first, investigate falling and recording ideas in a 367 floorbook or perhaps concept maps - draw on links with 'real' life.
Andy/Jill Exploring footwear - testing which shoes give best grip and why Julia/ Starting with marble runs - what affects the marble's Neill speed - table books, word spurs - trying to slow marble's run Dave/ Toys that need pushes or pulls - how can they be made to move - Caroline is their movement affected by the surface they are on?

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Case Study 7: DES 20-day (Cohort 2) Forces

Mark/Becki
Collection of balls - free activity - rolling to see how far they go - what forces are acting - use a clipboard for group's findings

Day 3 - Primary School D

379 Comments from evaluation sessions:
Anne (unstructured exploration of a collection of balls) They came up with lots of ideas including Do the ball all have air in them? The table tennis ball had dented and one said, "If you put it in hot water it will push it out - the air will expand". We challenged them to find ways of making the balls start moving... "You could wait for the wind to blow it", "You could blow it by yourself", "Using a force will make them move". When asked to explain stopping there were comments such as "It hasn't got enough force to carry on". We also received ideas about gravity, "It keeps you on the ground". When talking about a bouncing ball one said, "Every time it bounces it looses some force".

390 DW I think you got so much back from the children because you were good at asking Why? questions.

Caroline Our group had ideas about surfaces affecting a toy car's movement. Some said the tread on the wheels had more grip, one thought the rubber "was sticking to the lino".

Andy Lucy in our group explained the grip of shoes in terms of friction .. "two surfaces rubbing together as if they don't like each other .. the slipper has no friction because the two surfaces rub easily."

Mark It took our children (using a collection of balls) along time to decide what a fair test was. They realised when they pushed the balls down the slope that the force wasn't constant. Eventually they raised the idea of gravity.

Frances One child, during our floating and sinking activity explained density. Some said things floated because .. they had air in them, they were lighter than water, of their surface or shape.

Neil Toby seemed to be operating at level 4 in AT10. He tried to explain gravity and thought it was to do with air and pressure (a downward push) .. "It's a gas that pulls you to the ground".

Trish There was a confusion between whether gravity is a push or pull.

Catherine was quiet but made useful contributions in our group. When asked why it took more force to move a brick on it's side she said, "There is more weight pushing on top of it" - perhaps suggesting an understanding of pressure. None of the group used or had met the word force.

Rick Our group were looking at what happened when things were dropped. we were impressed by their recordings. They were told that a sponge ball was lighter than a ping pong ball because "it is full of air". We also met some alternative ideas about gravity.

420...

Day 4 - 13.12.90)
The day followed a similar pattern to the Wiltshire Day 4 (CS6). The following comments about classroom based work were noted by a scribe in each group.

**Andy**

His class had explored a collection of balls and thought about what happens when you drop a ball. There was a discussion which led some children to investigate whether heavy or light balls hit the ground first. They didn't appear to change their minds—they continued to believe the heavy one landed first.

He had asked them to indicate on a drawing (of the world with stick people at top and side dropping a ball) which way the ball would go. Some had the ball going down the page, some towards the surface and others outwards.

**Rick**

Some adults would find that hard—did they realise it was a representation of the world?

**Dave**

My group did a similar things dropping weights but ended up accepting a light weight and heavy weight hit the ground at the same time. One child asked, "Does gravity pull at the same rate (on different objects)?"

(There was a discussion about why Andy and Dave's children had reacted differently to the results of the investigation. It was suggested that perhaps once an idea has been formulated by one child and taken on by a group it takes a lot of evidence to convince them of anything different)

**Mark**

Some of my children thought gravity was air or air was gravity. One child said if you drop a hammer and a feather on the moon they reach the ground at the same time. They discussed air pressure differences between Earth and the moon. Children seemed eventually to appreciate that gravity was a force.

**Andy**

The idea of magnetic force came up—one child said we had gravity because the world was spinning.

**Caroline**

Used the toys that she had used on Day 3 with a group. They had a day to explore them and then she asked them about how they moved. Her class were able to explain actions reasonably well. They went on to model some of the mechanisms.

**Kay**

Her children had explored ways of making a ball move up a slope but some groups were still investigating materials. She discovered that even after an investigation about waterproofing some children still claimed the one they liked best was the best for making a raincoat.

**Adrian**

Elicited his children's ideas about why things move. They went on to look at things falling.

**Anne**

Discovered some alternative ideas... things fall because they've got air all around, another child thought there was a "string that you can't see". When asked which of two objects will hit the ground first (block and cotton reel) ... the block because it's harder, the reel because it is heavier, together (without an explanation of why).

(Yr 2) If you jump you would go up but you come down again. If
you were in space you might stay up ... If you threw the weight and the block up in space they'd float - there isn't any air up there. What pulls things down? Because of weight - air is lighter than the object so it can't come down but it forces the object down.

(Yr 1) What's gravity - it's outside. If we didn't have it we would float up. It's stuff that holds things down. When the wind blows it doesn't go up, it rolls around. If there is no air in the sky people go up.

(Yr 5) Why do things fall? There is nothing to hold them up ... gravity pulls things down. Will the heavier object hit the ground first? Most thought they would hit together.

... The group then discussed the PSTS elicitation cards in pairs before doing another concept map, this time taking the central idea of movement. The following analysis compares the results of these concept maps with those drawn by the same individuals on day 2 (straight after an input on Newtonian ideas). The 5 examples were chosen at random.

CONCEPT MAPS ON FORCES - DAY 2 AND DAY 4

Key: M - mentioned, U - indicated understanding, S indicated some understanding.

<table>
<thead>
<tr>
<th>IDEA</th>
<th>Frances</th>
<th>Andy</th>
<th>Adrian</th>
<th>Jill</th>
<th>Neil</th>
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<tbody>
<tr>
<td>FORCE</td>
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<tr>
<td>GRAVITY</td>
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<tr>
<td>PRESSURE</td>
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<td>RESISTANCE</td>
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<tr>
<td>NEWTON'S 1</td>
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<td>S</td>
<td>U</td>
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<tr>
<td>NEWTON'S 2</td>
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</tbody>
</table>
The rest of the day followed the pattern of the Wiltshire session although being so close to Xmas the poster on energy transfers were based on a cracker being pulled.
Analysis of Case Study 7

Group: Cohort 2 (LEA Y)

1st analysis: 20.12.90

This case study links with Case Study 6 and the following analysis should be read as an extension of the previous one and does not attempt to repeat points already made.

The nature of the teaching approach

The orientation/elicitation at the start of this cycle involved course members using floor books with their group and this proved successful without the problems that arose during Case Study 6 of unattributed comments (CS6: 85). Several course members started using correct scientific terminology immediately (CS7: 12, 14, 17, 20). Encouragingly this phase also indicated that course members were naturally raising questions and exploring answers in a practical way (CS7: 40).

The importance of orientation and elicitation with children was stressed again during this cycle and an example of a completed floor book, related to forces, used to reinforce the significance of children's existing ideas (CS7: 350). This example also included other elicitation strategies such as brainstorming, word spurs etc.

The school-based activities illustrated the course members implementing activities in this way and one pair provided an excellent and productive example of the use of relatively unstructured use of a collection (CS7: 380). However, tutor comment during the review of this work reminded them that the success of the activity was also due to the nature of their questioning (CS7: 391). This unstructured work with a collection of balls, carried out with infant children, contrasts with a very structure approach with a similar collection used with older children (CS7: 400). The course members involved with this group had set out with a much clearer idea of the investigation they hoped would be tackled. The children were far less responsive and it took a much longer time to reach the desired objective of a 'fair' test.

There was more evidence of constructivist approaches being used in course members' own classrooms during this cycle and it was particularly encouraging to find evidence of successful elicitation with a special class (CS7: 464).

The use of MIST teachers' module (CS7: 86) provided further opportunities for orientation and introduced some simple terminology and the discussion that occurred (not recorded) was useful in terms of elicitation. This was an element of orientation not used with the
Analysis of Case Study 7

other cohort and its use was productive. The overlap between orientation and elicitation, when working with adults, was evident during this session. With adults, and perhaps with children, it would seem that orientation and elicitation can happen simultaneously. This deserves further consideration in the next case studies.

The prioritising activity only took five minutes (CS7: 97) but again seemed to give course members some 'ownership' of the subsequent activities Concern 15.

During the exploration and investigative stages floorbooks proved very successful in providing an ongoing record of ideas, questions and activities. They also proved a practical means of collecting data for this analysis. Course members' control of the books led to the sharing of ideas being less 'threatening' and seemed to provide one strategy to address Concerns 10 and 20.

Concept maps were used immediately after the tutor input and during day 4 (see CS6 analysis, page 146). This provided more useful evidence of the extent of restructuring, which is analysed later, than was obtained during Case Study 6. The use of concept maps does provide evidence of individual ideas and restructuring/retention, but does not help those course members who still feel threatened in exposing their ideas and consequently need to be used in conjunction with other strategies such as the floor books used above. The use of individual 'Think Books' will be explored in the next cycle to see if these prove 'unthreatening' but also provide evidence of the individual's ideas.

Dialogue was used successfully, by the tutor, to move course members towards scientifically acceptable ideas (CS7: 310) as a result of challenging (the use of energy rather than forces) and then supporting more acceptable responses. This contrasts with an example during Case Study 6 when the 'right' answer was given (CS6: 313) in the same situation and then discussed. Generally, the 'expert' view was offered in a slightly less expositional manner with this group and the tutor was able to build upon the experience of the previous cohort and their response to the input, which some stated was 'too advanced'. I attempted to offer accepted ideas in a more tentative mode and encouraged course members to challenge and question the ideas.

The nature of science implicit in the session

Course members were raising a number of scientific questions during the elicitation phase of the work (CS7: 46, 54, 57).

When they were exploring the materials, the pairs were generally
Analysis of Case study 7

successful in identifying questions to investigate and this happened more quickly than with the previous group (Case Study 6). The quality of the subsequent investigations was high in most pairs, although Rick spent some considerable time expressing his dislike for practical work (not recorded) and this affected his work with Adrian (CS7: 122). Further examples of technological problems slowing down and frustrating investigations were found (CS7: 151).

There was some good use of investigative skills (CS7: 101) which included hypothesising as a result of initial tests and then further testing to challenge the hypothesis (in this case that surface area affected the rebound). This involved careful measuring and a quantitative approach to the investigation. Generally, the group engaged in much more quantitative investigations than during Case Study 5 and the control of variables was evident (CS7: 114). This group of three also used graphic means of presenting results effectively (CS7: 119). Another pair, that also carried out a carefully devised investigation were aware of the difficulties they had as a result of not controlling variables (CS7: 250).

The investigation into floating and sinking was another example of an investigation during which the course members involved had clearly documented the process they went through, highlighting their working hypotheses and predictions at each stage (CS7: 154). This was similar, in many ways to the floating and sinking work described in Case Study 6 (CS6: 230) and like that work, also involved appropriate use of a computer simulation as a means of extending the activity. They managed to develop generalised statements (CS7: 200) which they tested and found evidence to support. This work contrasts well with the previous investigation that this pair carried out (CS5: 106) which was far less sophisticated in terms of the scientific processes involved and shows clear evidence of progression in investigative skills. It is also an excellent example of how scientific knowledge and understanding can develop through investigative work. The theme of floating and sinking formed the basis of a first assignment for one of the pair (Frances) in which she documented children's investigations in the same concept area and compared and contrasted the process and the nature of the understanding resulting.

Course members’ knowledge and understanding of science

The initial discussions (CS7: 10,) provides evidence of some understanding of forces as pushes and pulls (CS7: 12, 34), gravity (CS7: 47) and magnetism (CS7: 49). There was no mention of friction during this case study (cf CS6: 53) although it is implicit in Adrian's description of the laboratory trolley (CS7: 70) and less comments about energy, although it is referred to by Anne, Mark and Adrian (CS7: 14, 58, 71). This maybe as a result of a slightly
tighter worded introduction by me, stressing the need to think about the forces involved. Indeed, my comment (CS7: 86) about the use of ‘force’ rather than ‘forcing’ may have been significant in helping to clarify ideas during the investigations. This input was not offered to Cohort 1.

Alternative frameworks held by individuals

Becki’s use of the word state (CS7: 33) implies a misunderstanding of the term and is of concern in terms of the treatment of this during Case Study 5 (CS5: 218). She does not show any awareness of the misuse of the term which can be compared with a similar situation in Case Study 6 (CS6: 28) when Mary corrected her misuse of the term. This could be an example of an adult able to use a scientific term correctly in the limited context in which it was first met but reverting to everyday use of the meaning in other contexts even when a scientific meaning is more appropriate.

Jill held an idea of ‘gravity forcing things down’ (CS7: 64) and Mark talked about ‘gravitational potential energy pushing down’ (CS7: 274). It is interesting that Mark reported his children’s confusion between air and gravity and the implied idea that gravity is the result of air pushing down (CS7: 449). This idea was also reported by Neil as a result of his work on the school-based day (CS7: 409).

When discussing the forces acting on a stone as it moves upwards, all course members appeared to hold an ‘impetus force’ construct ie they all suggested there was a force acting in the direction of movement as well as downwards. This may well be the result of confusion between energy and force. For example, Mark refers in his explanation to ‘kinetic energy’ upwards (CS7: 273) although he described this as ‘stronger pressure upwards’, Debbi to ‘muscular energy upwards’ (CS7: 285), Jill to ‘thrown energy’ (CS7: 301) and Julia, ‘it still has kinetic energy transferred from the person (throwing)’ (CS7: 309). Dave talks about ‘natural’ force upwards (CS7: 278). Anne offered, ‘The force exerted on the stone/marble by you began the upward motion. However, the force of gravity acting on the marble is pulling it downwards’ (CS7: 294), but still chose the option suggesting forces acting in both directions!

The other interesting area of alternative constructs concerned the relationship between gravity and mass. Five of the group, when asked to predict whether a 100g or 20g mass would hit the ground first when dropped, chose the heavier mass.

Consequently there appear to be three key and common alternative ideas evident:

i. A force is always acting in the direction of movement -
Analysis of Case study 7

an 'impetus force'.

ii. Gravity pushes things towards the Earth.

iii. The mass of an object affects the speed at which an object falls to Earth.

Evidence of restructuring of ideas

The consolidation exercise, based on the forces acting on an aeroplane, provided encouraging evidence, that during day 2, all course members had been able to use key terms appropriately (CS7: 338).

The concept maps were analysed and those produced soon after the input (CS7: 330) were basically sound and included no words, links or definitions that caused concern. Those completed on day 4 (CS7: 500) were less extensive and showed some fall off of retention of ideas but were again scientifically acceptable in terms of understanding demonstrated.

There is also evidence of restructuring of ideas in the feedback of work from school and comment on the children's responses. For example, Anne demonstrates she now accepts that different weights will reach the ground at the same time through her comments about her children (CS7: 466).

There was discussion about the extent to which ideas are resistant to change during day 4 and Andy claimed he was unable to challenge his children's ideas about heavy balls hitting the ground first (CS7: 429) even after, what he felt was convincing practical experience. Dave countered this with evidence from his class that children were prepared to modify their ideas in the light of evidence (CS7: 438). Kay's younger children who were still working on 'materials' were reluctant to change their ideas about which fabrics were waterproof and hung on to the one they liked 'best' being the most waterproof (CS7: 460), even after extensive teacher supported testing.

General Concerns/Issues

This cycle was the first to be run without a co-tutor although advisory teacher help was available for the school-based work. This has advantages and disadvantages. It could be particularly problematic if the group had a negative response to the tutor during the early stages. In this case, the relationship established in the first cycle ensured this was not a problem. However, the opportunities for tutors to collaborate, share experiences and discuss issues as they arise make it desirable for there to be another tutor available during at least one of the other sessions.
Analysis of Case study 7

The content difficulties, discussed in Case Study 6 were less significant during this cycle, illustrating perhaps the lessons that had been learnt as a result of the previous forces cycle. I spent less time with terms like 'acceleration', 'speed' and 'velocity' and there were no comments indicating the input had been too advanced. This cohort seem more prepared to deal with content areas in a quantitative way. This raises an important question for discussion at a later stage. Should the approach to developing knowledge and understanding in primary teachers be based on a qualitative approach? Kruger and Summer (in their input to the ASE Meeting at Birmingham, 1991) suggested that it should be. The present work has adopted a more balanced approach in which qualitative and quantitative work has been encouraged. The forces cycle, in particular, does seem suited to quantitative work, and the evidence discussed below suggests the majority of primary teachers on the course find it acceptable. There is also evidence that the quantitative approach used with forces led to further questions that were investigated and led to improved understanding (eg CS7: 212, 220, 232).

This cohort also seem to have less difficulties with accepting the value of science exploration and investigations at their own level. There was another good example of a course member working with the same content area (forces acting on toys) at her own level (CS7: 45), with children on the school-based day (CS7: 372) and with her own class (CS7: 454). This enable her to compare and reflect upon ideas offered in these different contexts.

The question of whether the first two days should be consecutive remains unanswered, since although the evidence of these two cohorts would suggest it is desirable the tutors on the similar course running at Bristol Polytechnic are finding it preferable to have a longer gap between the first two days.

The treatment of energy during this cycle was problematic since day 4 was so close to Christmas and motivation was lacking after Xmas lunch! The overlap between forces and energy in teachers thinking was evident during the first two days and it remains an issue to be resolved before the next course.
Case Study 8: DES 20-day (Cohort 1) Electricity

Group: 14 teachers from LEA X, Tutors: RR, ST

Sessions: Thursday 11th Feb. 9.15am - 4.00pm
          Friday 15.2.91
          Friday 8.3.91

Data Collection: RR field notes
                 Students' think books
                 Students' evaluation notes

Aims for the session 1 & 2:

1. To develop students' background knowledge and understanding of electricity;

2. To provide students' with an example of constructivism in action for adaption in their own teaching

Day 1

9.15 RR (Introduction to 4th cycle. Reviewed previous cycles, mentioned the fact that Forces had been particularly difficult and a little threatening, hoped Electricity would be less so. Explained why electricity - area of concern for primary teachers that is seen as particularly difficult. Stressed need for context in classroom. Mentioned safety issues - referred to Be Safe! Asked course members to maintain an individual 'thought book')

9 ...

9.30 RR Please write down 4 sentences about electricity, individually. Discuss them with a partner and then address the questions on the elicitation card.
             Caroline/Joy, Lorna/Ann, Joy/Chris, Mary B/Ann, Barbara/Gill, James/Philip/Lorna.
             ...
             Outcomes (from Think Books)...

Ann We need electricity for lights to work.
Electricity is made from turning turbines.
A pylon carries electricity.

20 Batteries produce electricity, they store it.
...

Andrea Electricity is dangerous.
Electricity powers many things and is useful.
Most artificial light sources in a house are electric.
There is a relationship in electricity between amps, volts etc. and I don't understand it.
...

Lorna Electricity makes machines and lights work.
Electricity is a form of power which is manufactured from coal, oil, water or nuclear material.
Electricity can be dangerous if safety precautions are not taken.
Electricity can be produced by batteries.
Electricity requires wires to carry it to machines.

James
Electricity makes the lights in my house come on.
My dad says the battery in the car makes electricity which makes the motor go.
Electricity can be dangerous.

40
Electricity can be found in nature.

Phil
We have electricity in our house.
Electricity killed my hamster after it ate through the cable.
I which on the electricity when mum was changing the bulb, she wasn’t pleased.
Our cooker runs on electricity.

Mary
Electricity is a means by which we can heat light and cook in our homes.

50
Electricity is an energy source by which industry is powered.
Electricity is the means by which society progresses.

Caroline
Electricity is the flow of electrons through a conductive material producing a current.
Electricity can produce heat, light, sound and movement.
Electricity relies on a non-conductive material or a break in the circuit to provide an on/off switch.

Joy
Electricity is a very useful source of power.

60
Electricity can come from the mains or from batteries.
Electricity is needed to operate most modern household equipment.
Electricity can come from nuclear, hydroelectric, coal-burning power stations, also wind, waves etc.

Lin
Electricity is a C20 innovation, changed to Electricity is vital to C20 life.
Electricity is a major source of power.
Electricity has revolutionised industry.

70
I rely heavily on electricity in my home and when there’s a power cut I have no lighting or heating and I can’t even make a cup of tea.

Chris
Coal / oil are used for making electricity.
Electricity is dangerous.
We need electricity for heat, light and power - source of energy.
Electricity reaches us in a grid.
Electricity can take effect only if there is a complete circuit.

Electricity is essential to modern life.
Electricity has been in our homes for about 70 years.

What is electricity?

Electricity is a form of energy.
Electricity passes its energy on in movement in 'machinery', household equipment etc.
Electricity produces heat in electric fires when its flow is restricted - resistance.

Electricity is very useful when used correctly but should never be misused ie plugs should be earthed.

Electricity can take effect only if there is a complete circuit. Electricity is essential to modern life. Electricity has been in our homes for about 70 years. What is electricity?

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Objects that use electricity -
All (who answered) listed domestic and industrial uses.

Where does electricity come from?
Source of energy to turn turbines to work generators
National grid, conversion of a power source (listed)
Natural sources (listed) are processed into electricity at a Power station. Static electricity - can that be harnessed?
Ions +ve/-ve (discharges of) created by natural/chemical magnetic lightning.

Source of energy (listed).
Comes from nuclear, hydroelectric etc.
Positive and negative ions in the atmosphere. energy from other sources (listed).
From a national grid. Conversion of one power source (listed) to another via turbines and generators.
Sources (listed)
Batteries, burning coal, HEP, + & - ions in the atmosphere.
Energy from other sources changed into electricity.
Does it travel in waves? How is it changed?

How is electricity made?
Why does a coil in a magnetic field produce electricity?
same question - Will any old winding work? Why do some cars have a +ve earth, others -ve?
In a battery there's a carbon rod and a chemical. There is a flow of electrons between the battery's terminals. Also made in HEP - don't understand steam > drive turbines > Where is electricity?
Batteries have chemicals.
In a battery there's a chemical reaction - it releases something.
Isn't there a difference between natural and manufactured electricity?
Is there a link with magnetism?
In a battery there is a chemical reaction between one rod and the solution surrounding the rods copper sulphate is changed to
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zinc sulphate. Copper particles released carry charge to the copper plate. One plate becomes anode one cathode. Is there a link between magnetism and electricity?

5. What is the difference between electricity from plugs and batteries?
   Ann Plugs have higher voltage. Batteries act as a store but a chemical reaction occurs.
   Andrea Plugs - from the grid, batteries - stored. I don't know how batteries work.
   Lorna One is ac (manufactured) and the other dc (chemical reaction)
   James A/C, D/C what's the difference? Plugs - manufactured, battery - chemical reaction.
   Phil Alternating and direct current.
   Mary High voltage in plugs - batteries act as a store.
   Caroline Electric from plugs is inexhaustible and stronger than batteries (except large ones). A plug is fused for safety and has 3 separate wires. Is one for the flow of electricity to object, one to take it back to the mains and one for safety?
   Joy Plug dangerous, batteries not. Plugs have fuses and three wires, earth, live and neutral. Power from the mains is stronger. Batteries run out of power. Mains inexhaustible supply. Mains runs to earth.
   Chris Electricity from a grid and batteries are stored electricity. Batteries contain acid and plugs don't.
   Gill Difference of voltage.

10.00 RR (Discussion about the need for 'orientation' and time to start talking about the content area - there was general consensus that this was necessary in this content area. RR then asked individuals to draw the inside of a simple torch that he demonstrated.)

160 Features of drawings:
   Batteries properly connected - All
   Bulb draw with one evident connection - All except Lin, Phil, James and Joy
   Bulb with two connections - Only Lin, Phil, James and Joy
   Circuit evident - All except Ann, Gill, Chris, Mary, Lorna, Andrea
   Switch as a break in the circuit - All except Gill, Lin and Lorna

170 Written explanations included:
   Mary B Electricity from the batteries passes into the bulb through one wire, into a very fine coil which controls flow of electricity producing heat/light which is reflected, passes on down the other wire through a strip to switch where circuit can be broken. Does it make any difference which direction the batteries are placed?
When (switch) is pressed on the metal pushes the battery which makes a connection with the bulb (spring pushes up) making a circuit. Off circuit broken.

(RR then asked individuals to light a bulb using a 4.5v battery - all achieved this within a couple of minutes, observe carefully and draw the bulb in detail showing what you think is happening)

..
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Features of drawings:

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<th>AR</th>
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(There was a lengthy discussion about how a bulb lights. Course members added to their 'Think Books' using different colours. All thought electricity travelled around a circuit in one direction. RR introduced common alternative idea of clashing current. Several (see above) had not been able to predict what the connections in the bulb's base must be like. Lin had an idea about there 'being a substance in the base which let the electricity through'. However, once Mary B suggested the correct connections and explained the flow of electricity through the bulb all agreed that was a reasonable explanation.
The heating effect was discussed and resistance was introduced by several course members. Very thin wire (Brillo pads) was tested and the heating effect observed. The question of why the filament doesn't burn was explored. RR broke the glass from a bulb to demonstrate that the filament does burn in some conditions. The idea of inert gas was suggested. RR mentioned that other adults have sometimes suggested there is a vacuum in the bulb. Andrea said she had thought of that but rejected the idea because of what she learnt from the forces cycle about vacuum. She knew the bulb would implode.)

11.00

(After reminding the group how much discussion was possible about one bulb and a battery RR suggested pairs used the 'Challenge Approach to Electricity' to continue their explorations of circuits. Phil and James were by this time working on more sophisticated switches since both felt confident about simple circuit work.
During this part of the session RR worked with pairs, introducing 'short circuits' and different ways of connecting two bulbs. Some pairs decided to use digital ammeters to measure the flow of electricity in different parts of circuits. Phil used ammeters and voltmeters to explore some circuits.)
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The following comments come from analysis of 'Think Books':

Ann
Explored series and parallel circuits using bulbs, bulbs and motor, bulb and buzzer. Noted direction of buzzer and motor significant.

'Needed parallel circuits to make 2 items of different voltage work'.

Used ammeters with RR's help and measured current both sides of a bulb. Repeated using two batteries. Developed simple symbolic system for drawings. Bulb and buzzer in series led to confusion about why bulb 'doesn't seem to work'. Made correct prediction of current in parallel circuit. 'Taking more current when there is a parallel circuit'. 'One item (in series) produces a strong current. Two dilute it.' Explored simple switches in series and parallel circuits.

Andrea
Explorations covered short circuits, 'We added a single wire touching both terminals and produced a short circuit ie bulb went out because electricity opted for shortest/least resisted route around single wire. Very long wire dimmed bulb - resistance through long wire increased but bulb still lit.

After discussions about resistance and measuring current using ammeters -
Bulb - lower resistance > requires higher current
Buzzer - higher resistance > requires lower current.
Circuit will 'read' required current and sent lowest amount therefore circuit with a bulb and buzzer will make a buzzer work and not a bulb.

There is a finite amount of current that can come from a battery. Why does the buzzer only work one way round?

Lorna
Tested various materials for conductivity. First test suggested graphite did not conduct. RR tried it and discussed why some non-metals conduct. Went on to explore circuits culminating in a parallel circuit consisting of 2 bulbs and a buzzer with a switch to operate all three. Then measured current in simple circuit. RR discussed relationship between resistance and current. In response to question about 'volts' used voltmeter to measure emf across 1 and 2 batteries.

'Voltage is pressure with which electricity is pushed around circuit. Amps is amount of current. Resistance comes from lights and buzzers.

James
Explored switches, materials that conduct and went on to make simple electromagnets.

Caroline
Chose to use meters early in her explorations. 'When a bulb is not present in a circuit there is a high (ampage) current. The current is reduced to 0.29 when a bulb is added. Therefore the bulb is a resistor but does not use up all the current. The current either leaving or entering the battery does not change. She correctly predicted changes in current in series circuit. In
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parallel circuit 'there appears to be more power and it's spread almost evenly between the 2 bulbs. Does the bulb use up power? - should resist flow and keep current to light up bulb. Therefore bulb slows down current. 2 bulbs in series slow down current twice rather than just once. This accounts for the difference in readings. Greater resistance equals less current (figures listed).... Voltmeter measures pressure across a battery. Does electricity go to the thing with more resistance. Therefore buzzer works but bulb doesn't? Objects with a low resistance need a higher current to work and therefore bulb doesn't light up but buzzer does'.

Joy Explorations as Caroline.

Lin 'Electrical current is slowed down when wire changes from thicker to thin. The resistance produces heat.' Produced a checklist for when a bulb will not light (correct). Explained short circuits. Explored series and parallel circuits. In the latter, 'each is a complete circuit. If you take one out the others will work. Buzzer only works one way round. Lights in the house must be wired independently (in parallel) otherwise if one blew the others wouldn't work. Problem with Xmas tree lights is that they're in series. If one blows the circuit is broken. In circuit A (parallel) each smaller circuit is getting 4.5v and this results in battery being used up quicker therefore each works. You can short circuit by placing wire across eh bulb terminals/ across battery terminals. In circuit B (series) the bulbs and buzzer share the power and therefore lights don't come on. Simplest circuit is B but most effective circuit is A.'

Went on to use ammeter without help. Connected it the wrong way round and and got readings of +.31 one side of the bulb and -0.31 the other. Concluded the bulb used up 0.62 amps! Also used ammeter to measure 'strength' of battery. Discovered mistake and used a voltmeter to measure emf of 1 and 2 batteries. Used V = I x R to carry out some simple calculations correctly.

Chris Simple circuit exploration - short circuits explained. Tested conductivity including graphite. Measured current in series and parallel circuits. Found bulb didn't work in series with buzzer 'Is it because the voltage is too low?' Tested how many bulbs a battery could light in parallel (6).

3.10pm (RR asked individuals to write down their ideas about how a simple circuit works based on the day's activities and explanations and add evaluation comments about the day if desired)

Mary B Electricity is flowing from the + terminal of the battery to the -ve if connected by a wire. To set up resistance, a bulb is inserted. The electricity flows from the bottom of the bulb up the filament where heat is generated because the fine wire resists the flow. Thus heat energy is converted into light energy and the bulb lights, but the wire doesn't burn because
there is an inert gas within the bulb. The electricity continues to flow down the other pin in the bulb, out through the screw side and back to the battery. The battery contains potentially 4.5V to push electricity around the circuit which decreases as the battery is used. The amount of current depends on the voltage of the battery and the resistance of whatever has been put in the circuit i.e. \( C = \frac{V}{R} \) - less resistance, more current. The electricity is presumably made up of negatively charged electrons (minute particles) flowing along the wires when a circuit is complete. Flow ceases when the circuit is broken.

Gill

The circuit must be complete for the bulb to light up. The battery is the source of power. The voltage in it is gradually used up. The voltage is constant within the circuit at any one time. Voltage can be increased by using more than one battery. What is inside a battery? Acid? What happens inside the battery when the bulb is lit?

A very interesting day - not too high-powered. At the right level, thank you.

Chris

The electricity passes from the battery through the wires to the bulb and along the wire back to the battery making a circuit. The wire, although plastic, is made of metal which conducts electricity along/through it making the bulb light up. If the circuit is broken no electricity will pass through the wires (it is believed that the electricity flows from +ve to -ve). The metal case on the bulb will allow electricity to be conducted allowing the filament to light up (bulb). the higher the resistance the lower the current. Found this out using a buzzer and bulb on a battery.

Thoroughly enjoyed today. the practical experience was invaluable. I did not feel threatened by what was asked of us today. The pace was just right. Thanks.

Lin

(Annotated diagram) Electricity flows along wires +ve to -ve. Battery contains approx 4V potential/stored energy which is only released when a circuit is made. Needs to pass through some resistance ie a bulb in order to measure the current. Acid inside battery produces a chemical reaction - produces direct current.

Inert gas in a bulb won't burn. thin wire filament in a bulb (coiled) completes the circuit - gets hot - produces light - current is slowed down by thinner wire. Metal wire is a good conductor of electricity.

Joy

'Potential' electricity is stored in battery in a chemical form. The battery converts chemical energy to electrical energy. The effort of the electrons moving through the filament and overcoming the resistance results in heat and light. Flow of negatively charged electrons around the closed circuit. they actually move from -ve terminal of battery to +ve. Electrons in
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380 the circuit all move at the same speed. As they move through the filament of the bulb they meet resistance, this resistance affects the flow of current (amps) through the whole circuit.

Caroline Still think the same except that electrons do not go round like water in a pipe. Battery is like a thinking machine and decides whether there is enough power to light a bulb and a buzzer. It tends to work the object with greater resistance and may not work any other object if power isn’t sufficient. Battery sends out a message to see what’s in the circuit before it decides what to do.

Mary None of my work during the day proved how electricity travelled. Would have found it better to have been told about it.

James Volts ‘push’ electricity through the circuit to and from the bulb. Within the bulb there is another circuit which allows the filament (because of shape / material made out of and inert gas surrounding it) to light up without burning up. Amount of current depends on voltage and resistance. Voltage is produced by the battery.

Lorna Electricity is flowing from the positive terminal of the battery to the negative terminal. It has to pass through the bulbholder which is causing resistance - the bulb is lit by the electricity. The electricity flowing towards the bulb is equal to the electricity flowing from the bulb; the current is constant. If a series of bulbs is connected to the battery the electricity flowing to the first bulb would be greater than the electricity flowing from the last. The greater the number of bulbs the greater the resistance.

Ann When a circuit is made a wire has to lead from the +ve terminal and -ve terminal of the battery to the light bulb. The side and end of the bulb has to be in contact with the wires. More amps are used with a bulb as there is less resistance than eg buzzer or motor. Both sides have equal power.

Phil The electricity flows around the circuit taking the path of least resistance. The electrons jiggle about. The bulb contains a piece of more resistant wire that heats up in an inert gas. As it heats it glows. The battery unconnected means that not much activity is going on. Until the circuit is connected allowing the passing of electrons from +ve/-ve to -ve/+ve (jiggling around).

Barbara There is a chemical reaction inside the battery - to do with acids? an electrolyte - electrolysis - produces energy. This energy flows through the wires and round the circuit, but not like water - it is transmitted from particle to particle - from +ve to -ve very rapidly - instantaneously - at the speed of
of bulb/motor etc. when heat/light/movement is created - this resistance seems to act equally in a circuit, not just were it is!

Very useful - very instructive just to be able to fiddle about. Not threatening.

(Day 2 of this cycle had been cancelled due to bad weather. Consequently course members had not had time to plan their work with children, although the age range and pairings had been finalised at the end of Day 1. Transport difficulties meant some did not arrive until 9.15am. RR suggested that the first teaching session (9.45 - 10.30am) be used to elicit the children's ideas about electricity based on the SPACE questions used with them on Day 1. Time left at the end of the first session was to be used to provide free play experience for their group with batteries etc. in order to help them decide how to approach the afternoon session which was to be used to develop the children's ideas about simple circuits.

The pairs and age ranges chosen were (James was absent):

Margaret / Andrea Y1 (Shaun, Sarah, Laura, Mark) Gp. 1
Phil / Lee Y1 (Chaise, Craig, Lucy, Charley) Gp. 2
Barbara / Lorna Y3 (Kevin, Andrew, Victoria, Barry) Gp. 3
Gill / Christine Y3 (Alex, Gemma, Joanne, Rebecca) Gp. 4
Mary b / Lin Y3 (Philip, Matthew, Louise, Becky) Gp. 5
Joy / Caroline Y5 (Andrew, Ireena, Jason, Kirsty) Gp. 6
Mary / Ann Y5 (Steven, Louise, Barry, Kim) Gp. 7

Group 2 went for a walk to look for uses of electricity all the other groups worked in the room available. At the end of the first session each pair analysed their evidence using a standard format and presented their results on large sheets which were displayed for all to see. Before this analysis RR suggested course members think about the origin of some of the children's alternative ideas and also reflect on the extent to which those ideas were a result of the phrasing of their questions. These sheets have been used to provide the evidence below. The sheets were amended after the second session during which most groups worked on the progression offered on day 1. Course members used a variety of methods of recording the children's ideas including word spurs and charts (Group 4). There was also evidence of strategies to facilitate discussion such as the child who wished to contribute handing over a pen to the teacher (Group 1). At the end of the second session RR questioned each child individually to assess their understanding of circuits.

Most pairs operated as observers and teachers during session 1, although most observers became participants at some stage. All
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except 2 pairs were using photocopied data collection sheets. In the second session both partners in some pairs taught and used their notes.)
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Question: What is electricity and what is it used for?

Yr. 1
Shaun  Electric fires, lights, radio, TV
Can see it when near - see the cover - electricity is inside,
500  like blue lightning
Can feel it if you touch it - hurts like fire
You can get lights that don't plug in
Sarah  Makes heat, radiators, makes houses warm
Can smell it when close - warm smell
Can touch it - warm radiators
Laura  Electricity makes things work, lights, cookers, microwaves, heater.
Electricity makes everything work in the whole wide world.
Mark  Radios, cookers, microwaves, lights.
Chaise  Could kill you
Train set and lights, tea urn, alarm system, a clock
Craig  Batteries, fire alarm has a bell inside
Computer, kettle
Lucy  Wet hands dangerous
Computer
Charley  I know I don't know about electricity
Fridge because it's got wires at the back
Torch

Yr. 3
520  Kevin  Powers lights, cooker, gun, remote control and computer game
Andrew  Oven, plugs, hot water in radiator, lights, iron, heater, drill, car
Victoria  Fire alarm, radiators, TV, torch
Barry  Fridge, calculator, fire alarm, lights remote control car
Alex  Put fingers in plug and it will give you a shock
TV
If you put water on a heater and turn it on you get an electric shock
Gemma  Electricity can spark you and you fall down (seen on Home and Away - TV Soap)
It travels around the world in wires .. loads, joined to each other
Joanne  Connected with lights
Die from an electric shock (Home and Away)
Rebecca  Can harm you sometimes
Philip  Radiator, light switch, wire
Matthew  Microwaves, kettle, fire alarm, Ghetto blast
Louise  Lights, radio, door bell
Becky  TV, radio cassette player, cooker
540  It makes things work

Yr. 5

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Andrew
It's stored where you want to use it (in plug / wires)
Also stored in battery
(listed household uses)

Ireena
Electricity is batteries, it's in plugs
(listed household uses)

Jason
Makes lights work - (listed other household uses including freezes)

Kirsty
Dangerous and powerful
Makes electronic things work
Spot light, keyboard

Steven
It's a powerful force. It moves in a current of waves and is
very dangerous.
Comes in light

Louise
(Aware of dangers) If you stuck a stick in a switch it can kill
you. (Relates it to lightning - very unsure of ideas)

Barry
Types of power that runs our house. It flows through pipes
Electricity can kill

Kim
Flows in a circuit of power

560
Helps lights to light up
It is an energy that operates machinery
Can kill you.

Comments

Y1 - obviously aware of domestic uses of electricity but only
Laura mentions its wider uses (perhaps too wide!). 'Alarm' is
offered by two, as a result of looking around the school. Only 2
mentioned the dangers explicitly.

Y3 - again the focus is on domestic uses. Radiators are a
curious feature in 3 responses and the fire alarm features
again. Becky is the only one to generalise - it makes things
work.
Over half refer to the dangers (as a result of a TV programme in
at least 2 cases).

Y5 - Household uses are listed, although only one mentions
making things cold (ie refrigerator or freezer). They are making
more general statements and the idea of it being stored is
evident. Some are using terms like current, circuit and power
reasonably accurately although not necessarily with
understanding. There is more often an attempt to generalise the
uses - it runs our house, makes electronic things work. The
dangers are evident in at least 5 out of 8 responses.
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Question: Where does it come from? How is it made?

Yr.1
Wires into a plug, through wires, through pipes

Shaun
Lightning from the sky, thunder, from the sun because lines of yellow, and bits of sun come down and then the sun grows again

Sarah
Bits of electricity in little tubes

From heat and heat comes from Sun and from God. Comes to Earth because Sun is powerful and shines on Earth. From lightning and thunder. Comes to Earth and traps in special machines. Comes through cracks into our house - in door - push electricity around to make heat inside

600

From sky - wind blows it down

Mark
Special powder from the sky. People go in planes to get it, make a packet for it. Put electric in machines. Shovel it up

(Has he seen the newspaper advertisements showing bags of electricity?)

It comes from big special things - all pipes gas/electric

(describing a local substation)

Wires into plugs

Yr.3

Andrew
In wires, in walls, underneath us and on the ceiling

(It comes from) an electronic place where they make wires and electricity

Lightning comes from clouds in the sky

(It comes from) burn old tyres and plastic bags (saw a TV programme about recycling)

Wires all around

Alex
Underground - seen pipes

621

(It is made by) light-flies with lights on their backs which change into electricity

Gemma
Lightning breaks the light (power cuts)

Joanne
Under your floor - comes up your wall and into your lights.

(It comes from) a special place when they plug it in electricity comes through

(It is made by) the sun lights it down. When its stormy lightning is dangerous

Rebecca
Lightning

Philip
Found in plugs

Comes from one big battery in a building

Matthew
National power - a building gives houses electricity through pipes. Put the power on. Put the plug in the plug holder. Switch on.

(It is made by) sun beams shine on the ground to make heat
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Louise  It is made every time you rub a balloon on your jumper. It sticks to the wall.

Becky  When you plug in electricity comes in. It comes from a company - a building - any building. It is made from Oil or lots of batteries together.

Andrew  Batteries, plugs and sockets .. it is carried by wires
Ireena  Wires .. telephone is from electricity .. batteries, plugs, a tall building
Kirsty  Comes from a box with fence and gate at back of house. Warning picture on it.
Steven  Uranium .. you generate it eg from water, turns wheel to make a small amount of electricity, some goes to houses but some is saved to make more electricity
Barry  A power station. It travels through the air, you can get a shock from a pylon
Kim  It starts underground. From coal? We do something to materials that came from underground. It just starts, needs a force or something to generate it, it makes electricity.

Comments

Yr.5  - ideas about the origins of electricity are very imaginative and draw on a variety of sources. The recent advertising campaign for electricity that illustrates 'bags' of electricity may well have influenced one child. The sky and Sun are seen as the source by several. The one who refers to the yellow lines did have a large wall display in his classroom illustrating the sun's rays as yellow strips. Lightning is also seen as being a source of useful electricity. There seems to be no evidence of them being aware of generation or power stations (except perhaps Mark). For most it is seen as being made 'naturally'.

Y3  - some still hold on to 'natural' generation but more are aware of the role of people in the generation process and special rooms and buildings are suggested. They are also more aware of electricity travelling through wires (and pipes) and going all around the house. Becky's idea of it being made from 'lots of batteries together' is interesting and similar to Philip's idea of the 'big battery'. Louise is the only child of any age to mention static electricity.

Y5  - the 'natural' ideas have disappeared and most are aware that electricity is made somewhere. The ground, or underground now becomes the source for some (perhaps based on limited knowledge of nuclear power - Steven). This class had had a theatre company present a play about 'generating power' a few
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months before and this provided them with some of their vocabulary.
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Questions: Differences between mains and batteries?
How fast does electricity travel?

Yr.1
(Most knew batteries had electricity in them)
Chaise The electricity - the push that goes into the batteries to make the torch light up.
Sarah Batteries have got a bit of electricity in them.. open them up, electricity goes in, seal it and put stops on. Comes from tube in battery out of a crack in the base .. pushes the light through the wire.
700 (Speed varied from very fast to very slow. Sarah thought it slowed down to come to Earth or it might hit people.)

Yr.3
Andrew Only 12v in a battery, thousands in a house
Becky It's a different kind
Otherwise there was little response to this question.
Most though it travelled really fast although Gemma thought it went slowly if it only had a little way to go.)
Becky It goes fast because as soon as you turn it on the electricity is there. It has to come all the way from the building. When you switch off the electricity goes away.

Yr.5
Andrew Pay for mains .. batteries run out .. don't have to switch a battery on .. batteries can leak .. electricity stored in batteries but comes to plugs.
Ireena There's a battery in a plug. Batteries don't have wires. Get a bill with a plug.
Jason A battery is not safe
Kirsty A battery is not as dangerous - no wires - no shock. You can put a battery where you want it - no bill
721
Steven Higher voltage from plugs
(Barry and Kim agreed.
All thought it travelled very fast.)

Comments

The younger ages are aware batteries have electricity in them and that electricity comes from plugs but seem to have little idea of any differences. Most already consider electricity must travel quickly although there are some alternative ideas evident. Two Y3 children articulated a difference but only one referred to voltage.

The Y5 group were able to articulate the differences reasonably well and show evidence that they are aware of the difference.
Case Study 8: DES 20-day (Cohort 1) Electricity

Safety and cost feature regularly. Ireena’s alternative idea about a plug containing a battery (she described a fuse) is unusual.
Case Study 8: DES 20-day (Cohort 1) Electricity

**Question: Which materials will electricity travel through?**

**Yr.1**
- **Shaun**
  - Cooker has metal and plastic - electricity comes into metal
  - To stop electricity put wood on it - make holes for electricity to go in - stays there, gets bigger, goes back where it comes from and blows up.
- **Sarah**
  - Seeps through cracks on the cooker. Can turn cooker off and stop pushing heat around.
- **750**
  - Wire, wood, shoes, socks, carpet - not through chair
  - Electric blanket - pump bits round to make it warm.

**Yr.3**
- **Kevin**
  - Plastic wires (after discussion realised they had metal inside)
- **Victoria**
  - Thick plastic with some air in it and when you switch on air blows the light on.
- **Barry**
  - Thick plastic light straw
- **Philip**
  - Goes through split wire but not through plain wire (this was challenged and tested)
- **760**
  - Others mentioned metals

**Yr.5**
- All said electricity went through metals although Barry said 'some metals'. Kim said 'it sometimes depends how much oxygen there is in the air'.

**Comments**

**Y1** - some are beginning to appreciate that electricity doesn't travel through all things. Alternative ideas are still apparent and this is evidence that plastic covered wires with crocodile clips should be used with caution.

**Y3** - still some confusion evident about plastic wires and one (Victoria) holds very unusual ideas about air in wires.

**Y5** - have established sound ideas about metallic materials although there are exceptions like Kim.
Evidence of ideas about circuits

Yr.1

Group 1 - all managed to light a bulb using a 4.5v battery although none used wires. Lee continued to think electricity was 'magic'. Sarah held on to ideas about it travelling through cracks. She made a bulb light up, could say where it was touching but could not produce an accurate drawing to show this. Her drawing indicated a battery terminal touching the glass.

Laura was the first to light her bulb and say how she had done it. Mark produced an accurate picture of the points of contact but reverted to saying only the base had to touch when questioned at the end of the session. When assessed at the end only Laura and Sarah chose the correctly connected bulb. Mark and Laura both held 'clashing current' ideas. No evidence of this was obtained from the other two.

Group 2 played with torches for several minutes at the end of the first session and this provided some fascinating insights into their ideas. Chaise tried to switch off a torch by pressing the outer insulating cover which he had removed and was holding in a different hand from the torch. They all removed and replaced batteries in a torch and observed the bulb.

An interesting comment was made by Chaise at the beginning of the second session, 'We don't do any science because we're too young' - Didn't you do some this morning? 'No'. By the end of the second session this group had managed to light a bulb using wires and knew where to touch the bulb. Craig and Chaise both produced accurate drawing during the second session showing their working circuits. Lucy suggested the terminals were 'the power'. All correctly identified the picture showing the right connections at the end. They all used the terms battery, bulb and wires. Chaise and Craig had sound ideas about flow around a circuit, the other two held 'clashing current' ideas.

Yr.3

Group 3 managed to light bulbs and used wires and bulbholders to make simple circuits. Barry and Victoria found it very hard to connect the bulb initially and needed help. Most started by trying to connect the bulb with one wire. Andrew said the wire was covered 'to stop the electricity from going all over the place'. He also said 'wires have to be connected to a power source'. Kevin and Victoria needed help when using a bulbholder. These two also found it hard to draw a circuit. Victoria was easily able to correct her mistakes after she was questioned. Kevin needed much more help as his original diagram showed wires that didn't touch the bulb. By the end all were assessed to
understand electricity travelled through metallic objects. None used the word circuit until it was introduced but all understood the need for an unbroken route. They all correctly chose the picture of a bulb. They all expressed ideas about 'clashing currents'.

Group 4 all lit bulbs and went on to use wires and bulbholders. At the end all identified the correct picture. Joanna and Rebecca held acceptable ideas about circuit flow. The other two held ideas about 'clashing currents'. Alex remained convinced about this even after individual work with a buzzer and motor. All understood a circuit could not be broken and still work.

Group 5 included two children (Philip and Mathew) who initially chose a wrong picture at the end although both corrected themselves on being questioned about how they had successfully made the bulb work. Matthew and Becky immediately chose the correct picture. All four held 'clashing current' ideas which had not been challenged during the teaching session.

Yr.5

Group 6

Andrew  Knew about a complete circuit being needed during morning session. By the end of the second session he could apply ideas learnt about +ve and -ve and how to connect a bulb. He was using the word circuit and knew metals conducted electricity.

Ireena  Draw a complete circuit in the morning and knew about placing the wires on the bulb. She was unable to apply ideas about +ve and -ve to a different battery. She knew electricity went round and used the word circuit accurately. She knew electricity came up battery terminals. She thought silver foil was not a metal. Thought electricity was 'in the middle of a battery and is going both ways'.

Jason  Initially thought the wires needed to touch the sides of a bulb and held on to that idea even when he made a bulb work. Eventually he learnt that wires on the black insulating part of the bulb wouldn't work. Knew that anything metal would conduct.

Kirsty  Had no idea of how to connect a bulb and needed help after several minutes perseverance. Blamed the equipment. In the afternoon she got the bulb to light through luck - she still didn't understand where to put the wires on the bulb. Talked about electricity travelling through the metal terminals. Produced poor diagrams. Knew volts were the power in a battery and found out electricity could be stopped by putting wax on a bulb. ... When assessed at the end Kirsty and Jason failed to select the correct drawing of a working circuit but both had sound ideas about flow around a circuit. Andrew and Ireema chose the correct circuit but others held ideas about 'clashing current'.
**Case Study 8: DES 20-day (Cohort 1) Electricity**

**Group 7**

**Steven**

Drew a torch and knew batteries have to be connected and the bulb has to touch but is unsure how to connect it. His drawing was accurate and showed a complete circuit and switch. 'When the torch is switched on a metal plate is pushed down. At the bottom a spring is pushed and pushes against the first battery. After the first battery is touched it travels higher. So each battery connects together. So the last battery touches another metal plate, that touches the bulb and makes it shine. In the second session he drew a detailed diagram of a bulb. Decided the uprights must connect to side and base (clearly shown) but also drew arrows showing 'clashing currents'. After discussion about buzzers he said, 'it might matter with different things'.

**Louise**

Initial drawing shows little understanding although her comments included ideas about electricity flowing from the battery to the bulb and her drawing shows two wires to the bulb. Her attempts after practical work in the second session were more accurate. Her drawing of a bulb has interesting annotations, 'the electricity come from the bottom of the bulb and the side of the battery', 'the electricity it go all over the body, up the wires and up the two metal wires (in the bulb?) and wire over the top'.

**Barry**

Drew a good diagram of a torch at the start showing a complete circuit. The bulb connections are a little unclear (although two connections seem apparent) but the description of the switch is sound, 'I think a little bit of metal is joined to the switch. when you flick the switch a little bit of metal joins two bits of wire together so the power can get through'. His drawing of a bulb did not show a prediction of what is in the base. He expressed his views about flow on these terms, 'electricity has to go up two separate ways. One up the side, one up the middle, it clashes in the middle so lights up'. However, later in a discussion he said, 'It goes up one side and down the other. It can travel either way'. He held on to this view when assessed at the end.

**Kim**

Not sure of a complete circuit initially although her torch drawing shows some evidence of a circuit. Her comments clearly indicate she knows electricity travels from the battery to a bulb through wires but makes no mention of returning to the battery. Had an idea about energy, 'the light burns off energy inside the batteries'. Her drawing of a bulb does show a prediction about inside the base. She shows two wires going to the base. She shows 'clashing currents' arrows which appear to have been erased and replaced by flow around the circuit, 'the wires have always got electricity running through it to keep it (the bulb) lit'. She used a buzzer and concluded, 'If something needs a live and dead wire it only goes one way'.

...
Case Study 8: DES 20-day (Cohort 1) Electricity

All four chose the correct circuit and only one (Kim) retained ideas about 'clashing currents'. The other three held accepted ideas about flow around a circuit.
Case Study 8: DES 20-day (Cohort 1) Electricity

Analysis of assessments of ideas about bulb connections

<table>
<thead>
<tr>
<th></th>
<th>One wire</th>
<th>Correct connections</th>
<th>Short circuit</th>
<th>Wires to side of bulb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>1</td>
<td>6</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Y3</td>
<td>-</td>
<td>11</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Y5</td>
<td>-</td>
<td>6</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
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<td>1</td>
<td>23</td>
<td>2</td>
<td>2</td>
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</tbody>
</table>

Analysis of assessments of ideas about the flow of electricity

<table>
<thead>
<tr>
<th></th>
<th>Clashing currents</th>
<th>Empty wire</th>
<th>Correct flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>2</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Y3</td>
<td>10</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Y5</td>
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<td>-</td>
<td>5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>15</td>
<td>-</td>
<td>9</td>
</tr>
</tbody>
</table>

Comments

Y1 - initially there was evidence of very unusual ideas, perhaps linked to their imaginative ideas about where electricity comes from. Some tried to connect wires to the glass part of a bulb and Chaise's notion of a switch is interesting (and amusing!). All eventually managed to light a bulb but only one group progressed in the time available to use wires in their circuits. Most, by the end could identify the correct circuit but they had little to offer about the flow of electricity around the circuit. The free play with torches and the ensuing discussion does seem to have been beneficial to group 2. Drawing circuits was difficult since most lacked the skills to work in fine detail and the possibility of using larger bulbs and batteries is worth consideration.

Y3 - ideas about circuits are becoming more acceptable although they all needed practical experience to realise that two connections were necessary. Alternative ideas (like Andrew's) about how electricity travels are still evident. Bulbholders were introduced to this age and they caused some problems. One or two
had obviously not had enough time with the bare bulb since they tried to connect the wires to the plastic part of the holder. By the end of the day all were assessed to understand the need for a complete circuit. However, notions of 'clashing currents' dominated their thinking about flow and this needs challenging. One or two pairs tried to challenge these ideas unsuccessfully and the best way of doing this needs further consideration.

Y5 - most started the day with sounder ideas about circuits and the need for an uninterrupted path. These ideas were refined during the sessions, particularly in terms of the connections to a bulb. The term circuit was introduced by the children and used confidently. The practical experience was essential to help them understand the connections to a bulb and it was disappointing that 2 were unable to choose the correct diagram in the summative assessment. Some were beginning to be aware of 'voltage' but their is little evidence of acceptable understanding. Even those children who can use all the 'right' words (eg Steven) still held alternative ideas about circuits and his drawing of the bulb showed he firmly held the idea that electricity met in the bulb. However, the older children's ideas appeared to be more readily changed and by the end there were far less advocates of 'clashing currents' than with the younger age group. Only one Y5 child introduced the word 'energy'. The same child held a very unusual idea about 'dead wires'.

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Other notes:

Some questioning techniques during elicitation period were closed or leading -

Barbara - What happens if we smash the alarm glass? What sort of electric vehicle might you see every day? B1 - A tractor? No I was thinking of a milk float. No, that wasn’t what I was thinking of!

Very reassuring questioning from Margaret and Joy.

Lorna demonstrated how to light a bulb. Two children in her group were eventually successful several minutes later and seem to have ignored this - they were surprised and very pleased by their own success.

Chris was very worried about not being able to deal with alternative ideas about 'clashing currents'.

Lorna asked about whether electricity is stored in power stations. She had visited two and assumed it was but the children's questions had caused her to rethink her own ideas. This was discussed with her.

There was evidence that the pacing and techniques used on day 1 (eg drawing torch, looking at a bulb carefully, not using bulbholders) were influencing the way course members worked with children.

Several commented that they had already elicited their own children's ideas about electricity after day 1.

Andrea and Margaret were keen to use bigger bulbs and batteries to help the Y1 children see the point of connection more clearly.

Mary identified the alternative idea of one child concerning 'clashing' and conventional current flow. She though he saw components having differing affects eg a buzzer requires directional flow, a bulb requires 'clashing currents'. One of her group also though the material might affect the direction and flow of electricity.
Day 4 8.3.91 am RR, pm RR/ST

Because day 2 was cancelled due to snow the plans for day 4 were revised to accommodate an input on the scientist's view of electricity.

9.15 Review of school-based day and discussion of children's ideas elicited from own classes - reference to tutor analysis of school-based data, which was circulated (CS8, 450-1000), and the SPACE findings concerning electricity.

RR outlined Ohm's law, used the water analogy (see CS9: 27) and discussed electricity in terms of electron movement.

10.15 Choice of activity - reading/browsing at resources, articles available; further exploration of circuits/magnetism; discussion of school-based data and RR's analysis; use of computer simulation (Shell). Ann, Mary E and Chris spent considerable time using the latter successfully.

11.30 Video (Ashley, Victoria park I) to illustrate time and careful questioning necessary to elicit children's ideas.

1070 Further discussion of school-based work on electricity. This included the significance of children's experiences outside school which influence their scientific ideas.

The afternoon followed the same pattern as case study 9 (CS9: 447) and the majority of course members' heads joined them to explore follow-up work to disseminate the course to other staff. The comments from the heads about the impact of the course to date were all positive.
Group: Cohort 1 - 14 teachers from LEA X

1st analysis: 16.3.91

This case study covers similar content (electricity) to Case Studies 1, 2 & 3. However, the structure of the DES course meant more time was available to cover the topic. In the event the second day of the cycle was cancelled due to the weather and the original plans were modified at short notice. The first day covered an introduction to simple circuits. The school-based day involved a systematic attempt to look for progression in children's ideas about electricity and simple circuits. The final day included the 'scientist's view' of electricity. The afternoon of this day was used to plan ways of supporting colleagues in school and involved the participation of course members' headteachers.

The nature of the teaching approach

The orientation opportunities during day 1 were structured as elicitation and explicit use was made of questions used during the SPACE project (CS8: 94). The same questions were also used with children during the school-based day (CS8: 450). This was intended to reinforce the similarity between the approach used with them as adults and the approach they could use with children. It was also a more explicit attempt than previously used to develop their own knowledge and understanding about electricity through consideration of the ideas (acceptable and alternative) of children in the same content area (Concern 14). This was achieved during day 4 by offering the group my analysis of the children's ideas (CS8: 564, 660, 726, 770) for consideration and discussion, particularly about the nature and origin of ideas about 'clashing flow'.

Returning to the nature of orientation offered, the course members had prior warning of the cycles content. However, it was evident from informal conversations during the first part of the day, when they were all asked to write some sentences about electricity (CS8: 10), that some needed this informal discussion to focus their thinking on electricity. Some admitted that they had "not really thought about electricity before" and the time to orientate themselves was necessary. However, the way the session was structured provided this opportunity for those who needed it. This aspect of the approach was discussed with the group (CS8: 155) and there was agreement that the time for informal discussions as part of the first exercise had been valued. This supports my view after Case Studies 1, 2 & 3 about the emphasis to be placed on orientation (Concern 1). Adults make time for themselves within the structure offered as long as it is flexible enough to allow this. Children need to be encouraged to orientate to new content through specific scene-setting activities and free-play. There is evidence that this
Analysis of Case Study 8

is recognised by course members and on day 3 one pair started the session with a walk to set the scene for their group (CS8: 473). Others reported, on day 4, that work with children in their own class had started with freeplay activities with simple circuit equipment or torches.

Elicitation was tackled in a structured way through several means, all of which were recorded in individual 'Think Books': initial ideas (write down four sentences about electricity (CS8: 19); paired discussion and individual notes based on SPACE questions (Which things use electricity?, Where does electricity come from?, How is electricity made?, What is the difference between mains electricity and electricity from batteries?) (CS8: 94); individual drawings of a torch (CS8: 158) and a bulb (CS8: 181). Each of these exercises provided valuable evidence of existing ideas that I was able to use in a formative way to make decisions about interactions with individuals, pairs and the whole group. For example, the drawings of the torch highlighted confusion about connections to the bulb which provided a suitable starting point for discussion and exploration (CS8: 181). The 'think books' proved to be practical and useful for several reasons (Concern 3). They were not found threatening by course members (CS8: 362, 435), they were easy for individuals to maintain, they provided a record of an individual's ideas (CS8: 235) and were useful as a record for the individual course member to refer back to and for me as tutor to assess. The 'think books' were maintained throughout the cycle and proved particularly useful during the investigative work that was done during the first day. As well as looking at the books during the day, as I joined a pair for discussion, I also collected them in at the end of the day to check for any alternative ideas that needed to be dealt with. The 'think books' were used in a similar way to floorbooks but seemed more suitable for adult users and offer potential for use with older children (Key Stage 2). I had explored their use with student groups in a variety of content areas (electricity, light and materials) and found them valuable as a source of evidence of existing, developing and applied ideas. This successful elicitation strategy contrasts with the use of elicitation sheets during Case Study 3 which were found more threatening and provided no more information than that obtained during this session.

During the elicitation phase course members immediately began using scientific terms (CS8: 101) and informally discussing their meanings as they had done in Case Studies 6 & 7. The ethos of the group was now established in such a way as to require clarification of terms used in everyday language.

It was also encouraging to see so many questions listed in 'think books' from this phase (CS8: 100, 112, 113, 114, 115 etc.). Not all were suited to scientific investigation but the number raised was
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higher than in previous cycles. It may be a result of the structured approach to elicitation, to the developing recognition of the importance of questions in science or to the nature of the content. The latter seems least likely, particularly since the student groups (Case Studies 1, 2 & 3) covering the same content did not raise as many (Concern 17).

As noted, the drawings of the inside of a torch provided further elicitation of existing ideas and useful evidence in a practical and easily analysed form (CS8: 161, 189). The annotations and explanations that course members were encouraged to add were particularly valuable (CS8: 172).

The importance of elicitation with children was emphasised again throughout the cycle and particularly on day 4 when a video was used to illustrate the time needed to probe a child's understanding in order to gain a meaningful insight into their ideas. The video shows a 6 year old being questioned about circuits. For the first ten minutes the answers given are consistent with a sound understanding of simple circuits. However, the child then reveals a major alternative framework underpinning all of his previous answers. This provided a stimulus for discussion about the importance of spending time clarifying the nature of children's existing ideas (CS8: 1068).

The elicitation phase developed naturally into the tutor intensive stage of the session when the majority of the group worked together discussing and exploring the workings of a bulb and a simple circuit (CS8: 202). This followed a similar pattern to that used during case studies 1, 2 & 3 and although every attempt was made to follow student-initiated lines of development the nature of the subject meant a fairly predictable route was taken. During this part of the day students ideas were constantly elicited and challenged and wherever possible this was done through practical explorations (CS8: 212, 214). This phase involved some sharing of a 'scientist's view' eg about the flow of electricity around a circuit to confirm their ideas. This provided a contrasting form of tutor input to the exposition evident in earlier cycles and was intended to illustrate the an approach to exposition that may be more appropriate in a classroom context (Concern 19). The integration of the 'scientist's view' at this stage provided a different perspective on the timing of this within a cycle (Concern 16) although it was always intended that the more significant exposition would occur on day 2 (see Case Study 9).

After this structured introduction pairs were invited to pursue their own explorations and investigations (CS8: 228). The tutor role at this stage involved working with pairs and extending their work through discussing and challenging their ideas. Several pairs opted to use digital ammeters and voltmeters that were available (CS8:
The individual pairs were required to make decisions about their particular activities to ensure they retained ownership (Concern 15). However, I did question two pairs about whether it was appropriate to move to a quantitative approach at this stage and encouraged them to explore circuits in a more qualitative way. Those that had successfully constructed a variety of simple circuits found the quantitative approach helpful. They began to appreciate the relationship between current and resistance (CS8: 256) and that the flow either side of a component is the same (CS8: 280). This avoided any possible confusion with regard to attenuation which I had met with student groups. The particular problem of a bulb and buzzer in series led to numerous discussions (CS8: 243) about possible explanations and eventual understanding of the link between resistance and current. There were a few instances where misuse of the meters led to alternative ideas (CS8: 310). The adoption of a quantitative approach is related to Concern 21.

The structure of this session provided opportunities for those pairs who wished to explore materials and equipment in an unstructured manner to do so (eg CS8: 263). This addressed Concern 13. The direction of the work was less tutor-dominated than Case Studies 1, 2 & 3 and the pacing was less frantic and appreciated by course members (CS8: 363).

The cancellation of day 2, and the need to include day 2 material on day 4, meant that the activities planned to encourage the application of ideas (see Case Study 9) were not possible.

Course members were, however, offered the opportunity to use a computer simulation of circuits (Shell) and this option was taken up by several, including one who had previously found the simulation on floating and sinking useful. On this occasion, with adults, the program proved valuable and encouraged further practical investigations with real equipment. It led to the application of ideas developed on day 1 in terms of predicting the current and voltage in various circuits.

The tutor exposition on day 4 occurred after day 2 of Case Study 9. This allowed me to draw on the experience of observing another colleague (CS9: 26) offering the 'scientist's view'. This was particularly helpful since he used a water analogy which allowed me to reflect on Concern 12. When I used the same analogy with this group I was explicit about why I was using it, the advantages and the disadvantages and the implications of using models, analogies and metaphors with children.

This cycle required me to address differentiation more explicitly than on previous ones. There were some course members who felt confident about this content area (CS8: 225) and they were provided
Analysis of Case Study 8

with more challenging activities at the stage when I worked intensively with the rest. I had asked the group to indicate who considered that they were confident of their understanding at the beginning of the day and suggested that it would be appropriate for them to work through the elicitation activities. This provided me with evidence to assess their understanding and needs (CS8: 165) and I negotiated with them the area they would like to develop. This led to a variety of work (CS8: 274) but interestingly they chose not to explore a quantitative approach. Other pairs worked at their own pace and level and this provided further opportunities for differentiation through tutor intervention.

The Nature of Science

As with other cycles this provided evidence, through the approach used, of the importance attached to practical activities and this was valued by most and evaluative comments support this (CS8: 361). One course member retained the desire to be told the 'right answer' (CS8: 352) and regarded practical work as unhelpful. This was a view she had expressed in previous cycles and provided evidence of the extent to which individuals retain their own individual constructs (in this case about the nature of learning in science).

The importance of the links between process and content have been explicit throughout as has the importance of talk and discussion as part of a constructivist approach. During this cycle this was reinforced explicitly during day 1 (CS8: 222) and during the school-based day (CS8: 487). The structuring of the work, in pairs, and the group discussions provided more evidence for course members of the significance the tutors attached to the social construction of ideas.

The nature of the content covered in this cycle meant that there were less opportunities to raise more philosophical issues about the nature of scientific process and, in particular, the status of generalisations they may formulate. During the tutor input on day 4 the tentative nature of 'scientists' ideas' was stressed and the origins of the 'conventional' direction of the flow of electricity was discussed to illustrate the fallibility of scientists.

Course members' knowledge and understanding of science

The initial elicitation highlighted some lacked knowledge about the need for complete circuits and the connections in a torch, especially to the bulb (CS8: 163). At this stage only 4 (out of 16) linked the heating effect to the working of a bulb (CS8: 200). Surprisingly, compared to previous adult groups, there were no alternative ideas about 'clashing flow' (CS8: 204). The use of meters also seemed to avoid alternative ideas about attenuation.
from developing or being expressed. The notes made during day 1, by course members, and at the end of the day indicated most had sound ideas about simple circuits and some were developing an acceptable understanding of the relationship between current and resistance (and in some cases, voltage) (CS8: 257, 314). By the end of day 1 most had understood the importance of the heating effect (eg CS8: 328). There is also evidence that an earlier concern, resulting from work with student groups, that I may have fostered misunderstandings about the flow of electricity in a broken circuit, had not occurred with this group. They clearly understood that no electricity flows (even to the break) in an incomplete circuit (CS8: 340, 354, 366, 420).

Alternative ideas

This is less evidence of this group holding ideas that do not correspond to the accepted scientific explanation than with previous adult groups (eg Case Studies 1, 2 & 3). Therefore it was less difficult (Concern 11) to deal with all those that were exposed. Analysis of the explanations offered at the end of the first day indicated a couple of concerns. Caroline, whose earlier contributions and explanations (CS8: 53, 117, 276) had been sound (apart from the idea of the 'bulb slows down current' (CS8: 285)) ends the day with an explanation about the battery being a 'thinking machine' that 'sends out a message to see what's in the circuit before it decides what to do'. This attempt to explain the relationship between current and resistance was discussed with her in some detail on day 4. Lorna's explanation contains a contradiction with regard to ideas about attenuation. She states the current is constant both sides of a bulb (CS8: 407) but then explains a series circuit in terms that suggest she thinks the 'current gets used up' (CS8: 409). This was the only example found of a course member, at this stage, illustrating alternative ideas with regard to attenuation.

The children, on the school-based day, provided course members with a wealth of alternative ideas to reflect upon (eg CS8: 660). These included a large number who held ideas about 'clashing flows' (CS8: 785, 950). Course members were encouraged to think about the origin of these alternative ideas and think about the extent to which a teacher's question or use of language might foster or instigate an alternative idea (CS8: 480). This produced valuable discussion and some concern about how some ideas, such as 'clashing flows' could be challenged through practical activities.

Overall, I felt confident that this case study provided evidence of improved practice on my part in the teaching of electricity. It is the first time in the enquiry when I was able to make a direct comparison between a B.Ed. student session and an INSET session. In
terms of aims and content covered they are very similar. However, in terms of tutor role I consider I was able to give the teachers more control over their learning and the development of activities than I did the earlier student groups. In part this was due to the longer time available, but more significantly I felt more confident and more secure in my understanding of the teaching approach I was using. The reflection that had taken place over the last eighteen months had helped me construct a better understanding of the 'constructivist' approach I was using.
Study 9: DES 20-day (Cohort 2) Electricity

Group: 14 teachers from LEA Y, Tutors: RR, DC (1.3.91 am)

Sessions: Thursday 28.2.91 9.15am - 4.00pm
Friday 1.3.91
Thursday 7.3.91 Primary School F
Thursday 21.3.91

Data Collection: RR field notes
Students' think books
Students' evaluation notes

Aims for the session 1 & 2:

1. To develop students' background knowledge and understanding of electricity;

2. To provide students' with an example of constructivism in action for adaption in their own teaching

At the start of day 1, three course members (Andy, David and Mark) decided to work independently of the rest of the group since they felt reasonably confident about circuits. After a discussion about flow of current in series and parallel circuits they decide to explore the quantitative aspects of circuits and used ammeters, voltmeters and a computer simulation to explore and investigate their ideas. In the afternoon, they used a control box with Contact and developed a programme for a pedestrian crossing.

Neil and Rick were also confident about simple circuits and after the first structured session they went on to explore generating a current by reversing the action of an electric motor.

Other pairs followed the Challenge Approach and all investigated conductivity, short circuits, series and parallel circuits and switches. Several pairs used ammeters in their simple circuits. Caroline and Kay made a working torch.

The day was relatively unstructured after the first hour and a half (concentrating on elicitation and the workings of a bulb). At the end of the afternoon they were asked to note down what they now knew about electricity.

On day 2, DC introduced accepted scientific ideas about electricity using a water analogy (40 minutes), worked with a group of 6 KS 2 teachers on simple electronics (for 20 minutes) and then answered questions about the nature of electricity and
referred to particulate nature of materials and electron flow.
The rest of the morning of day 2 was taken up by reading time,
informal discussions and further explorations / investigations.

The afternoon consisted of an input on children’s ideas about
electricity (RR) during which a video (Ashley at Victoria Park
I) and a transcript of children talking about toys was used to
illustrate alternative frameworks etc. They then formed new
pairs (in response to a request) and planned the school-based
work using the structure presented (elicitation based on SPACE),
free play and introduction to simple circuits. Frances explained
that the Y5 class we were using had done some work on circuits
recently.

Notes from Think Books:

Barbara (end of day 1) Electricity goes round in a circuit. The higher
resistance encountered the lower the current needed, which is
why the buzzer worked but not the bulb when joined together in
the same circuit (series). Using parallel circuits both worked
because the total current from both circuits gave enough power
to work the bulb too. Bulbs work by wires taking electricity
round and heating up the filament, but it doesn’t burn because
inside (the) glass is inert gas. Connect to battery on side and
bottom, not both tips on battery touching bottom.

Jill (end of day 1) Electricity flows when a circuit is complete, the
amount of current in the circuit is the same going into the
battery and coming out. Two bulbs in series will work. If a bulb
and buzzer are in series the buzzer will work but the bulb will
not. The buzzer has higher resistance and therefore a lower
current is needed to make it work. The bulb has a lower
resistance and therefore a higher current is needed. If a short
circuit is introduced to a circuit containing a bulb more
electricity will flow through the short circuit because there is
less resistance and therefore the bulb will go out although
there is still electricity going through it. If the circuit is
broken there is no electricity present at all.

(day 2 referring to electromagnetic investigation) By turning
the nail, the needle in the compass changed direction showing
the flow of electricity was in one direction.

Trish (end of day 1) I understand how a bulb works. that electricity
flows in a circuit. Two bulbs will work in series and in
parallel but a buzzer and bulb will not work in series because
the buzzer has higher resistance.

Debbi (end of day 1) Electrical energy is made by transferring
movement energy eg wave power etc. Mains electricity is of a higher voltage and therefore dangerous whereas batteries are much lower. I understand about the structure of a bulb and about high and low resistance - high means it is harder for the electricity to flow through. I know how to use an amp meter and I can explain why buzzers and bulbs in series work/not work. I know what electricity is, up to a point. I can use more complicated switch systems eg traffic light systems.

(day 2) DC’s analogy put yesterday’s series/parallel circuit in context. It does concern me that although I understand it now, I won’t in a year’s time unless I use it. It’s like this with children - it makes a nonsense of SATs. Having read (the Usborne book) I have now sussed why a bulb lights (as opposed to how - like yesterday) - electrons bumping into (the) wire’s atoms.

What is it about the Earth that causes the magnetic effect?

Frances
(end of day 1) Electricity flows in one direction. The more things in a circuit the lower the current needed. Some things have greater resistance than others. I now understand how a bulb actually lights up.

Pauline
(end of day 1) Electricity generated by the battery flows from the positive side in one direction and if the circuit is complete continues to flow round. I have experimented with parallel circuits and circuits in series. I realise now that I didn’t understand fully how a light bulb works, but do now.

Kay
(end of day 1) (I have learnt) The workings of a bulb - I have unlearnt that there is a vacuum in a bulb. I understand why a bulb works now and that there is not a wire in the green blob!

This morning I had no concept of - or never thought about before - ‘how a torch works’ and this afternoon I made one. I am beginning to understand the difference between current/resistance - although I doubt I could explain my understanding in a coherent manner. I fully understand about switches - we’ve had a good day.

Julia
(end of day 1) I now have a better understanding of a ‘short circuit’. I had assumed that if the light/buzzer etc. wasn’t working then there was no current passing through. I now realise that there is electricity passing through but not sufficient to make the bulb/buzzer etc. work. I can appreciate a short circuit is a drain on resources.

Neil
(start of day 1) Electricity is the flow of electrons through the particles of conductive materials.
(end of day 1) Electricity can be generated in a dry cell or by
a generator. It flows in a circuit from +ve to -ve poles, the current flows along the circuit (electrons). A bulb placed in th
130 circuit has a filament, which causes resistance and consequently glows. (diagram showing constriction in a tube and labelled high and low pressure). Devices which give a high resistance only take a low current. Things which have a low resistance cause a high current to flow. You can have a series or parallel circuit (illustrated).

Anne 
140 (end of day 1) The light bulb - I found this so useful as I certainly hadn't really looked at a light bulb closely before and had never thought about how it functions. I valued the morning session and felt I was keeping up and reaching some level of understanding of electricity actually flowing. However, the exploration and work done on series and parallel circuits wasn't so clear once we introduced switches.

Caroline 
150 (end of day 1) I have had my view changed about a light bulb being a vacuum. I think now that there is a gas inside the bulb which stops the wire from burning. I understand that electricity flows around in a circle and does not come into conflict from both sides of the battery. I didn't know that it was resistance that made the bulb light up. Although I'm not 100% sure of how and I couldn't explain it to anyone else. I'm glad I know how a torch works and I'm pleased with myself.
**Study 9: DES 20-day (Cohort 2) Electricity**

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Initial sentences about electricity

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### Ideas about sources

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### Differences between mains electricity and batteries

| Chemicals | *    | *    | *    | *    |      |      |      |       |      |      |          |
| Safety    | *    | *    | *    | *    |      |      |      |       |      |      |          |

230 Kay added 'energy travels to a plug but is stored in a battery' 'Power in a plug is decided you are in control with batteries'. Caroline said batteries 'have a limited amount'.

How switches work

All included the idea of a 'broken circuit' apart from Anne who suggested it 'stems flow'.
Study 9: DES 20-day (Cohort 2) Electricity

Drawings of a torch

240
Barb Jill Tris Deb Fran Paul Kay Julia Neil Anne Caroline

Batteries * * * * * * * * *
properly connected
Bulb - * * * * * * *
1 connection
Bulb - * * *
2 connections
Circuit * * * * * *
250
Switch * * (*) * * * (*) (*) (*) (*) *
(not clear)
Inside bulb *

Julia's drawing showed components not linked.

Drawings of bulb after observations

280
Barb Jill Tris Deb Fran Paul Kay Julia Neil Anne Caroline

Filament * * * * * * * * * *
Wires in base (*) * (*) * * * * *
correct (changed)
Green * * * * * * * * *
insulator
Base * * * * * * * *
insulator
Gas (*) v air v v v v
(v - vacuum)
Clashing *
 currents

Rick (no book available) also held a 'clashing currents' idea.
Caroline had 'been told it was a vacuum in college'. Kay said 'I
know it is a vacuum'. Kay was also convinced (as a result of
initial observations that there was a wire through the green
insulator.

280

Day 3

This day took a similar format to Day 3 on CS 8.

Y1 Kay and Caroline

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Study 9: DES 20-day (Cohort 2) Electricity

Julia and Debbi
Anne and Barbara

290 Y3 Dave and Jill
Rick and Pauline
Y5 Mark and Andy
Frances and Neil

The following comments, based on observations and analysis sheets completed by the course members, are intended to extend, challenge or support the detailed evidence of children's ideas in CS 8.

In CS 8, Y1 groups - ideas about where electricity comes from were similar to CS 8 ('Jesus' and 'it's floating up in the air' were two examples). They had considerable difficulty manipulating simple equipment.
The bulb was thought to 'have real fire inside'. Their drawings rarely showed connections in the circuits.
Safety was mentioned by 2 (of 12) and one talked about this in terms of acid in a battery.

When asked about how it is made, one said, 'the machine makes an invisible thing that goes down the wire'.
'Electricity is stored safely in the bulb'.
When playing several wrapped wires around the bulb and battery or pushed the wires into the holes on bulbholders.

All of Caroline's group were able to light the bulb in the morning session using wires but this seemed to have been forgotten over dinner. One thought one battery 'prong was hotter than the other'.

One child who said very little made the most sophisticated circuits - light, buzzer and light in parallel.
Julia found herself with two 'defeatists' and found it very frustrating - the session was unsatisfactory for her. The children couldn't get past the idea of 2 connections and didn't seem to appreciate the significance of the metal part of the wire. They needed more freeplay without teacher attention. Julia wondered, 'How could they ever cope without being told?'
Barbara also had a 'frustrated' child who kept saying, 'I don't know how to do this'

Her group also had great difficulties making working circuits and need 'sensitive and gentle pointers' from the teacher before they could construct circuits.
'Electricity comes from rubbish, there are wires and these wires in the rubbish all join together', '50p pieces', 'the fuse in the plug makes it work', 'batteries in the wall', 'it comes from stones rubbed together'.

There ideas about safety were influenced by a TV detective series which had recently featured an electrocution via a metal gate. 'There is a force field of electricity around a power station'. 'It is made by coal, burnt in fires, electricity is stored in a big pump to be used by houses'.

'Power is sucked through both prongs (of a battery), more comes up the bigger one'.

'Inside the bulb the wires produce electricity'.

'The plastic is thick and fat so the electricity can't get through. The metal is thin and allows electricity to pass through.'

(describing bulb) 'The two pieces of wire go down to the bottom past the green stuff into the silver plate thing. I think that one goes to the side and one goes to the bottom.'

One thought there was light in a battery and when challenged to think about batteries used in a Walkman she said they were different kinds of batteries.

One group had no problems lighting a bulb using just the battery in the morning but in the afternoon, when required to use wires, they had more difficulty and they tried to do it with one wire. One wound the wire around the bulb and connected it to the bottom in an attempt to make connections to side and base. Only one had the idea of a circuit (and used the term).

'Battery acid goes up the wires into the bulb'.

Two thought there was switch inside the battery which was turned on when the bulb was moved.

... Y5/6 - Electricity 'comes from the Sun', from 'lightning', 'a dynamo' and 'through the air in special waves'

'Generated from dams - the water comes down and hits a wall or something that has wires behind it'.

One produced (unprompted) a drawing showing the correct connections inside a bulb.

The children were very 'unforthcoming' during the elicitation phase. Andy - 'We only got through 4 questions - did they think it was an exam? They didn't want to share ideas, they kept looking at each other.'

Assessment of bulb connections and flow around a circuit was made by each pair at the end of the afternoon session:

One wire Correct Both to side Both to bottom Clashing Correct

Y1 1 7 1 1 5 3

(one said all would light and another said none would)
Day 4

Review of work in course members' classroom - majority had been able to implement some activities related to electricity.

(Reception/Y1 class had had free play activities) One thought fire was coming out of the battery, another that the power was coming from God. Some thought there were wires inside batteries or other batteries. Most of the older children (Y1) when questioned about the flow of electricity, held clashing current ideas. The children were good at helping each other, especially if one got stuck. They were encouraged to draw their circuits but these did not show connections.

Her Y1 children were convinced they needed to wedge the bulb under the contacts to make it work properly. Again, clashing current ideas were common. She didn't have any buzzers to use as challenging evidence. She didn't know what to do about these ideas.

She also discovered several who thought electricity travelled along telephone wires.

They had talked about wet hands being dangerous and she wanted to know why this was so.

He had a child firmly holding on to a 'cross-over' idea about currents and this was influencing other children. The problem of short-circuits (not identified by the children) was proving frustrating for some of his Y5 children. Some of his children were talking about 'volts'. They were saying, 'the volts in a battery were less powerful than those in the mains' and that, 'more volts kill'. They raised safety concerns but knew very little about where electricity comes from. He found the success of the work depended on group composition.

RR asked them to:

1. Write a list of checks to make if a simple circuit failed to work.
2. Suggest a list of symbols to use for drawing diagrams of circuits.
3. Draw and then make simple circuits using AND and OR logic for switches.
4. Draw a circuit for a hall lighting system.
5. Draw a circuit with a switch for reversing the direction of a motor.
6. Design and make a display case for a chocolate egg (provided) from which the egg could not be stolen without setting off an
alarm.

All completed 1, 2 and 3 successfully although 3 was seen as very difficult by several until they tried. Debbi needed encouragement to tackle this.

None tackled 4 and 5 as 6 was more motivating.

440 At the end of the morning RR had 3 minutes to steal each egg. Several alarms were set off! Kay, Dave and Caroline had worked together on a sophisticated design and Neil worked alone on a 'floating' design. There was evidence of collaborative work amongst groups in order to 'beat' the burgler!

2.00pm The course members' heads (12 of them) joined the group. RR went through principles that underpinned course - constructivism, process/content links, collaborative work, assessment - and outlined the purposes of this phase of the course in terms of dissemination.

Heads and course members (in separate groups) then set aims for this phase. These were generally common to both groups although the heads included work with parents and governors. These lists were compared and discussed before strategies for meeting these were explored in mixed groups (Heads and course members).

The afternoon concluded with individual heads and course members discussing specific action plans for their schools. These were briefly shared in a plenary discussion.
Study 9: DES 20-day (Cohort 2) Electricity

Notes:

Have I fostered alternative ideas about short-circuits with previous groups ie still some current through through the bulb?

Dealing with individual needs - assessment - subgroup - differential task / questions / application (day 4) RS/NB

Vacuum ideas commonly held (5) cf CS 1 and 2 - was it socially constructed on this occasion?

Only two (Neil and Frances) made explicit links with magnetism during elicitation.

Only two (Julie and Anne) included 'energy' in initial sentences. Another two referred to electrons and particles at this stage.

Neil used electron explanation at start, one other mentioned particles.

Debbi thought mains was dangerous because the electricity travels faster.

Frances and Debbi talked about 'latent electricity'.

Dangers evident in sentences.

4 referred to static electricity and 1 to lightning.

9 referred to energy transfers.

Mains electricity is faster.

Fewer (5) included circuits in their torch drawings cf CS 8.

only 3 showed 2 connections to bulb

Good prediction of connections in base.

Pauline and Rick held 'clashing currents' ideas.

Rick thought green insulator in a bulb was 'a resistor to restrict flow to the filament' or 'to stop vibration'.

Very positive reaction to expert view - evidence of correct timing.

Use of video valuable - stressed the need for extensive probing.
Study 9: DES 20-day (Cohort 2) Electricity

Explicit links with SPACE - some criticisms of questions.

Fairly accurate use of current / resistance / parallel / series at end of day 1.

Need to internalise ideas evident in Debbi and Caroline's comments. Day 4 comments about input - it was good at time but I'm not sure how much I remember because I haven't used ideas (Julia)

Restructuring - Julia re short-circuits

Anne - very positive evaluation of looking closely at a bulb - identified concern about going too far too quickly - this came up in day 4 discussions and was extended to cover issues of continuity.
Analysis of Case Study 9

Group: Cohort 1 - 16 teachers from LEA Y

1st analysis: 24.3.91

This case study covers similar content (electricity) to Case Studies 1.2.3 and 8. This analysis should be read as an extension of the analysis of Case Study 8 and it does not attempt to repeat points made there although there is further evidence to support points made in that case study. This case study covers a full 4-day electricity cycle, rather than the shortened 3-day covered by Case Study 8. Therefore the pattern of this cycle follows the planned sequence. Day 2 of this preceded Day 4 of Case Study 8 and allowed me to draw on the experience of the Cohort 1 when offering the scientist’s view of electricity to the Cohort 2 (Case Study 9).

The nature of the teaching approach

Differentiation, due to some course members having more experience than others was required and the approach to this cohort was slightly different. Three course members identified themselves as the outset as feeling confident enough to tackle different activities to the rest (CS9: 1) and I assessed their knowledge and understanding through discussion (CS9: 4) as the rest of the group tackled elicitation activities similar to those used during Case Study 8 (CS8: 10). It was evident that they understood the basics of simple circuits but needed to clarify their understanding of the differences between current, voltage and resistance. I therefore suggested that they immediately use the digital meters to explore and investigate flow in a circuit and recommended that they use a computer simulation (Shell) to make predictions and confirm their ideas. This they did during the first part of the morning.

On day 2, the visiting tutor provided further opportunities for differentiated work. On this occasion the content covered was simple electronics and most of the Key Stage 2 teachers joined him. This included the 5 who opted for differentiated work on day 1.

During the elicitation activities and structured session on the workings of a bulb, I identified another pair whose understanding was sound (CS9: 11) and I suggested they tackle a different area of particular interest and they chose to explore the generation of a current (CS9: 13). I supported their work on an individual basis and did not draw they into large group discussion during the morning. It is noteworthy that all those who were confident in this area and had previous experience were men (in fact the other group that worked systematically through simple circuits with me were all women).

The orientation opportunities during day 1 were identical to those
used in Case Study 9 and the outcomes were again informative and were used in a formative way to structure the particular activities and discussions.

Think books were used again and based on my experience with the previous cohort felt no need to change my approach to these and the evidence they provided both throughout the day and at the end of the day was valuable (CS9: 47). The Think books were collected at the end of day 1 and assessed to highlight any areas of particular concern, or alternative ideas that needed addressing on the second day.

The case study provided further evidence on day 1 (not documented) of the need for orientation for some course members and the initial activities provided opportunities for informal discussion about the nature of electricity and electric circuits which contributed to the cycle proving to be unthreatening, even though the content was found difficult and novel by many (see end of course evaluation analysis).

The 'scientist's view' was offered informally on day 1 (as during Case Study 8) and explicitly on day 2 of the cycle (in contrast with Case Study 8, but following the pattern used on previous cycles). The day 2 input drew heavily on a water analogy (CS9: 26). This was found helpful by course members (CS9: 88) (Concern 12). DC's approach to the input was relaxed and well-received. He covered the content in a quantitative, as well as qualitative, manner. He responded positively to questions asked and course members were made to feel their ideas and suggestions were valued. He was explicit about the content being difficult but dealt with the ideas in a reassuring way, allowing course members to question and clarify their ideas at each stage of the exposition. There was no evidence at the time or in evaluation comments that any course members found this input, or the cycle generally, as threatening (Concern 20).

The reasons for offering a scientist's view were outlined by me at the start of this session in order to avoid any confusion about the way in which the ideas and approach used with them as adults might be adopted in the classroom. It was made clear that the input was at an adult level, dealing with ideas that were not appropriate, in this form, for use with primary aged children and stressing the link between the input and the previous practical work (Concern 19). This case study provided evidence that the timing of the input on day 2 is appropriate (Concern 16). The group were able to draw on this during their school-based work on day 3 and in their own classes. This was not possible for Cohort 1 (Case Study 8) who were, due to circumstances outside tutor control, offered the input on day 4 (CS8: 1050).

The morning of day 1 and the latter part of the morning of day 2
provided opportunities for student-initiated and directed activities and this part of the cycle was even more unstructured and less tutor-dominated than the same session in Case Study 8. This is evidence of my growing confidence to allow course members to pursue exploration and investigations at their own pace and in their own ways (Concern 13 & 15).

This case study involved an explicit activities (CS9: 421) that required application of ideas from day 1. The initial activities (fault check list, suggested symbols for circuit diagrams and circuit diagrams) were all successfully completed (CS9: 434) providing evidence of understanding of simple circuits and switches. Another, more open-ended problem solving activity was contextualised as an 'Easter Egg Alarm' and was extremely motivating (CS9: 438) as well as providing evidence that all of the group could wire up circuits that included a variety of switches, some of which were quite sophisticated (CS9: 443). This case study provides sound evidence of Concern 6 being addressed.

Course members' knowledge and understanding of science

The initial elicitation highlighted that the existing knowledge course members had was generally less than that of the Cohort 1 (Case Study 8). Only 5 included circuits in their torch drawings (CS9: 240) and only 3 showed two connections to the bulb in a torch.

In the initial sentences 4 referred to static electricity and 1 to lightning. None of the Cohort 1 teachers included either. Both cohorts included mention of the dangers frequently. A large number of Cohort 2 teachers (9) included 'energy transfers' in their sentences which indicates a retention of ideas about energy from cycle 2 (Case Study 7). Only two course members included any mention of electrons and particles at the beginning of the day (CS9: 126, 173), or the heating effect (CS9: 163). One made explicit links between electricity and magnetism at the elicitation stage (CS9: 191).

During the session on the workings of a bulb the predictions made about the connections inside a bulb were generally better than Cohort 1 (75% correct as opposed to 50% correct).

By the end of the first day, in common with the other cohort, some were developing an acceptable understanding of the relationship between current and resistance (and in some cases, voltage) (CS9: 46, 57). By the end of day 1 most had understood the importance of the heating effect (eg CS9: 52). Again, there is also evidence that an earlier concern, resulting from work with student groups, that I may have fostered misunderstandings about the flow of electricity in a broken circuit, had not occurred with this group. They clearly
understood that no electricity flows (even to the break) in an incomplete circuit (eg CS9: 67)

**Alternative ideas**

There were two course members who held ideas about clashing flow (CS9: 272, 274). One of these, Rick, also held a novel idea about the green insulator in a bulb. He thought this might be 'a resistor to restrict flow to the filament' (not documented). The idea that a bulb contains a vacuum, which was a common alternative idea amongst students, was held by 5 (CS9: 269). Caroline had been told it was a vacuum in college (CS9: 274) and was supported by others (CS9: 274). However, I was left wondering the extent to which this idea is socially constructed, the drawing were done individually, but conversations were influencing the ideas used in these.

Another idea that deserved probing concerned 'latent electricity' which was mentioned by Frances and Debbi in their initial sentences.

The school-based day (eg CS9: 334, 361), discussion of the SPACE findings and follow-up work in their own classrooms (CS9: 394, 395, 410) provided course members with a variety of alternative ideas to reflect upon. The school-based day exposed a large number of children who held ideas about 'clashing flow' (10 out of 24) and this alternative idea was also evident in their own classes (CS9: 397, 402). It was one which they found difficult to challenge (CS9: 405).

**Evidence of Restructuring**

The evidence collected at the end of day 1 and during day 4 indicated course members ideas about simple circuits had been clarified (CS9: 107) and in some cases extensively restructured. For example, Julia comments on her own restructured ideas about short circuits (CS9: 119). However, she made a perceptive comment on day 4 about the need to internalise and use new ideas, "I'm not sure how much I'll remember if I don't have to use them".

Most of the explanatory notes made at the end of day 1 include evidence of sound ideas about current and resistance (eg CS9: 130)

Notes at the end of day 1 (CS9: 108) and informal discussions during day 4 indicated none of those who thought a bulb contained a vacuum had retained that idea. The two who had started with ideas about 'clashing flow' explained their alarm circuits in terms of accepted ideas about current flow.

**General concerns**
Analysis of Case Study 9

Although the case study provided evidence that course members did not any longer feel threatened by a constructivist approach there is evidence that, in at least one case, they have worked with children who might feel threatened by the approach (CS9: 371). However, the root of this problem is more likely related to the elicitation questions (based on the SPACE materials) or to the fact that the children did not know the teacher. Several criticised the specific questions, even though they were encouraged to word them in appropriate ways to make them relevant for the children they were working with.

The latter may also be the reason for the problems experienced by Julia (CS9: 322). The need for exploratory play was stressed before the school-based session but this is still something that needs to be emphasised. The feedback of work from course members' own classrooms indicated this was happening in most cases (CS9: 393) although it was more likely with younger children.
Case Study 10: DES 20-day Interviews (Cohort 2)

Interviewee: Caroline (Cohort 2)

Sessions: Monday 15.7.91 (in school)

Data Collection: R R field notes
                 Tape
                 Students’ outcomes

Interview Questions

1. You said the constructivist approach has been valuable - how has it affected your teaching?

Let’s look at some areas of science covered on the course -

2. Can you explain to me what happens to the ice cubes left in the bottom of a glass out in the sun all day?

3. Can you explain how a paraffin lamp works?

4. Can you tell me what forces are acting on a tennis ball -
   a. when it is hit
   b. when it crosses over the net
   c. when it rolls to a stop?

5. Can you link the following words -
   gravity - mass - weight - acceleration - force?

6. Can you draw a torch showing the necessary connections to make it work?

7. Can you explain what is happening when a simple circuit is connected to make a bulb light up?

8. Are you aware of any alternative scientific ideas you held which were changed as a result of the course?

1 RR On your evaluation form you said that the constructivist approach has been valuable to you. In what ways has it affected your teaching?

   C I think before I would have done an approach where more I would have given the children a work card and been quite prescriptive whereas now whenever I’m doing a new scientific concept I always start by doing (sic) where the children are and starting from their ideas. Usually I use a floorbook and the children do this now on their own ... brainstorm and write down each others comments. So I always try to find out exactly where the children are and then the ideas that come out of that we use to develop into investigations on their own ... using their ideas.
Case Study 10: DES 20-day Interviews (Cohort 2)

RR Can you give me a specific example of this from your recent work?

C Say when we were doing 'Sea shore' work with boats ... they had a collection of materials that could be used for making boats. We had a floorbook and the children sorted the materials and then said which would be the best material (for a boat) and why. What did the material have to be to be good for a boat? Then they had to devise their own tests and did it and came back and found that they had to re-evaluate what they said because some had said the cardboard would be best and not the foil. They went away and tested again with another test and they eventually came out with a result which they then used to ... when they made the boats they looked back on what they had done.

RR What do you see as the biggest problems in using a constructivist approach?

C First of all, it was getting the children used to it ... getting them so that they didn't mind me writing down what they said and also getting them out of the idea that they didn't always have to write something down in their books. They always wanted to write something! I'm lucky in this classroom 'cos the children are calm usually but I can see within other classrooms within the school they would have a problem with the classroom organisation and actually being able to work with a group for that length of time without any disruptions. We do Highscope and so they (the children) are used to the teacher settling with one group.

RR Can we now look at some of the areas of science we covered on the course.... Can you explain what happens if I put some ice cubes outside all day in the sun.

C They melt ... because ... the heat in ... from the sun aggravates the particles in the ice and so they move around more so they make more space and it melts into a liquid. I think.

RR What if it stays there longer?

C It will evaporate ... ... I don't know ... they would turn into a vapour ... well if you heat something further it turns into vapour or steam so I suppose it does that, but you can't see it can you ... not on the playground.

RR What is happening to the particles?

C They are spreading out even further ... when they are solid they are more close together ... they are moving more.

RR You know paraffin lamps where you have a container with paraffin and you light a wick. Can you explain how they work?

C The paraffin would soak up the wick slowly and you light the wick ... it is something to do with ... it's not the liquid paraffin that burns, I don't think, its the smell of the paraffin ... it gives off a vapour. Because if it was just the paraffin, the wick would burn really quickly and it doesn't.

RR Can you explain this in terms of particles?
Case Study 10: DES 20-day Interviews (Cohort 2)

C  ... The ... it turns from a liquid into a gas I suppose .. when it is heated up ... it gives off smoke or carbon or whatever it is ... it is like the ice cubes .. the particles in the liquid paraffin are aggregated by the heat and in some way that makes them change their form .. from a liquid into a gas ... RR You mean the particles themselves change in some way? C Yes, I suppose they must. RR How? C I suppose they move around more. RR So it is not dissimilar to the way a candle burns. What I am trying to do is to see to what extent you have retained and can apply ideas you met on the course. To move on to Forces. Think about a tennis ball. I want you to think about the forces acting at the moment it is hit, as it passes over the net and when it rolls to a stop. (outcome drawn as it was explained) C When you hit it .. gravity is pulling it down, the force from the person hitting it forward, there is some sort of drag acting the other way and force acting on it from above... pressure 'cos everything has pressure on it. The person's force would be the biggest, drag would be quite big and gravity. When it goes over the net .. still gravity, still the force from the person or it wouldn't still be moving would it? There is still some drag ... what it is moving through pushes against it and maybe a very small bit pushing down on it. The ball itself is keeping itself moving in some way . some spin in it. When it rolls to a stop there is gravity and friction from the surface it is rolling on and there is still a force from the person. RR Do you remember the question on the course about the forces on a stone, thrown up, as it travels up? What forces were acting? C Gravity, something pushing down and the force from the person who throw it up. RR Will you link these words - gravity, mass, weight, acceleration and force in a simple concept map (written outcome produced). C Force and acceleration are linked .. the amount of force determines the acceleration ... gravity is linked with acceleration because gravity is always .. present so therefore it affects the acceleration .. it is always pulling it down .. the weight affects the acceleration and is linked with the force. If it were heavier you would have to give it .. if it was lighter you would have to give it more force if you wanted it to go further .. than if it was heavier. So if you had a light ball and a heavy ball and you wanted them to go the same distance you would have to give the light ball more force than the heavy one. RR If you are throwing them or dropping them? C If you are throwing them .. and if you are dropping them... no
Case Study 10: DES 20-day Interviews (Cohort 2)

maybe not if you are dropping them.

RR What is the link between mass and weight?

C The mass is the ... the weight is how heavy something is and that can change ... or is it the mass? The weight is something that can change but the mass can’t. If you had something on the moon .. a weight and a feather the weight is different but the mass is still the same...

RR What is heaviness?

C Gravity.. you can link weight to gravity.. if there is no gravity there is no weight. Weight of an object can vary according to conditions, mass stays the same...

RR Can we go back to electricity - can you draw a torch showing how it works.

C (Draws torch case, reflector, batteries - correctly aligned, a switch - showing on and off and connections for on, a connection between battery and switch, switch explained), bulb connected at base to battery and side to switch - confirmed by a question)

RR If I draw that as a simple diagram, can you explain to me what is happening when the bulb lights up.

C The electricity is coming out of one end of the battery, going in the bulb, through the filament and going round in a circle. The filament is heating up and producing some heat which produces the light... the metal is heating up and the particles are becoming aggregated but they can’t go anywhere so they heat up and create light... they can’t change their form.

RR Is anything getting used up?

C The battery .. the power inside.

RR One of the things we talked about was the current going around the circuit and we measured it. If I measured the current here and here (pointing to both sides of the battery on the circuit diagram) will the readings be different or the same?

C They will be the same .. if you measured them at the same time, but if you left the battery on and came back in half an hour they would both be less.

RR Are you aware of any idea you had when you came on the course that have changed?

C I thought the bulb was a vacuum ... when I came I didn’t have any clue about the particle theory .. I only did Biology and I failed that! I understand that solids are particles packed tightly, in a liquid they are not so tightly packed and in a gas they just more freely around. They are affected by heat. Forces .. no.

RR explained alternative idea about force acting in the direction of movement.

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Case Study 10: DES 20-day Interviews (Cohort 2)

Group: Frances (Cohort 2)

Sessions: Monday 18.11.91 (in school)

Data Collection: RR field notes
Tape
Students’ outcomes

RR On your evaluation form you said that the constructivist approach has been valuable to you. In what ways has it affected your teaching?
F I give children more time now to work on their own ideas. For example recently a boy was making a robot and wanted to make the eyes light up. He made a circuit and asked how to make a switch. I gave him some ideas and let him go and explore them and sort out his own.
...
The class is doing some work on senses, linked to a radio programme. They have being devising their own tests for finding the most sensitive parts of their hands.

RR Have you used floorbooks, concept maps or other ways of recording children’s ideas.
F The children have journals and they write down things as they go along but I haven’t used floorbooks or concept maps.

RR Let’s think about some of the ideas from the course. Can you explain to me what happens when ice cubes are left out on a sunny day?
F You want it (explained) with molecules?
RR If you like.
F As it (the ice) warms up molecules move around faster and take up more space.... causes heat ... temperature to rise. The ice cubes get warmer ... the temperature from outside helps it (the ice) to melt. It changes from a solid to a liquid.

RR What happens when this occurs?
F I don't know .... as it evaporates particles disappear into the air ... they don't disappear.

RR What are the particles like in a solid?
F They’re close, in a liquid they’re further apart. As it melts they spread out more... their activity gets frenzied and eventually the particles go off into the air.
...

RR Can you explain how a paraffin lamp works (draws one)?
F I never seen one.

RR What about a candle?
F You light the wick and the wick burns, then the wax melts and the wax burns.

RR Is the liquid wax burning?
F No the solid wax burns and gives off liquid .. it changes it to a liquid form... Initially we thought the wick burnt but then we
observed the wax burning.

RR What are the forces acting on the tennis ball (draws three positions)?
F There is always a force from above, gravity (arrow from above pointing down) and one from below ... there is always an equal and opposite force. The first ball has a force from the hit (shown as arrow in direction of movement). The ball over the net has a force from air resistance (shown pointing towards the ball against direction of movement) and no other forces. The ball rolling has friction acting (shown correctly) and its own momentum as it rolls.

RR Can you link any of these words?
F Gravity is a force, force affects acceleration, mass affects acceleration, gravity affects weight. I get mass and weight mixed up ... mass is measuring weight as well (ie same units).

RR Can you draw what inside this torch to make it work?
F (drawing shows complete circuit and correct connections to the bulb)

RR What's happening when it works?
F Electricity comes .. flows out one end, goes into the bulb, up one filament, heats up the coiled wire, causes it to glow and then passes right around, through the battery in a circle.

RR If we measured the flow what would we find?
F The current is the same all round .. but the ability of the battery to make electricity is being used up ... heat energy is forming light energy ... it comes from electrical energy.

RR You did quite a lot of work on floating in one cycle can you explain to me how a block of wood floats?
F There is pressure from below. If the weight of the block is less than the pressure of the water it will float. It is the uplift in water that causes things to float. Gravity is pushing down from above. The density (of the block) affects whether it floats or not... two objects can have the same weight but one that is denser might sink... its also affected by how salty the water is .. it (salt) makes the water heavier .. denser, so objects would float.

RR How has the course affected you?
F It made me more aware of what I think and what I don't know. I know I need to check my notes or look things up ... I wouldn't have thought of doing that before (the course).
Case Study 10: DES 20-day Interviews

Group: Ann (Cohort 1)
Sessions: Tuesday 19.11.91

Data Collection: RR field notes
Tape
Students' outcomes

RR Can you give me some examples of from what you have done recently that has been affected by the course?
A I use floorbooks .. throughout the schools we're using them all the time. This term I've been doing a topic on the Post Office so we been designing our own airmail envelopes and that started by finding out what the children knew about the weights of papers .. so they tested the papers an devise their own envelope. There was a competition to see who could make the lightest one. They had to be a certain size, that was the fair test. I think the fair testing was the crucial thing I learnt on the course. I don't think we've got that quite right in school yet but we keep on talking about it. Saying its got to start from reception so that when they get to juniors they will understand what the concept is. It takes a long time, longer than a year..

I don't presume I know what children think any more. One child surprised me with the papers because she insisted the tin foil was lightest. She devised a test (I asked them to find out without weighing) .. she dropped different papers, I think, and the tin foil hit the ground first but she still insisted it was lightest, due to its silvery colour. I don't ignore what they say anymore ..I take more note of their petty reasons and question them .. get them to explain more .. why .. the course had lots of effect .. I've been on lots of courses and that was the best, there was a lot of days, a lot on input , I liked doing something at my own level.

RR Can you explain what happens to ice on a sunny day?
A They melt in the heat .. the volume stays the same but they change into something different .. the ice .. solid changes into liquid.

RR Can you explain what that change involves?
A Um .. the temperature of the ice starts getting warmer, consequently the matter changes from ice to water.

RR What is matter?
A I remember particles .. solid matter is where particles don't move as quickly... liquid matter .. gas .. the spaces between the particles is far bigger.. the particles are split up, there is the same amount but there is more space between them ...

RR How do they get more space?
A There is air inbetween them?
RR What does heating do to the particles?
Case Study 10: DES 20-day Interviews (Cohort 1)

A: Makes them move quicker ... if you carry on heating (the water) it would turn into a gas ... therefore they (the particles) would bounce more, move quicker with bigger gaps ... less confined.

... I would not have been able to say that before the course.

RR: Can you explain a paraffin lamp?

A: Paraffin is sucked up the wick ... combustion doesn't happen until ... flame needs oxygen ... when the liquid meets the flame. The flame starts burning the wick first ... and then it carries on burning because the paraffin is drawn up the wick.

RR: What burns?

A: It is the gas coming off at the top ... it changes ... liquid to gas ... it is the gas that burns ... there is a gap at the top of the wick ... the gas particles are moving quicker.

RR: Tell me about the forces on this tennis ball (drawn).

A: Gravity is acting on them all (shown correctly) ... its pulling the ball down. The first one has a force of the raquet (shown correctly)... The second one has a force from the side (shown correctly). It's going through the air. There is a force from the movement of the raquet, the initial thrust, otherwise it wouldn't go over the net (shown in direction of ball)... as it rolls to a rest, you've got forces of the ground ... friction (shown correctly) ... I was a bit hazy about this ... what about the pressure of the atmosphere, that would be very slight (shown upwards on all of them).

RR: Can you link these words.

A: Weight and mass ... mass is the shape of the thing ... weight with gravity ... without gravity you can't weigh anything, you would be weightless. You need a force to produce acceleration. Velocity is the actual speed of something ... you need a force to produce a speed. I don't want to link weight and mass ... on the moon your weight varies ... the mass ... the amount of force put on a mass to make an acceleration will ... the amount of mass will depend on the amount of force needed to accelerate.

RR: Can you draw the insides of a torch.

A: (drawing did not show circuit) ... the main thing is the bulb ... this is ridiculous, I've done this with the children ... you've got your batteries ... that, the terminal must hit, it doesn't have to hit the end but it has got to touch somewhere ... either side ... or the end ... you can get the bulb to light up without touching the end of it ... usually I think the terminals are ... positive ... you have a switch ... which stops the contact between the bulb and the power.

RR: Is the other end of the battery connected to anything?

A: Usually there is a spring which fixes it in, it doesn't have to be ...

This is the crucial bit here (the bulb). You need to make a
circuit.. the electricity goes around the bulb. (drawing shows wires to both sides of the bulb) .. the current can go either way. The current is the power from the battery .. this (the filament) is a piece of wire that heats up at a low temperature and causes light .. you don't have to have it (the connections) either side of the bulb, you could have it both on one side. As long as you wires are touching both terminals (of your battery).

.. I've done this with children, and I remember they all thought you had to touch the end bit! We did just finding out where.

RR  That can't work .. (pointing to incorrect bulb connections)
A  Can't it, I remember giving them this apparatus just to light up the bulb .. I remember all this .. but I'm not getting it right .. the children did light up the bulb and work out how to do it ..there's a classic example of where I'm not very knowledgeable but I'm doing it with the children .. they are way ahead of me .. they made switches from all sorts of things. One made a good one with a spoon... I need a lot more play, one day is not enough for me... I need to do a lot more work.
Case Study 10: DES 20-day Interviews (Cohort 2)

Group: Kay (Cohort 2)

Sessions: Friday 6.12.91

Data Collection: RR field notes

380 Tape

Students' outcomes

RR On your evaluation form you said that the constructivist approach has been valuable to you. In what ways has it affected your teaching?

K I use it to an extent, for example with this work on electricity [points to displays, including children's elicited ideas about what electricity is, Xmas cards including working lights and a record chart showing which children can make circuits, tell others about them etc.]. I .. let the children go so far on their own and then I intervene. I let them experiment more on their own than I would have done before I went on the course, but I don't use it (constructivist approach) totally because I (find) I haven't got the time to deal with all the children in this way.

RR What about the extent to which you elicit children's ideas [pointing to the wall display]?

K It depends on the subject area, but yes I am and in other subjects not just science ... the poster is a development of a floorbook. I gave the children a battery, I didn't say anything and wrote down in a floorbook what they said about it. They described it and in each group one knew it was a battery and then we talked about what it was for. Once they had mentioned light, we went on to make a bulb work. They tried to make the bulb work and were all successful. We looked at the bulb and which bit lights up, what was inside ... I did it with a group of 8.

RR Are there times when you use the children's ideas for activities and challenge them?

K The ideas on the poster are memos for me to expand later on. I knew where I wanted them to go .. looking at making a circuit and they all did. The ideas are for future development and for me to see whether they have changed their minds.

RR Have you used floor books on other occasions.

K Recently we went out on an Autumn walk. We collected leaves and brought them back and the ideas they had about them went in the floorbook.

RR Do you put the floorbooks on display?

K No, not really, I've used them for me not the children. They become scrappy and I sometimes rewrite it for the classroom, on the wall.
Can you draw a torch?

K [draws bulb and 2 batteries, switch and no connections] .. I've completely forgotten all this you know!...

There's a connection to the switch some how ..........

RR Try and connect these [draws 4.5v battery and bulb].

K Wire comes from one to the base and one (from the otherside) to the side of the bulb [draws correct connections].

RR What happens when the bulb lights up?

K Electricity is generated and it goes .. I'm dreading saying the wrong thing ... I think the power is going in a circle ... I can remember doing this on the board, there was a theory that it came from both sides ... but I'll say because it is called a circuit it goes round.

RR What is going round?

K Electricity, generated from the battery.

RR How is it producing light?

K ...... the filament .. the electricity is .. I can't remember ... it somehow goes into the filament and makes it light.

RR If I could measure the flow electricity both sides of the bulb what would I find?

K There would be less coming back because it has been used .. the battery is re .. it's going back into the electricity.

RR Do you want to add to the torch diagram?

K .... the battery .. there must be wires going from the batteries to the light with the switch above that which breaks the circuit .... [draws wire from base of bulb to base of battery and another from the side of the bulb to the base of the same battery] .. I know it is wrong .. one would go to the top of the battery.

RR What about this [draw a 1.5v battery and a bulb]?

K One to the bottom, one to the top.

RR If I put ice cube in a glass out on a sunny day what will happen?

K The sun warms the ice and it melts , that's all to do with the particle theory. The sun heats the ice, the particles, do they expand and move about .. they change .. because the particles in the ice are moving about faster the overall status of the ice changes into water ...

RR Are the particles in ice moving?

K In ice I don't think they are moving as fast.. until they become water .. it is the heat that makes them move faster.

RR You said they expand?

K No, they don't expand do they .. because they are moving they take up more space. I remember you telling us about them bouncing off the walls.
Case Study 10: DES 20-day Interviews (Cohort 2)

RR If it’s a sunny day what happens to the ice next?
K It evaporates .... I can’t remember, but I did understand this
at the time .. the sun heats the particles and .. what do they?
.. I can’t remember.

RR (offers scientific explanation)
K Nothing happens to change the individual particles. I first
thought when they evaporated something .. I thought they might
have changed in weight or something to lift them.
RR What happens when a candle burns?
K When it burns the particles when they are heated .. the heat
gives them more energy, they move around and become liquid and
they flow down the candle. As they get away from the heat they
slow down and solidify. The particles have got less energy ..
I’m alright when you have refreshed my memory .. so they
(particles) have more energy and move around more.
RR So what’s burning?
K Some of the particles nearest the flame .. the wax melts .. the
wick burns, the wax doesn’t burn, it melts.
Go on tell me!
RR The wax melts, is draw up the wick ..
K That’s it ... now you’re talking about it it comes back.

RR What about forces?
K I was absent, and I didn’t really understand it, that a table is
exerting pressure up.
RR If a rolled a tennis ball what forces might be acting?
K The force upwards from the floor, there’s a gravity force
coming straight down .. a pull downwards .. and if you roll it
there is a force from behind ..
RR What about when it is on the move?
K The upwards and downwards ones and the .. I’m not sure about
this, as something rolls it is exerting its own force [indicates
a rotational direction] as this comes up its pushing itself, the
force in inside it turning.
RR Any force in the other direction?
K I don’t think so.. not on a flat surface.

RR What is causing it to stop?
K When you push it, you’re giving it so much force, but that force
gets used up so that it’s no longer .. if you put it on its own
it doesn’t move and so you’re giving it some force and it uses
up the energy from that force.
RR [offers scientific explanation]

RR Did the course change any of your scientific ideas?
K Lots in each part.
RR But did they change?
K Well looking back on something like the candle I thought I had
changed my ideas!
It takes time.

I was thinking today (about the children's electricity work) and I thought I've got to look at my (course) notes to progress further on this. I wanted to get them to light up two bulbs and add a switch. I thought I'm not certain about that I'll have to refer back. So I know it is there somewhere and if I read it again I would understand it. I should have looked through it last night!

I feel much more confident but I'm not sure about my ideas. I felt slightly intimidated on the course because I am not a scientist, my degree is in English.

Who did you think of as an expert?

Dave, Frances, Rick, Mark.
Case Study 10: DES 20-day Interviews

Group: Anne (Cohort 1)

Sessions: Friday 6.12.91

Data Collection: RR field notes
Tape
Students’ outcomes

RR On your evaluation form you said that the constructivist approach has been valuable to you. In what ways has it affected your teaching?

A I use it 100%, before the course .. we got well into the course, if you remember I quoted something that I had done with evaporation .. with a saucer, we had tested out and a child thought that it (the water) was going to go through the shelf into the cupboard ... we took the books out (of the cupboard) to look and see. Immediately, I was at one with what you were saying about the constructivist approach. Bless their hearts, the staff have taken it on board as well, in different measures but they are all of the same mind that it is an excellent way of working .... This term we have been dealing with celebrations and it a good topic to address multicultural aspects of the curriculum. I decided, obviously I work closely with my Y1 colleagues, to take festivals of light. That led me into candles. We have got quite a lot of work on candles [points to various classroom displays including posters of children’s ideas about candles]. I have elicited what their thoughts have been and their observations have been and .. that is the bones of the display. There are the usual chestnuts of alternative ideas .. the colour of the flame will be the same as the candle .. the look of delight on their faces as you light them and they see what colours they are ... [reads from the display] wax is runny plastic, it is hard but the fire burns it .. you can almost see the logic of it. The follow up involved me trying to bring safety in as well. I was trying to explain that runny plastic is extremely dangerous... my questions included, What is the wet stuff?

R Have you used floor books.

A Yes, but they're being used as part of a research project I'm doing and they are at the Poly. Other teachers are using them to a lesser degree. I introduced them to 2 of my colleagues when they were doing SATs and they found them absolutely amazing for their teacher assessment. The really work and they use them in Maths as well.. I found the orientation bit for the science, that part of the constructivist approach just follows through with whatever you are doing, especially number .. [describes an example related to the class-shop that is evident in the home corner] ... if it works in science why shouldn't it work in
other areas.

R  Do you ask children to apply ideas later on, some time later?

A  A week before last I put a battery and bulb out on display. They just had hands-on seeing if they could light the bulb. Some could, some got frustrated. So we closely looked at the bulb like we had on the course, with a lens. I was amazed, I think it was Rowena, she said, "Oh, look, its got a bump on the side and when the bump touches one of those (battery terminals) and the bottom touches one my bulb lights up". It was super, this child hadn't had her 6th birthday yet! She had done some work on electricity with me last year and so it was coming back to her. I made a book this term called 'How does it work'. It is simply their drawings to explain how it works. All involved came up with explanations ranging from, "There's a jug of water inside the battery and it goes up a pipe and makes a bulb light up". And so I knew I had quite a lot to do with Nathan! It is difficult because you can't let them see. We did holding hands and the squeeze [referring to course handbook] to get the idea of a circuit. Their were varying degrees of what they had taken on board but there were about 6 that said to me that electricity comes out of the battery, up into the bulb and back to the battery. They followed the route with their fingers. I did this with individuals. The remainder held the famous clashing currents idea.

R  Will you draw what's inside a torch and how it works.

A  There's a reflector, a battery and another battery.

R  Which way round are they.

A  [draws correct orientation] There's a light bulb .. glass .. a switch [draws correct connections to base and side of bulb, but is uncertain about connections to batteries]

R  Show me how to connect this battery [draws a 4.5v battery and bulb]

A  [shows correct connections to base and side]

R  If I gave you a battery like this [draws a cylindrical 1.5v battery] can you show me how to connect this?

A  I'm not sure if both connections go to the bottom (of the bulb) .. no its got to be one to the side [draws wires to top and bottom of battery].

R  Now let's go back to the torch drawing.

A  [draws wire from side of bulb to switch and from bottom of bulb to the battery.. after thought adds wires from switch to the battery]

R  Can you explain what is happening when the bulb lights up.

A  There are ... particles inside the battery, some that are negative and some positive. The negative ones are carrying particles that aren't charged .. it (they've) still got juice in it (them). Particles are inside the battery .. when they make contact they are charged ... electricity travels through the
Case Study 10: DES 20-day Interviews

wires to the bulb, it goes up to the filament, the filament gets warm, it vibrates ... the little coil ... it heats, makes light. the electricity flows back to the battery to the positive side but is now longer carrying juice.

R If I measure how many are flowing out and back would it be the same, more or less?
A My logical brain would say less because some is used up but on the other hand if it flows has there been a loss? They are not charged when they return, so you haven't lost any ... there is the same number.

R A glass with ice cubes in it is left out on a sunny day, what happens?
A The temperature would cause the ice to melt.
R How can you explain that to yourself? What does 'the temperature causes the ice to melt', what is the temperature?
A The heat
R Are they (temperature and heat) the same?
A No, did I say temperature, if they are outside in the sun the temperature would be greater, but the heat causes it to melt. I can see the diagram with the chocolate ... particle theory ...
R How can that help, what are the particles like in ice?
A Tightly packed and not moving very much. When heat is applied they bounce around more. They expand?
R Do individual particles expand?
A No, they just move around more.
R Does that help us explain the change to a liquid?
A They're no longer packed so tightly together. They move and create more heat. When something moves ... they bounce around and heat is given off.
R What happens then?
A The liquid becomes warm in the sun and it may then well evaporate ... it goes down through the cupboard! The particles are now moving at such a rate they are no longer contained within a ... it changes to a vapour or gas.
R Can you use particle theory to explain what happens when a candle burns?
A In the solid state they (the particles) are closely packed together. You light the wick which produces heat. The heat starts to make the particles in the wax move more. They start to really bounce around and the wax starts to melt, it gives off a vapour and the vapour burns.
R Will you tell me what forces are acting on a tennis ball in these three situations, as I hit it, as it travels over the net and as it rolls to a stop.
A In the first there is the force of the hit [drawn in correct direction] and gravity pulls down. In the second, as it goes
Case Study 10: DES 20-day Interviews

over the net, gravity still pulls down, and air resistance pushes all around but more against the direction of movement [draws 2 correctly directioned arrows]. When it rolls along there is gravity downwards, an equal and opposite force upwards and friction against the roll [draws three arrows in correct directions].

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### Volume 2: Appendices

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#### 2nd School Experience

| Cycle 4 | 2 | Technology | Use of skills | Workshop |
| Technology & Science | 2 | Technology | Problem solving & | |
| | 2 | Field Work | Pond study | Discussion |

### Year IV

| Introduction | 2 | Children’s ideas of science | Video & discussion |
| Cycle 5 | 2 | Own ideas v. Ch ideas | Materials |
| | 2 | | Energy |
| | | | Electricity |
| | 2 | Using collections | Light |
| **Joint Topic 3 with Maths** | 11 | Planning activities and attainment targets | Free choice | As for Joint topic 2 |
| Cycle 6 | 4 | Review of printed material | Range of schemes & programmes | St develop and apply |
| | | Radio/TV/IT | programmes | evaluation criteria to |
| | | | | available material |

**TOTAL TIME** 64 hours
1. INTRODUCTION

1.1 The need to enhance the knowledge and skills in science of primary teachers is widely recognised. The introduction of the National Curriculum has brought training needs in this area into sharper focus. Last summer, in order to address these needs and increase the number of suitably qualified staff, the Department earmarked provision for designated courses under the LEA Training Grants Scheme. These arrangements will continue for 1991-92.

2. REVISED CRITERIA

2.1 The criteria for the courses have been modified with a view to increasing the flexibility and effectiveness of the provision. HE providers, in consultation with LEAs, are invited to submit proposals against the revised criteria.

2.2 It is not necessary for institutions to seek re-designation of courses approved last year, as the revised criteria are intended to apply only to new proposals. However course providers, in consultation with local education authorities, may wish to take advantage of this opportunity to modify provision to take account of the greater flexibility afforded by the revised criteria.

3. AIMS

3.1 The main aims of the courses should be to develop teachers' confidence and ability in the subject knowledge and understanding which will enable them to teach the programmes of study in KS1 and KS2, and to appreciate the place of science within the wider curriculum. The courses should also give attention to the practical skills associated with the subject, including the teaching approaches, the assessment of pupils' progress and attainment during KS1 and KS2 and the preparation of schemes of work.

4. CLIENT GROUP

4.1 In the first instance, it is likely that LEAs will wish to give priority to training certain key groups such as primary phase advisers and science coordinators (including heads and deputies where they assume this role). The Department believes however that it is important for all teachers attending designated courses to be given specific guidance on how to disseminate their newly-acquired knowledge and expertise to their colleagues.

4.2 It is likely that there will be a wide variation in the levels of knowledge and skills of course participants. Indeed, some teachers may start from a comparatively low knowledge base and lack of confidence in their ability to come to grips with the subject.
5. MODES OF DELIVERY AND LENGTH OF PROVISION

5.1 Normally these courses will need to equate to about 20 days full-time provision in order to achieve their aims. Alternatively, so as to ensure the best possible match with students' needs, it might be appropriate to negotiate more flexible arrangements. The time might, for example, be broken down into two or three blocks of 4 or 5 days each plus a number of single days with associated tutorial support, though local circumstances may favour different patterns.

5.2 Whatever the pattern, participants need time to reflect on work undertaken, apply it in their classrooms and to share experiences with colleagues. Flexible learning materials might also be used for supported self study. Recognising the crucial need for effective materials of this kind for teachers of primary science, the DES, in collaboration with NCC, SEAC, HMI and ASE has recently commissioned a pilot project aimed at producing distance learning materials.

5.3 Group size should normally be between 12 and 20.

5.4 Participants should be set assignments that focus on the application of the knowledge and skills to their own school. For example, they could refer to:

i. their own classroom teaching;
ii. the preparation of schemes of work;
iii. the assessment of pupils; and
iv. the planning and delivery of INSET for their colleagues.

5.5 Wherever possible, providing institutions should seek to encourage head teachers or senior line managers either to participate in, or be informed about that part of the course relating specifically to the dissemination of the knowledge and skills acquired by their staff.

5.6 Providing institutions are urged to explore the possibility of acquiring accreditation for the courses. Whenever possible, credit should also be given where trainees can demonstrate that they have already acquired some of the relevant knowledge and skills through attendance at a previous course.

6. COURSE CONTENT

6.1 The courses should:

i. develop teachers' scientific knowledge;
ii. enable them to become familiar with the use of computers and some simple equipment;
iii. extend their understanding of the processes of science;
iv. develop their proficiency in making cross-curricular links with mathematics, technology, geography and language;
v. provide specific guidance on how best to disseminate the knowledge and skills acquired to their colleagues.
6.2 A substantial proportion of the course should be devoted to extending the participant’s knowledge and understanding of science, particularly in the area of physical science. The course should reflect the crucial importance of scientific exploration and investigation (Attainment Target 1). Participants should acquire so far as is possible the knowledge, understanding and the skills necessary to teach all attainment targets in Key Stages 1 and 2 (ie up to level 5). Teachers will have individual needs in terms of content but the following areas in the profile component on knowledge and understanding of science may need particular attention:

i. forces;
ii. energy;
iii. types and uses of materials;
iv. electricity and magnetism;
v. information technology.

6.3 The course should explore the ways in which the work can be matched to the different needs and abilities of pupils. Courses will need to reflect the aims identified in section 3. Teaching methods should at all times reflect good classroom practice involving a variety of approaches and the use of a range of resources.

6.4 The course should equip participants to assess and record pupil achievement and progress in relation to the attainment targets.

6.5 Upon returning to their schools, teachers will be required to disseminate the knowledge and skills acquired to their colleagues. Accordingly, courses will also need to develop skills in dissemination. This might include guidance on:

i. identifying the needs of the school;
ii. leading the whole school in corporate planning for science;
iii. organising school-based INSET activities;
iv. developing a longer-term staff development policy in science and staff support strategies; and
v. monitoring and evaluating the effectiveness of the school’s development strategies.
7. CRITERIA FOR SUBMISSIONS

7.1 In addition to outlining the course content and structure, the following questions need to be addressed by institutions putting forward proposals for the courses:

i. how do the course content and teaching approaches enable teachers to gain the confidence and competence to teach the programmes of study?

ii. what strategies will be used to enable teachers to become better at recognising and recording their pupils' attainment?

iii. by what means does the course encourage teachers to support their colleagues and disseminate their knowledge and expertise?

iv. what collaboration has there been with LEA/EAs in (a) the identification of the client group (b) the preparation of the course (c) planning the future support and development of both the course and course participants?

v. what links are there with other support structures which build on existing activities and networks?

vi. how will the expertise and resources within the LEA and providing institutions be coordinated and used?

vii. how will the course respond to individual school and teachers' needs, expertise and experience?

viii. how will the course enable school-based work to develop?

ix. is the course structure coherent?

x. in what way does the course allow for continuity and progression of ideas?

xi. how will the course leaders assess the extent to which participants' knowledge and understanding of science has been increased?

7.2 In addition to the above, the following issues will need to be addressed where a course proposes to use distance learning materials:

i. what is the responsibility of the tutor in terms of using and adapting material according to individual and group needs?

ii. how will the course structure enable groups of teachers to share experiences and reflections?

iii. how does the material enhance the course experience and quality?

iv. does the course fit into any Regional Credit Transfer schemes?
Original BCHE DES 20-day Course Proposal (September 1989)
BATH COLLEGE OF HIGHER EDUCATION

DPSE - INSET MODULAR

CERTIFICATE IN PROFESSIONAL STUDIES

TITLE: Developing Science in the Primary School

AWARD: Satisfactory completion of the course will lead to the award of the BCHE Certificate in Professional Studies.

MODULE IN THE DPSE: The course will count as one module in the CNAA Modular DPSE Course.

HOURS: 120

HOST INSTITUTION: Bath College of Higher Education.

RATIONALE

There is considerable evidence (including HMI, IPSE (1988), Kruger and Summers (1988) and Wragg et al (1989)) that in HMI's words,

"The most severe obstacle to the improvement of science in primary school is that most teachers lack a working knowledge of elementary science appropriate to children of the age."


The implementation of the National Curriculum for Science will make even greater demands of teachers and require them to have knowledge and understanding of science above the level that can be expected of the children they teach. Co-ordinaters will need increased expertise in encouraging and managing change within individual classrooms and the whole school.

This need to improve teachers' background knowledge of science and their confidence to teach science, coupled with recent research on the nature of learning in science, are the reasons for proposing this course.

The course is based on a constructivist approach to teaching science, that is advocated in the NCC Non-Statutory Guidance, and owes much to the work of the Children's Learning in Science (CLIS) Project at Leeds University. This views the learner as an active constructor of his/her own knowledge who approaches any new learning experience with existing ideas. These ideas will affect any new understanding developed. As a result eliciting existing constructs, basing new experiences on those existing ideas and providing time for reflection and the re-structuring of ideas are essential elements of the approach proposed.

The nature of science that underpins the course is that contained in the Science Working Group's Report, Science for Ages 5-16,

"For the child, as for the scientist, the way understanding is developed depends both on the existing ideas and on the process by which those ideas are used and tested in new situations." Implicit in this, is the acceptance of
science as an investigational activity.

The course will also be informed by an action research approach and classroom enquiry activities will be an integral part of the course members' work. They will be encouraged to become reflective teachers and make decisions about how their practice might be modified as a result of systematic observation of existing practice. Experience in this area has provided evidence that this approach is the most successful in terms of improving teachers' confidence and competence in teaching science.

Course members will be provided with opportunities to work collaboratively with each other in a classroom situation. This is intended to help them develop their knowledge and understanding in science by enabling them to identify children's alternative frameworks and reflect on these in an attempt to relate them to their own and accepted scientific frameworks. They will also be required to identify appropriate activities aimed at developing the ideas elicited from the children. This process is intended to help them articulate their own needs in terms of further background knowledge.

The approach to assessment on the course will be one that regards it as an essential element of good classroom practice. It will be seen as a process by which evidence of learning is collected and recorded in an appropriate way. This will involve observing what the learner does, listening to what they say and looking at the outcomes of, and what they communicate about their activity. Structured support during school-based work with children should enable teachers better to recognise and record pupils' attainment, particularly in terms of knowledge and understanding.

The course will also explicitly address the means of ensuring equality of opportunity and access for all children to a relevant, broad and balanced science curriculum.

PLANNING

The course structure is based on the successful elements of Bristol Polytechnic's CAPSE 14 Course 'Science Enrichment for Primary Teachers'. CAPSE 14 has evolved as a course for curriculum leaders over the last four years and is the result of collaboration between Bristol Polytechnic and Avon LEA.

Several college staff have been involved in planning the present course in collaboration with colleagues at Bristol Polytechnic. Representatives from Avon and Wiltshire LEAs have been involved at the planning stage and support the course proposal. It is intended that LEAs and the linked institution (Bristol Polytechnic) will pool available expertise and resources to facilitate course delivery of the highest quality. Bristol Polytechnic is offering a similar course to complement provision in the region.

INTENTIONS

Upon completion of this course, participants will have:

- increased their background knowledge and understanding in science to enable them to teach the programmes of study in the national curriculum;
- developed their role as curriculum leaders in managing change at a personal and institutional level;
- broadened their experiences through visits to and work in other schools;
- improved their skills in planning science work matched to individual needs and abilities of pupils;
- improved their skills in implementing science work and assessing individual children and recording their progress;
- improved their ability to evaluate science work with children;
- become familiar with the use of simple equipment;
- experienced ways in which information technology can support, enhance and extend scientific work;
- developed their ability to plan coherent science schemes of work that avoid fragmentation of the science curriculum;
- developed their ability to link scientific work with other curriculum areas, especially design and technology, mathematics and language.

CONTENT

The following elements will be included in the 5 four day cycles of the course -

Scientific knowledge and understanding.
Specific areas of knowledge and understanding will be drawn from these general areas:
- Materials and their characteristics;
- Living Things;
- Forces and their effects;
- Earth Science;
- Energy.

(It is likely, taking account of the particular needs of students on the course, that one will be covered in each of the 5 cycles)

Knowledge and understanding in science, related to the programmes of study concerning Profile Component 2, will be the focus of planning, implementation and evaluation of science activities throughout the course.

Scientific process skills.
The inexticable links between Profile Component 1 (Exploration and Investigation) and Profile component 2 (Knowledge and Understanding) will be made explicit in all sessions.
This will be particularly evident in the school-based INSET element, that involves work with children.

(This focus will be emphasised in the first cycle)

Assessment and Record keeping.
This will be the focus of analysis and evaluation of school-based work (Day 3 of each cycle and follow-up work in course members own schools).

(This focus to be emphasised during cycles 2 & 3)

Management of school-based INSET for the professional

Page 246
development of colleagues. This will be the focus of the evaluation of science activities on all four days. This will cover:

- implementation of strategies for school development programmes; identifying and establishing links with support agencies; evaluating and using published material - distance learning packages and other support material (to be included in planning sessions);
- school-based INSET to be designed and carried out by course members.

(This focus to be prioritised in the final two cycles)

PROFESSIONAL RELEVANCE

This course will be relevant to teachers in primary schools who have responsibility for or an interest in developing science in their school. This includes heads and deputies where they assume such a role. The course can be readily modified to meet the needs of classroom teachers by changing the emphasis placed on particular focii. It is therefore intended to offer courses in the future designed for this client group.

METHOD

Workshops, tutor supported school-based work, collaborative planning, implementation and evaluation of school-based work with children, directed work (including practical work in course members' classrooms and school) and discussions. The course is designed to run with a group of 16 teachers.

COURSE STRUCTURE

The course will comprise 5 cycles of four full days. Each 4 day cycle will operate a similar format but include different elements (outlined above).

Format of each cycle

Day 1 AM and PM. Workshops covering background science at the level of course members in a specific area of science.

Day 2 AM Background science workshops continued. 
PM Preparation and planning for work in school, based on content related to workshops.

Day 3 School-based INSET activity (see below).

(Two week interval while course members trial activities in their own schools and involve other teachers in their schools)

Day 4 AM Evaluation of own school work.
PM Development of area of science in response to school experience.

The college based workshops will include;
- orientation activities to introduce the area of content involved;
- elicitation of course members exiting constructs (individual records,
discussion in pairs, small groups or whole group);
- activities based on the existing constructs identified;
- discussion of outcomes, modifications of constructs, possible developments;
- input from tutors addressing needs that cannot be met through practical activities;
- opportunities to apply restructured ideas in different situations.

School-based INSET with children will be based on an action research model and involve:
- collaborative planning between course members, class teachers and course tutors of activities planned to develop pupils' knowledge and understanding in an area of content covered by college workshops (taking account of the need to integrate components of the science curriculum in a coherent manner);
- working in pairs for preparation and teaching (each pair works with a group of five children);
- adopting roles whilst working with children of teacher and observer (the 'teacher' leads the activity while the 'observer' collects data on the activity);
- analysing data in terms of aspects of the science curriculum that have been covered, existing constructs that are evident and possible developments) and formulating new plans (roles will then be reversed for the next activity with children);
- whole group evaluation of findings and negotiation of needs for subsequent workshops.

The school day will comprise two teaching sessions and two analysing and evaluating sessions. The schools will be chosen to ensure a variety and will, in most cases, be course members' schools. The first cycles are likely to involve several course members in one class, later cycles will involve less course members in each class.

ASSESSMENT

There are three assignments which will be undertaken with tutorial guidance.

1. A case-study of work with children that illustrates the essential role scientific processes have in children's learning in science. (approx 3000 words).
2. The production, implementation and evaluation of appropriate assessment tools for science.
3. The production, implementation and evaluation of an INSET package that is designed to develop science in the course members' school.

EXTERNAL EXAMINER

To be agreed

STAFFING

At present, planning is being co-ordinated by Ron Ritchie. He has been involved in in-service work in science for several years. As an Advisory Teacher for Science in Avon he was actively involved in the development of the CAPSE 14 Course, which he has taught on since it started. He has considerable experience of running courses aimed at improving teachers' scientific knowledge and their ability to manage change.
within their schools.

The teaching team will include college staff and a teacher tutor with experience of this form of INSET.

**INDICATIVE BIBLIOGRAPHY**

Harlen, W. *Teaching and Learning Primary Science* Harper 1985
Driver, R. *Children's Ideas in Science* Open University 1985
CLIS *Aspects of Secondary Students' Understanding of Energy* University of Leeds 1987
Hitchcock, G. & Hughes, D. *Research and the Teacher* Routledge 1989
Pople, S. & Williams, M. *Science to 16* OUP 1987
Appendix 4

Revised BCHE DES 20-day Course Proposal (November 1989)

BATH COLLEGE OF HIGHER EDUCATION

INSET COURSES FOR PRIMARY TEACHERS IN SCIENCE
AND THE NATIONAL CURRICULUM

1. INTRODUCTION

There is considerable evidence (including HMI, IPSE (1988), Kruger and Summers (1988) and Wragg et al (1989)) that in HMI's words,

"The most severe obstacle to the improvement of science in primary school is that most teachers lack a working knowledge of elementary science appropriate to children of the age."


The implementation of the National Curriculum for Science will make even greater demands of teachers and require them to have knowledge and understanding of science above the level that can be expected of the children they teach. Co-ordinaters will need increased expertise in encouraging and managing change within individual classrooms and the whole school.

This need to improve teachers' background knowledge of science and their confidence to teach science, coupled with recent research on the nature of learning in science, are the reasons for proposing this course.

The course is based on a constructivist approach to teaching science, that is advocated in the NCC Non-Statutory Guidance, and owes much to the work of the Children's Learning in Science (CLIS) Project at Leeds University. This views the learner as an active constructor of his/her own knowledge who approaches any new learning experience with existing ideas. These ideas will affect any new understanding developed. As a result eliciting existing constructs, basing new experiences on those existing ideas and providing time for reflection and the re-structuring of ideas are essential elements of the approach proposed.

The view of science that underpins the course is that contained in the Science Working Group's Report, Science for Ages 5-16. Implicit in this, is the acceptance of science as an investigational activity, "For the child, as for the scientist, the way understanding is developed depends both on the existing ideas and on the process by which those ideas are used and tested in new situations."

The course will also be informed by an action research approach and classroom enquiry activities will be an integral part of the course members' work. This will involve both work in their own classrooms between sessions and, in a more intensive way, the school-based sessions of the course. Experience in this area has provided evidence that this approach is the most successful for improving teachers' confidence and competence in teaching science and at the same time extending their own background knowledge and understanding.

This development of course members' scientific knowledge and understanding will be enabled through opportunities to work collaboratively with each other in classroom situations. They will identify examples of children's existing ideas or alternative frameworks and through analysis of these explore the relationship of the children's ideas with their own. This process will serve to clarify their own ideas and help them to become better able to recognise those of the children. They will also be required to identify appropriate activities aimed at developing the ideas elicited from the children. As a result course members should be in a position to
articulate their own needs in terms of further background knowledge.

The approach to assessment on the course will be one that regards it as an essential element of good classroom practice. It will be seen as a process by which evidence of learning is collected and recorded in an appropriate way. This will involve observing what the learner does, listening to what they say and looking at the outcomes of, and what they communicate about their activity. Structured support during school-based work with children should enable teachers better to recognise and record pupils' attainment, particularly in terms of knowledge and understanding.

The course will also explicitly address the means of ensuring equality of opportunity and access for all children to a relevant, broad and balanced science curriculum.

LEA CONSULTATION

The course structure is based on the successful elements of Bristol Polytechnic's CAPSE 14 Course 'Science Enrichment for Primary Teachers'. CAPSE 14 has evolved as a course for curriculum leaders over the last four years and is the result of collaboration between Bristol Polytechnic and Avon LEA.

Several college staff have been involved in planning the present course in collaboration with colleagues at Bristol Polytechnic. Representatives from Avon LEA and Wiltshire LEA have been involved in the planning process. It is intended that the LEAs and the linked institution (Bristol Polytechnic) will pool available resources and expertise to facilitate course delivery of the highest quality. Bristol Polytechnic is offering a similar course to complement provision in the region.

2. AIMS

Upon completion of this course, participants will have:

- increased their background knowledge and understanding in science to enable them to teach the programmes of study in the national curriculum;
- improved their understanding of how children and adults develop knowledge and understanding in science;
- improved their skills in planning science work matched to individual needs and abilities of pupils;
- improved their skills in implementing science work and assessing individual children and recording their progress;
- improved their ability to evaluate science work with children;
- had the opportunity to become a more reflective practitioner;
- become familiar with the use of simple equipment;
- experienced ways in which information technology can support, enhance and extend scientific work;
- developed their ability to plan coherent science schemes of work that avoid fragmentation of the science curriculum;
- developed their ability to link scientific work with other curriculum areas, especially design and technology, mathematics and language;
- developed their role as curriculum leaders in managing change at a personal and institutional level;
- broadened their experiences through visits to and work in other schools.

3. CLIENT GROUP
This course will be relevant to teachers in primary schools who have responsibility for or an interest in developing science in their school. This includes heads and deputies where they assume such a role.
The course can be readily modified to meet the needs of classroom teachers.

4. MODES OF DELIVERY AND LENGTH OF PROVISION

Workshops, tutor exposition, pair and small group activities, discussion, tutor supported school-based work involving an action research model, collaborative planning, implementation and evaluation of work with children and directed work (including practical work in course member’s own school). The course is designed to run with a group of sixteen teachers for 20 days.

5. COURSE CONTENT

The following elements will be included in the 5 four day cycles of the course -

Scientific knowledge and understanding.
Specific areas of knowledge and understanding will be drawn from these general areas:
- Materials and their characteristics;
- Living Things;
- Forces and their effects;
- Earth Science;
- Energy.

(It is likely, taking account of the particular needs of students on the course, that one will be covered in each of the 5 cycles)

Knowledge and understanding in science, related to the Programmes of Study concerning Profile Component 2, will be the focus of planning, implementation and evaluation of science activities throughout the course.

Scientific process skills.
The inextricable links between Profile Component 1 (Exploration and Investigation) and Profile Component 2 (Knowledge and Understanding) will be made explicit in all sessions. This will be particularly evident in the school-based INSET element, that involves work with children.

Assessment and Record keeping.
This will be the focus of analysis and evaluation of school-based work (Day 3 of each cycle and follow-up work in course members own schools).

Management of school-based INSET for the professional development of colleagues.
This will be a focus of the evaluation of science activities on the fourth day of each cycle. This will cover:
implementation of strategies for school development programmes; identifying and establishing links with support agencies; evaluating and using published material - distance learning packages and other support material.

6. COURSE STRUCTURE.
The course will comprise 5 cycles of four full days. Each 4 day cycle will operate in a similar format.

**Format of each cycle**

Day 1  AM and PM. Workshops covering background science at the level of course members in a specific area of science.

Day 2  AM  Background science workshops continued.
        PM  Preparation and planning for work in school, based on content related to workshops.

Day 3  School-based INSET activity (see below).

(Two week interval while course members trial activities in their own schools and involve other teachers in their schools)

Day 4  AM  Evaluation of own school work.
        PM  Development of area of science in response to school experience.

The college based workshops will include:
- orientation activities to introduce the area of content involved;
- elicitation of course members existing "scientific" ideas or constructs (individual records, discussion in pairs, small groups or whole group);
- practical explorations and investigations based on the existing constructs identified;
- discussion of outcomes, modifications of constructs, possible developments;
- input from tutors addressing needs that cannot be met through practical activities;
- opportunities to apply restructured ideas in different situations.

School-based INSET with children will be based on an action research model and involve:
- collaborative planning between course members, class teachers and course tutors of activities planned to develop pupils' knowledge and understanding in an area of content covered by college workshops (taking account of the need to integrate components of the science curriculum in a coherent manner);
- working in pairs for preparation and teaching (each pair works with a group of children);
- adopting roles whilst working with children of teacher and observer (the 'teacher' leads the activity while the 'observer' collects data on the activity);
- analysing data (in terms of aspects of the science curriculum that have been covered, existing constructs that are evident and possible developments) and formulating new plans;
- roles will then be reversed for the next activity with children, so that course members take on both roles;
- whole group evaluation of findings and negotiation of needs for subsequent workshops.

The school day will comprise two teaching sessions (of an hour each) and two sessions for rigorous analysis and evaluation. The schools will be chosen to ensure a variety and will, in most cases, be course members' schools.

7. ASSESSMENT
There are three assignments which will be undertaken with tutorial guidance.

1. With reference to collected case-studies of work with children and further reading illustrate the way in which the development of children's knowledge and understanding is linked to process skills. This should identify alternative frameworks that children hold in a chosen area of science content and discuss strategies for dealing with them. (approx 3000 words).

2. The production, implementation and evaluation of appropriate assessment activities and procedures for science.

3. The production, implementation and evaluation of an INSET package that is designed to develop the scientific knowledge and understanding of teachers in the course members' school.

8. EVALUATION

Formative evaluation will occur throughout the course, based on course members' feedback through formal and informal methods. Established college and LEA procedures will also be used to provide summative evaluation. This will include the report of a college appointed external examiner.

9. INDICATIVE BIBLIOGRAPHY

Harlen, W. *Teaching and Learning Primary Science* Harper 1985
Driver, R. *Children's Ideas in Science* Open University 1985
CLIS *Aspects of Secondary Students' Understanding of Energy* University of Leeds 1987
Hitchcock, G. & Hughes, D. *Research and the Teacher* Routledge 1989
Pople, S. & Williams, M. *Science to 16* OUP 1987
**DES 20-day Course Outline**

The courses ran from September 1990 - July 1991 for two cohorts. Cohort 1 involved 14 teachers from LEA X and Cohort 2 involved 16 teachers from LEA Y. Cycles 1, 2 and 4 were used for data collection related to this enquiry.

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Appendix 6

Plans for DES 20-day Course Sessions used for data collection

6.1 Pre-course meeting

Welcome

Background to the course - HMI findings, NC requirements, PSTS findings, LEA collaboration

Introduction of tutors

Introduction to course members using questionnaires (pairs)

Eliciting existing confidence - proforma

Course structure - constructivist approach, reflective teacher, process / knowledge and understanding, assessment, cycle structure and content

Innovative aspects

My research - purposes and permission to collect data

College - accreditation, handbooks etc.

6.2 Materials Cycle

The same plans were used for both cohorts although times differed slightly and the order on day 4 was modified.

RR and IS tutored Cohort 1; RR, IS and ST were tutors for Cohort 2.

**Day 1**

9.15 Introduction

9.45 Explore collections of materials - select 5 with something in common (pairs)

10.00 Feedback - key words listed, other brainstormed and grouped

10.15 Exploration of specific collection - raising questions

11.15 Review questions - look at scientific process and which questions are scientific - which can be answered through investigation within the constraints?

12.00 Select a question and devise an investigation (pairs)

Work on investigation

3.00 Review outcomes

**Day 2**
State of matter elicitation sheets (pairs)

Sort a collection into liquid / solid / gas

Discussion - what is a solid, liquid and gas?

Input - the kinetic theory

Planning for school-based day (see NPC material)

Day 3

School-based day

Teacher A teaches group of 4 whilst B collects data

Analysis of data

Planning for afternoon session

Teacher B teaches whilst A collects data

Analysis of data

Plenary discussion

Day 4

Approaches to investigations

The nature of variables

Revisiting a candle burning

Strategies for developing sorting and classifying skills in children

Review of school-based work.

Question-time
6.3 Forces Cycle

RR and TD tutored Cohort 1; RR, TD and ST were tutors for Cohort 2.

Day 1
9.15 Explore collection - what have each got to do with forces? (pairs)
9.45 Group discussions about outcomes
10.15 Prioritise theme cards (Structures, Floating and sinking, Pushing and Pulling, Starting and Stopping, Levers and balance, Friction) according to interest
10.45 Explore theme area and raise questions
11.15 Devise and carry out specific investigation
2.30 Report back
3.15 Input - key ideas about movement
3.45 Produce a concept map

Day 2
am Elicitation and input based on key ideas - mass/weight, gravity, pressure, speed/velocity/acceleration, drag/lift
pm Planning for school

Day 3
School-based day (as cycle 1)

Day 4
9.30 Feedback from work in own classrooms (3 groups)
10.15 Key ideas / issues that have arisen
10.45 Revision of key ideas about forces - another concept map
12.00 Brainstorm ideas about energy - group as forms and sources
1.45 Produce energy transfer posters using item from a collection
2.45 Energy transfers involved when a ball bounces
3.15 Open forum.
6.4 Electricity Cycle

RR and DC tutored Cohort 1; RR tutored Cohort 2

Day 1

9.15 am  Introduction
What do we know about electricity? - write 4 sentences
Discuss using key questions

10.00  Draw a torch - what’s inside and how does it work?

10.15  Explore simple circuits - free play - orientation

10.30  Coffee

10.50  Focus on a bulb and how it lights up
Simple circuits - heating effect
short-circuits
conductivity
simple switches

Review, consolidate and raise questions

Investigations or
Problem solving activities
  make a torch
  traffic lights
  hall lights
  dimmer switch

12.30 pm  Lunch

1.30  Options - Magnetism
  Further circuit work - using simulation
  Further circuit work - measuring

3.30  Generate models about electricity - in pairs

Day 2

9.15 am  Key ideas about electricity

9.45  Further problem solving - control technology
  Work on simple electronics

Reading time
Contexts for work on electricity

pm  Toys talk video
  Children’s alternative ideas
  Students’ alternative ideas

Eliciting children’s ideas about electricity - methods and questions

Day 3  School-based day
Day 4

am

pm The role of the coordinator, whole school development, INSET strategies
EVALUATION SHEET

Name: LEA:

Please rate the following from 1 (good/relevant) to 4 (poor/not relevant).

Cycle 1: Materials
Science activities and input at adult level ....................................................
How difficult did you find the ideas dealt with on this cycle?
(1 hard to 5 easy) ..........................................................................................

Comments:

School-based day ..........................................................................................

Comments:

Day 4 (review of school work / sherbert lemon activity) ....................

Comments:

Cycle 2: Forces
Science activities and input at adult level .................................................
How difficult did you find the ideas dealt with on this cycle?
(1 hard to 5 easy) ..........................................................................................

Comments:

School-based day ..........................................................................................

Comments:

Day 4 (review of school work / revisiting forces / energy) .....................

Comments:

Cycle 3: Light
Science activities and input at adult level .................................................
How difficult did you find the ideas dealt with on this cycle?
(1 hard to 5 easy) ..........................................................................................

Comments:

Page 261
School-based day ........................................................................................................
Comments:

Day 4 ................................................................................................................................

Comments

**Cycle 4: Electricity**
Science activities and input at adult level .............................................
How difficult did you find the ideas dealt with on this cycle?
(1 hard to 5 easy) ........................................................................................................
Comments:

School-based day ........................................................................................................
Comments:

Day 4 ................................................................................................................................
Comments

**Cycle 5: Living Things**
Science activities and input at adult level .................................
How difficult did you find the ideas dealt with on this cycle?
(1 hard to 5 easy) ........................................................................................................
Comments:

School-based day ........................................................................................................
Comments:

Day 4 ................................................................................................................................
Comments

Were you happy with the support available and how could it be improved?
What have you gained from the course?

Give specific examples of any changes to your teaching as a result of the course.

Were you happy with the amount of material covered?

Were you happy with the teaching methods used?

Was the balance between individual work, pair work, small group, large group work and input appropriate?

Do you have any comments about the handbooks and handouts?

Do you have any other comments about the course and possible follow up?

Are you prepared to be interviewed about the course at a later date?

Thank you for completing this, we hope you enjoyed the course.

Ron Ritchie (Course Tutor)
Bath College of Higher Education
Modular INSET Programme
UNIT EVALUATION REPORT
CA 311: Science in the National Curriculum (Avon)
Tutor: Ron Ritchie
External Examiner: Richard Mills

Introduction
This course was a collaborative venture with Avon and Wiltshire LEAs and gained DES approval as one of the 20 day courses run through central funding. The proposal was written jointly with colleagues at Bristol Polytechnic and close collaboration occurred during the planning and implementation.

Participants / attendance
Course members were selected after consultation with LEA advisory staff. Eighteen teachers were recruited and the majority of these were coordinators for science, including one from a special school. Attendance throughout the three units was extremely high (95%+), although two course members withdrew, one after a couple of sessions and another after a term. Sessions were run at BCHE (days 1, 2 & 4 in each of 5 cycles) or in local schools (day 3 of each cycle).

Staffing
The course was tutored by Ron Ritchie. Lee Towler (BCHE), Steve Stretch (Wiltshire LEA), Jim Sage (Avon LEA), Richard Ward and Chris Turner (BCHE) and John Griffiths and John Collins (Bristol Polytechnic) were involved in teaching. Di Ward (Avon LEA) was present during the planning of school-based work and on school-based days.

Course structure
The course involved 5 cycles covering Materials, Forces, Light, Electricity and Living Things. Each of these cycles involved 4 full days. The first was centre-based and involved workshops at the teachers own level. The second built on these experiences and often involved tutor input of the "scientist's view". The afternoon was spent planning work, in pairs, for the school-based day. Day three involved work with small groups of children using an action research approach informed by the Assessment in Primary Science Project (Avon, 1990). After several week's work back in their own classrooms the cohort came together to review this work and address concerns that had arisen.

Teaching methods
The centre-based sessions were usually based on practical workshops aimed at developing course members skills and knowledge and understanding in areas of science. This involved paired activity, small group and plenary discussion groups. The school-based days involved close observation of children and a rigorous analysis of the evidence collected in terms of the learning it demonstrated. Participants were encouraged to engage in classroom enquiries in their own classrooms between sessions. The last cycle dealt with INSET strategies for work with other colleagues in their own school or schools. Head teachers were invited in to join course members at the planning stage of this cycle.

Assessment
Fourteen out of sixteen course members submitted three written assignments. The quality of these varied from outstanding to a bare pass. All assignments did pass on the criteria used to assess them. All of the assignments provided evidence of the course impacting in the teachers' classrooms and, in the case of the third assignment having an impact on the work of colleagues.

**Methods of evaluation / Course members' views**

A variety of methods were used and course members' views were elicited at various stages of the course. At the end of the course more formal evaluation exercises were organised. Course members were asked to rate their own knowledge and understanding in areas of science at the start and end of the course. Analysis of these indicated an improved level of confidence by the end. They were also given an evaluation form to comment on individual sessions and cycles as well as more general points. These responses were analysed. The course tutor, as part of a research project, collected extensive data throughout the course to inform formative evaluation and tutor planning.

Course members were generally very positive about the course and gave many specific examples of how it had had an impact in their classes and schools. The cycles were all found valuable although Light and Living Things received the least positive evaluations. The latter was considered the easiest in terms of their own knowledge and understanding. Interestingly Forces was rated the most difficult but also the most useful/relevant. Several commented on how challenging they had found much of the course.

The school-based sessions were rated highly and the structure of the course was liked. The impact of the course most commonly mentioned concerned the adoption of a constructivist approach. Nearly all course members claimed to have spent more time eliciting children's ideas and taking them seriously.

The course handbooks (one for each cycle) were very positively evaluated and most found them very useful and worth sharing with colleagues.

**Other outside monitoring/evaluation**

This course was monitored by HMI (Dick Stockdale) who attended two full days. His informal report to the course team was very positive and Ron Ritchie was asked to write a paper for a National Conference on the DES Courses outlining the model used and its success. It was also monitored by the science adviser via the advisory teacher who attended several sessions. The external examiner (Richard Mills) received a sample of assignments and commented positively at the exam board about the quality of the course materials, student assignments and tutor comments on the assignments.

**General (Including facilities etc.)**

The facilities at the BCHE (PS 0.1) were acceptable and caused no critical comments. A book box was provided for course members' use.

**Future Developments**

The course will run next year, co-tutored by Chris Ollerenshaw. The course team will ensure the content of the course reflects present thinking with regard to the New Attainment Targets in the Science National Curriculum.

Ron Ritchie

**External Examiner's Comments**
It was most helpful to have a copy of the course outlines, with excellent statements on collaborative work, reflective teaching, classroom observation, language scrutiny.

The assignments undertaken were sensible and appropriate, reflecting a marriage of theory and practice, and drawing on direct observation and transcription. It was not always easy to distinguish between awards at Ordinary and Advanced levels and I wonder if the differentiation criteria are clear enough. No doubt, staff are continuing to work at this issue and one is only too aware of some of the difficulties.

In many instances, a personal statement at the end of a student's assignment, testifying to the insights gained, would have been both interesting and appropriate. In addition, self-assessment and peer-assessment, where possible, could help to establish a strong profile.

Tutor comment sheets were helpful and positive, giving enthusiastic feedback, laced with critical advice.

Most students seemed to have developed direct, first person styles, which fitted well with their material. This was to their credit and to the credit of tutors who had given appropriate encouragement and guidance.

Perhaps more students could be encouraged to word-process their assignments, not only as a means of aiding presentation, but also as a way of developing additional skills. Some needed help at proof-reading, particularly in the area of punctuation. Some were not entirely sure of the usual bibliographical conventions. It might be worth issuing a general statement to students on all these matters prior to the start of the course.

There was no doubt in my mind that the work under present scrutiny provided ample evidence of the course having sharpened students' awareness of children's learning, of classroom processes, of issues connected with assessment, of certain curriculum developments, to their own professional and personal satisfaction.

Course Director's Comments

The success of this course, and the parallel one run for Wiltshire LEA, has led to Avon sponsoring two cohorts in 1991-92. Wiltshire is also supporting one. The availability on a room for all of these (Sc0.5) has considerably helped with planning and teaching these.
## Data Collection Sheet (based on Assessment in Science Project)

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Initial Questionnaire for DES 20-day Science Course

Name:

School:

Describe some positive aspects of your science teaching:

Describe some positive aspects of the science going on in your school:

What made you apply for this course?

What concerns about science in your class would you like to address during the course?

What concerns about science in your school would you like to address during the course?

What do you hope to get from this course?

We hope you enjoy it!
### DES 20-day Science Course: Science Questionnaire

In the first column, rate your own knowledge and understanding [1 (good) to 5 (poor)]. In the second column, rate how easy you consider the content to teach [1 (straightforward) to 5 (difficult)].

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<td>AT 16</td>
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</tr>
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</table>

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Appendix 12

Interview Schedules

B.Ed. Students

a. Can you tell me how a bulb needs to be connected to a 4.5v battery in order to make it work?

b. Can you explain how the bulb works?

c. What is inside the bulb?

d. Look at each of these explanations of a circuit and comment on them (drawings provided).

   1. There will be no electric current in the wire attached to the base of the battery.

   2. The electric current will be in a direction toward the bulb in both wires.

   3. The electric current will travel in one direction but the current will be less in the 'return' wire.

   4. The electric current will travel in one direction and the current will be the same in both wires.

 e. Can you explain how a battery works?

f. Why does a battery run out?
Interview Schedules

DES 20-day Course Participants

1. How has the course affected your teaching?

Let's look at some areas of science covered on the course -

2. Can you explain to me what happens to the ice cubes left in the bottom of a glass out in the sun all day?

3. Can you explain how a paraffin lamp works?

4. Can you tell me what forces are acting on a tennis ball -
   a. when it is hit
   b. when it crosses over the net
   c. when it rolls to a stop?

5. Can you link the following words -
   gravity - mass - weight - acceleration - force?

6. Can you draw a torch showing the necessary connections to make it work?

7. Can you explain what is happening when a simple circuit is connected to make a bulb light up?

8. Are you aware of any alternative scientific ideas you held which were changed as a result of the course?
INTRODUCTION

The course model described below was developed through collaboration between staff at both institutions together with Avon and Wiltshire advisory staff. The DES approved a joint proposal and similar courses are now running at both institutions run by HE lecturers and advisory teachers from the two LEA.

DESCRIPTION

The course involves 5 cycles of four full days spread over three terms. Each cycle is based on a particular scientific theme (materials, forces and their effects, light, electricity and living things). The first day and a half of each cycle involves workshops at the teachers' own level. The second afternoon is spent planning for work with children. This is done collaboratively in pairs. Day three is spent in one course member's school. Each pair works with a small group of children. One observes and collects data, whilst the other works with the children. The first session (an hour) usually involves exploratory work, eliciting the children's ideas in the cycle's content area. An analysis and evaluation after this leads to planning activities for the same group aimed at challenging or developing their ideas and skills. A second teaching session involves the pair reversing roles. The day ends with another analysis and evaluation of assessed development in the children's skills and knowledge and understanding. There are then several weeks for related work in course member's classrooms before the final day of the cycle which reviews this work and provides opportunities for addressing concerns, especially related to their own knowledge and understanding, that have arisen.

APPROACH

The course is based on a constructivist approach to teaching science and owes much to the work of the Children's Learning in Science (CLIS) Project at Leeds University and the Assessment in Primary Science Project funded through the National Primary Centre (SW). Constructivism views the learner as an active constructor of his/her own knowledge who approaches any new learning experience with existing ideas. These ideas will affect any new understanding developed. Hence, eliciting existing constructs, basing new experiences on those existing ideas and providing time for reflection and the restructuring of ideas are essential elements of the approach used in sessions. The tutors' attempts to adopt this approach with the teachers offers a role model for their work with children.

The view of science that underpins the course is that contained in the Science National Curriculum. Implicit in this, is the acceptance of science as an investigational activity, "the way understanding is developed depends both on the existing ideas and on the process by which those ideas are used and tested in new situations." (Non-Statutory Guidance; A7). We have again tried to ensure that our approach to adult learners offers a model which they could use with children. We have encouraged teachers to come to an understanding of phenomena through exploration and investigation rather than through exposition, although the latter has been used when appropriate.

The course is also informed by action research and classroom enquiry activities are an integral part of the teachers' work. This involves both work in their own classrooms between sessions and, in a more intensive way, during school-based sessions of the course. Tutors' experience in this area has provided evidence that this approach is successful in improving teachers' confidence and competence in teaching science and at the same time extending their own background knowledge and understanding. This development of course members' scientific knowledge and understanding has been encouraged through opportunities to work collaboratively with each other in classroom situations. They identify examples of children's existing ideas and alternative frameworks and through analysis of these explore the relationship of the children's ideas with their own. This process serves to clarify their own ideas and help them to become better able to recognise those of the children. They are also required to identify appropriate activities aimed at developing the ideas elicited from the children. As a result of this intensive work with children during day 3 of each cycle and follow up work in their own classrooms, course members are able to articulate their own needs in terms of further background knowledge. These needs are then addressed during the last day of each cycle.
Assessment of children’s learning is an integral aspect of teaching and is approached as such throughout the course. Assessment, as a means of gaining insight into learning, is ongoing during the workshop sessions when a variety of strategies are used to collect and record evidence of the course members’ learning. The school-based sessions provide them with opportunities to develop their own assessment skills with children. These skills include active listening, focused observation and responsive questioning.

WORKSHOPS AT TEACHERS’ OWN LEVEL
The centre-based (classroom not laboratory) workshops involve:

Orientation activities to introduce the area of content involved. For example, during the forces cycle a collection of familiar everyday mechanisms was available for course members to try out and discuss, and they watched a video sequence illustrating examples of forces;

Elicitation of course members existing "scientific" ideas or constructs. This has involved various strategies including individual records, discussion in pairs, small groups and whole group. Numerous ways of recording these ideas have been used including posters, floor books, annotated diagrams, word spurs, concept maps etc. The elicitation has again involved questions about everyday examples of the phenomena and we have tried to ensure teachers have felt comfortable and unthreatened by the artefacts and materials used.

Practical explorations and investigations have been instigated by the teachers with tutor guidance. They have been encouraged to raise their own questions through open-ended explorations (in most cycles) and use these questions to devise more systematic investigations, based on the existing constructs they hold. The exploration phase has often taken some time and considerable constraint from tutors. It is this stage that has reinforced the importance of practical activities and the inextricable links between process and knowledge and understanding;

Discussion of outcomes, modification of existing constructs and possible developments has played a vital part in these sessions and we have explicitly referred to the social construction of ideas to reinforce the human nature of science and the tentative nature of scientific ideas;

Exposition from tutors addressing needs that cannot be met through practical activities has also featured. The particulate nature of matter was introduced during the materials cycle and accepted ideas about Newtonian physics during the forces cycle. This was often supported by computer simulations or video (eg MIST). The inputs of an ‘expert’s’ view have usually been in response to teachers’ questions and the tutors involved have attempted to present the accepted scientific ideas through dialogue;

Application of restructured ideas in different situations has been built into day 4. For example teachers were asked to use ideas about particle theory introduced during day 2 to explain how heat travels during day 4 of the materials cycle.

EVALUATION
The strategies being used on the course are being evaluated in a number of informal and formal ways. One of the tutors involved is carrying out an action research project based on the course which is providing considerable evidence which is being used in a formative way to influence planning and implementation. The extent to which teachers have restructured their ideas has been assessed as an ongoing part of the course using such means as concept maps (compared with those produced earlier in the course). This has produced evidence to show that the approach being used on the course is improving teachers’ scientific knowledge. Evidence from school-based sessions and from teachers’ own classroom work is providing evidence that the course is also having an impact in schools both in terms of the amount of science being taught and in the way science is being taught. The constructivist approach being used with teachers is being adopted by many course members.

Ron Ritchie (Bath College of Higher Education) / Chris Ollerenshaw (Bristol Polytechnic) 8.2.91
An analysis of teachers’ perceptions of the difficulty of teaching areas of science

Teachers were asked to rate each area of science (as described by the Attainment Targets in the 1989 version of the National Curriculum for science) according to how difficult they considered it to be to teach. The rating went from 1 straightforward to 5 difficult. In order to analyse the areas of concern all the 3/4/5 rating for each AT were totalled and a rank order of perceived difficulty to teach each produced, from most difficult to least.

Cohort 1 (September 1990)

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Comparative Data for Cohort 1, indicating areas of most concern at start and end of the course.

Rank order and total of 3/4/5 ratings were:

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**Total 3/4/5 ratings** 73 69
Comparative Data for Cohort 2 indicating areas of most concern at start and end of the course.

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<td>11</td>
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</tr>
<tr>
<td>4.</td>
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</tr>
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<td>5.</td>
<td>Earth &amp; Atmos.</td>
<td>9</td>
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</tr>
<tr>
<td>6.</td>
<td>Energy</td>
<td>9</td>
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</tr>
<tr>
<td>7.</td>
<td>Human Infl.</td>
<td>7</td>
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</tr>
<tr>
<td>8.</td>
<td>Materials</td>
<td>6</td>
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<td>Sound</td>
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</tr>
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<td>12.</td>
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<td>13.</td>
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<td>Total</td>
<td>3/4/5 ratings</td>
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An analysis of teachers' perceptions of their own knowledge and understanding in science

Teachers were asked to rate their own knowledge and understanding in science (as described by the Attainment Targets in the 1989 version of the National Curriculum for Science) from 1 *good* to 5 *poor*. In order to analyse the areas of concern all the 3/4/5 rating for each AT were totalled and a rank order of perceived knowledge and understanding in each area produced. The order goes from areas teachers perceived they had least knowledge and understanding to those in which they perceived they had most.

**Cohort 1 (September 1990)**

<table>
<thead>
<tr>
<th>AT</th>
<th>Variety of Life</th>
<th>Processes of Life</th>
<th>Genetics and Evolution</th>
<th>Human Influences on the Earth</th>
<th>Types and Uses of Materials</th>
<th>Earth and Atmosphere</th>
<th>Forces</th>
<th>Electricity</th>
<th>Information Technology</th>
<th>Energy</th>
<th>Sound and Music</th>
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<tr>
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<td>6 6 2</td>
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<td>0 9 3 2</td>
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Cohort 1 (June 1991)

<table>
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<td>8</td>
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Cohort 2 (September 1990)

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<td>10</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>AT9 Earth and Atmosphere</td>
<td>2 4 7 3</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>AT10 Forces</td>
<td>3 7 3 3</td>
<td>13</td>
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<td></td>
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<td>9</td>
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<td>13</td>
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<td></td>
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<td>AT14 Sound and Music</td>
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<td>AT16 Earth in Space</td>
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<td>AT2</td>
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<td>AT5</td>
<td>Human Influences on the Earth</td>
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<td>8</td>
<td></td>
</tr>
<tr>
<td>AT6</td>
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<td>AT10</td>
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<td>7</td>
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<td>Energy</td>
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<tr>
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<td>Sound and Music</td>
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<td>5</td>
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<tr>
<td>AT15</td>
<td>Using Light</td>
<td>4</td>
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<td>2</td>
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<tr>
<td>AT16</td>
<td>Earth in Space</td>
<td>2</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>
Comparative Data for Cohort 1, indicating areas of most concern in terms of the teachers' own perceptions of their scientific knowledge and understanding, at start and end of the course.

Rank order and total of 3/4/5 ratings were (beginning with areas of greatest concern):

<table>
<thead>
<tr>
<th>September 1990</th>
<th>June 1991</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. IT</td>
<td>Genetics</td>
</tr>
<tr>
<td>2. Forces</td>
<td>Energy</td>
</tr>
<tr>
<td>3. Materials</td>
<td>IT</td>
</tr>
<tr>
<td>4. Earth in Space</td>
<td>Earth &amp; Atmos.</td>
</tr>
<tr>
<td>5. Electricity</td>
<td>Forces</td>
</tr>
<tr>
<td>6. Sound</td>
<td>Sound</td>
</tr>
<tr>
<td>7. Light</td>
<td>Earth in Space</td>
</tr>
<tr>
<td>9. Earth &amp; Atmos.</td>
<td>Electricity</td>
</tr>
<tr>
<td>10. Energy</td>
<td>Light</td>
</tr>
<tr>
<td>11. Genetics</td>
<td>Materials</td>
</tr>
<tr>
<td>12. Variety of Life</td>
<td>Variety of Life</td>
</tr>
<tr>
<td>13. Processes of Life</td>
<td>Processes of Life</td>
</tr>
</tbody>
</table>

TOTAL 3/4/5 ratings 82 73
Comparative Data for Cohort 2, indicating areas of most concern in terms of the teachers’ own perceptions of their scientific knowledge and understanding, at start and end of the course.

Rank order and total of 3/4/5 ratings were (beginning with areas of greatest concern):

<table>
<thead>
<tr>
<th>September 1990</th>
<th>June 1991</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Forces</td>
<td>IT</td>
</tr>
<tr>
<td>2. IT</td>
<td>Earth in Space</td>
</tr>
<tr>
<td>3. Genetics</td>
<td>Sound</td>
</tr>
<tr>
<td>4. Energy</td>
<td>Earth &amp; Atmos.</td>
</tr>
<tr>
<td>5. Materials</td>
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<tr>
<td>6. Earth &amp; Atmos.</td>
<td>Forces</td>
</tr>
<tr>
<td>7. Earth in Space</td>
<td>Energy</td>
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<tr>
<td>8. Sound</td>
<td>Light</td>
</tr>
<tr>
<td>9. Electricity</td>
<td>Electricity</td>
</tr>
<tr>
<td>10. Light</td>
<td>Variety of Life</td>
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<td>Processes of Life</td>
</tr>
<tr>
<td>13. Variety of Life</td>
<td>Materials</td>
</tr>
</tbody>
</table>

**TOTAL 3/4/5 ratings** 109 35
Appendix 16

An analysis of DES 20-day Course Evaluation Forms

The sections of the Evaluation Sheets (Appendix 7) that involved numerical responses were analysed to rank the course day in order according to how good/relevant to poor/not relevant teachers perceived them to be. A mean value for each day (although days 1 & 2 were combined to elicit one response) on each cohort was calculated and the rank order with the mean values are shown below. (The italicised days were not used for data collection related to the enquiry):

<table>
<thead>
<tr>
<th>Cohort 1</th>
<th>Cohort 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials 1 &amp; 2</td>
<td>Forces 1 &amp; 2</td>
</tr>
<tr>
<td>Light 1 &amp; 2</td>
<td>Living things 4</td>
</tr>
<tr>
<td>Living things 1 &amp; 2</td>
<td>Materials 3</td>
</tr>
<tr>
<td>Electricity 3</td>
<td>Material 1 &amp; 2</td>
</tr>
<tr>
<td>Materials 4</td>
<td>Materials 4</td>
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<td>Electricity 4</td>
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<td>Forces 4</td>
<td>Living things 3</td>
</tr>
<tr>
<td>Materials 3</td>
<td>Forces 3</td>
</tr>
<tr>
<td>Forces 1 &amp; 2</td>
<td>Light 4</td>
</tr>
<tr>
<td>Forces 3</td>
<td>Forces 4</td>
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<td>Light 4</td>
<td>Light 3</td>
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<tr>
<td>Electricity 4</td>
<td>Light 1 &amp; 2</td>
</tr>
<tr>
<td>Living things 3</td>
<td>Living things 1 &amp; 2</td>
</tr>
</tbody>
</table>

Mean values:

<table>
<thead>
<tr>
<th>Cohort 1</th>
<th>Cohort 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials 1 &amp; 2</td>
<td>Forces 1 &amp; 2</td>
</tr>
<tr>
<td>Light 1 &amp; 2</td>
<td>Living things 4</td>
</tr>
<tr>
<td>Living things 1 &amp; 2</td>
<td>Materials 3</td>
</tr>
<tr>
<td>Electricity 3</td>
<td>Material 1 &amp; 2</td>
</tr>
<tr>
<td>Materials 4</td>
<td>Materials 4</td>
</tr>
<tr>
<td>Electricity 1</td>
<td>Electricity 1 &amp; 2</td>
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<tr>
<td>Light 3</td>
<td>Electricity 3</td>
</tr>
<tr>
<td>Living 4</td>
<td>Electricity 4</td>
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<tr>
<td>Forces 4</td>
<td>Living things 3</td>
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<tr>
<td>Materials 3</td>
<td>Forces 3</td>
</tr>
<tr>
<td>Forces 1 &amp; 2</td>
<td>Light 4</td>
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<td>Forces 4</td>
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<tr>
<td>Light 4</td>
<td>Light 3</td>
</tr>
<tr>
<td>Electricity 4</td>
<td>Light 1 &amp; 2</td>
</tr>
<tr>
<td>Living things 3</td>
<td>Living things 1 &amp; 2</td>
</tr>
</tbody>
</table>

Page 286
Course members were also asked to rate each cycle according to how difficult they found the ideas (scientific) covered from 1 *hard* to 5 *easy*. Those cycles not covered by data collection for the enquiry are italicised.

The rank order is again based on a calculated mean value for each cycle with each cohort.

<table>
<thead>
<tr>
<th>Cohort 1</th>
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</tr>
</thead>
<tbody>
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<td>Forces</td>
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<td>Materials</td>
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<td>3.5</td>
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<tr>
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<td>Materials</td>
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<tr>
<td>4.23</td>
<td>4.46</td>
</tr>
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</table>
Appendix 17

Concerns identified as a result of analysing Case Study 1

1. To what extent should I ensure an orientation period for adult learners?

2. Should I introduce appropriate 'scientific' words if they do not come from the group?

3. What strategies can I use to elicit students' existing ideas?

4. Should I implement sessions which are so tightly structured, paced and controlled and should this depend on the particular content involved?

5. How can I collect evidence of students restructuring their ideas?

6. How can I encourage students to apply their restructured ideas in novel situations?

7. What view of science do students take away from sessions like this?

8. How can I emphasise the importance of context for scientific activities with children?

9. When should I use the word "predict" - do I understand its meaning?

10. To what extent should I encourage individuals to expose their ideas?

11. Should I deal with every 'alternative framework' identified or focus upon common ones?

12. To what extent did the metaphors I used foster misunderstanding in the students?

Concerns identified as a result of analysing Case Study 2

13. Do I allow students adequate time for practical exploration and investigation? (CS2)

14. How can I use the relationship between adults' and children's constructs to improve adults' knowledge and understanding of science? (CS2)
Concerns identified as a result of analysing Case Study 4

15. How can I give students/course members more 'ownership' of their investigations?

16. At what stage of a DES course cycle is exposition most appropriate?

17. How can I encourage students/course members to raise scientific questions?

18. How can I meet 'individual' needs within the DES course structure?

Concerns identified as a result of analysing Case Study 5

19. What are the implications of exposition by an expert in terms of the students'/course members' views on their role as teachers?

20. How can I make constructivism less threatening to students/course members?

Concerns identified as a result of analysing Case Study 7

21. To what extent should I encourage students/course members to use quantitative approaches during investigations?