TOWARDS EFFECTIVE TEACHING IN PRIMARY SCIENCE:

AN ANALYSIS OF THE EVOLVING CONTRIBUTION OF THE SPACE PROJECT TO UNDERSTANDING THE ROLE OF THE TEACHER

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DECLARATION

This thesis contains some material which was part of my MEd dissertation. It is located in section 5 of chapter 7 and is clearly marked within the text.

I have used the analytical framework which I developed for my MEd and which has subsequently been published in the International Journal of Science Education. The framework is located in Appendix 19, and is referenced fully in the reference section.

The Primary SPACE Project on which this thesis is based was a joint research project. I have itemised my contributions to the Project in Appendix 1. The sections of research reports which I have included in Appendices 3 - 9 and 12 - 18 to support my thesis were all written by me.

ABSTRACT

The main aim of this thesis is to further understanding of primary science teaching through the analysis of a constructivist research project and its evolution into curriculum materials. My analysis is underpinned with views on the nature of constructivism, the nature of primary science and research into effective teaching. In particular, I seek to locate the Primary SPACE (Science Processes and Concept Exploration) Project within the paradigm of constructivism; to explore notions of children's ideas as either theories or everyday ways of knowing; to chart the influence of constructivism in the *Nuffield Primary Science* (*NPS*) curriculum materials and to observe case studies of classroom practice linked to both SPACE and *NPS.* My analysis locates SPACE in a form of constructivism particular to primary science (Harlen and Osborne, 1985) which has more in common with "good primary practice" than with other approaches to constructivism. The messages from the *NPS* Science Co-ordinator's Handbook are very similar to this, while the practice modelled in the Teachers' Guides relates more closely to "guided discovery". Observation of a teacher using *NPS* for the first time reveals practice very similar to that modelled in the Teachers' Guides in which the teacher is in control of the right answer. This is more successful than a SPACE teacher who tries to change the social dimension of classroom teaching and learning to give the children more ownership, according to constructivist principles. "Guided discovery" is acknowledged to be unprofitable for learning (Hodson, 1993) yet the children being taught using *NPS* had learning outcomes exceeding the teacher's expectations. I suggest reasons for the success of *NPS* based on research into effective teaching: that repetition of clearly stated key ideas leads to focused teaching in which learning activities are matched to intended learning outcomes. This approach does not view children's ideas as theories to be developed and is therefore not related to constructivism. I suggest that the way forward for primary science teaching is to embrace socio-cultural approaches so that the teacher's role corresponds more closely to society's norms for education in science, that children learn the accepted science view through supported negotiation, with their ideas viewed only as everyday ways of knowing.

GLOSSARY

This thesis contains terminology related to the National Curriculum of England and Wales (DfE, 1995) which is defined here.

Attainment target	The attainment which is required in any particular area of study. In science, it is sub-divided into eight levels of attainment. AT1 (Sc1) is related to 'doing' science (experimental and investigative science); ATs 2,3 and 4 are related to the knowledge content of science.
Key Stage One	The first two years of a child's schooling, between the ages of five and seven (years 1 and 2).
Key Stage Two	The four years of schooling which often take place in a junior school, between the ages of seven and eleven (years 3 to 6).
Programme of Study	The experiences which will enable children to reach the attainment targets.
Level description	A description of the attainment which denotes performance at a particular level.

ABBREVIATIONS

AT	Attainment target (see above)
CLIS	Children's Learning in Science
CPD	Continuing professional development
GLM	Generative Learning Model
INSET	Inservice education and training.
KS	Key stage (see above)
LISP	Learning in Science Project
NC	National Curriculum
NPS	*Nuffield Primary Science*
PoS	Programme of study (see above)
SCH	Science Co-ordinator's Handbook
SPACE	Science Processes and Concept Exploration
Y1, Y2 etc.	Year 1, year 2 etc. (see above under key stages 1 and 2)

CHAPTER 1

INTRODUCTION AND BACKGROUND TO THE THESIS

1. Personal Context and Aims of the Thesis

I have written this thesis first and foremost in order to contribute to our understanding of the development of effective science teaching in primary schools. The discussion is embedded in the context of the Primary Science Processes and Concept Exploration (SPACE) Project, a research project which was located within the constructivist paradigm and which inspired the production of the *Nuffield Primary Science* (*NPS*) curriculum scheme. By locating the thesis within this context I have taken advantage of my unique position as the only full-time researcher on that Project. The implications of my position for this thesis are that I have particular, unrivalled insights into the Project data and the methods of its production. Until now, the role of the teacher in respect of the children's learning, rather than as a co-researcher, has remained relatively unexplored: it was described subjectively but was not the focus of objective observation or rigorous analysis. It is an exploration of the teacher's role which is central to this thesis.

When I started to work on the SPACE Project in 1987 it was just beginning; funding had just been awarded and the proposal to obtain that support was all the documentation that existed. As the only funded researcher based in Liverpool I did the vast majority of the work involved in fleshing out and operationalising the general ideas which were suggested by the steering group. In doing this, I put my own slant on the developing work, a slant which is still evident when looking at the *NPS* materials, suggesting that my inputs were both relevant and significant. As SPACE was a team project I am in no way trying to imply that I can take sole credit for its development, and for this reason I have attempted to itemise what I consider to have been my main contributions. This itemisation can be found in Appendix 1, with a complete list of Project personnel in Appendix 2.

As the sole full-time researcher on the Project, and the most recently practising primary school teacher, I played a major role in the development, execution and writing up of the SPACE Project research. For this reason, I consider I am justified in including material from two of the SPACE research reports (Russell and Watt, 1990; Watt and Russell, 1990) to support this thesis. These research reports reflect the state of the Project team's thinking at the time of their writing, and this was largely intuitive. SPACE has been extensively cited (e.g. Harlen, 1993, 1996; Johnston, 1996; Qualter, 1996) and is "much acclaimed" (Roberts, 1996). It has had a huge impact upon research into primary science, as a look at any issue of *Primary Science Review* will show, and for these reasons the lack of methodological and theoretical rigour which underlies SPACE should not invalidate it as a piece of research. In fact, this thesis provides me with the opportunity to inject a theoretical perspective now, with the benefit of hindsight. Sections from the 'Sound' and 'Growth' reports are located in Appendices 3 - 9 and 12 - 18 in order to conform with the regulations of the University of Warwick. However, they are integral to the coherence of the thesis and should therefore be read as such, as signalled in the text.

I was interested to establish the extent to which the constructivist underpinnings of SPACE were retained within *NPS*, and how the materials as written were subsequently translated into classroom practice. This thesis, then, considers the current state of knowledge about effective primary science teaching by tracing the SPACE Project through from its inception to its transformation into the *NPS* curriculum materials and its implementation in the classroom. I will be analysing the Project methodology and the classroom practice which characterised the SPACE

Project before moving on to explore the nature of the relationship between SPACE and *NPS* and examining a case study of *NPS* in use in the classroom through participant observation of a teacher implementing the materials for the first time. By embedding the analyses in the literature pertaining to constructivism, primary science and effective teaching, the conclusions provide evidence that:

- constructivism as conceived in SPACE is very closely linked to "good primary practice";
- neither constructivism nor "good primary practice" is an effective way of teaching;
- effective teaching is reliant on having a good subject knowledge;
- *NPS* is different from SPACE, placing less emphasis on children's ideas and more on the accepted science view;
- *NPS* is effective in the [one] classroom;
- this effectiveness is not due to constructivism but to the emphases on assessment and developing key ideas.

Implications for future research and continuing professional development revolve around the crucial issue of developing teacher subject knowledge in science. In the following sections, I outline the scope of the thesis in theoretical terms before describing the shape the thesis takes, chapter by chapter.

2. The Context of Constructivism

Constructivism as a philosophy is based upon the viewpoint that individuals actively generate their own meaning of events and experiences, leading to the development of personal understanding. The term has been used quite loosely and embraces a number of different approaches within it. Its status as a useful educational theory is disputed, but it has been very influential in science education research over the last twenty years. Its relationship to science education stems from research which has shown that children approach science education with their own ideas about the world (Driver and Erickson, 1983), ones they have generated from making sense of their everyday experiences and which have the characteristics of being context-specific and resistant to change. Science educators and researchers have used this information as the basis for curriculum development in order that children's ideas are challenged by structured exposure to the scientists' view. The vast majority of this research and curriculum development has been carried out in secondary schools. That which has taken place in a primary environment has had a different emphasis: instead of challenging children's ideas, the focus is on helping children to make their thinking more scientific through investigation (Biddulph and Osborne, 1984; Harlen and Osborne, 1985; Harlen, 1992; 1993; 1996). These constructivist teaching experiences are intended to ensure that children can develop coherent conceptual frameworks rather than having school science and everyday science ideas set up in opposition to each other.

However, an acknowledgement of the existence of children's ideas need not imply an acceptance that the ideas should be changed. Solomon (e.g. 1983, 1988, 1995) advocates accepting the ideas as symptomatic of everyday language and thought, and encouraging children to differentiate between the two domains of thinking so that school science runs alongside everyday ideas. The approach of "social constructivism" which is advocated by Solomon amongst others, has been embraced by constructivists as contributing to their understanding. However, its advocates do not identify themselves with that tradition and for the sake of clarity I refer to that approach as socio-culturalism.

The location of SPACE within the constructivist paradigm is one of my prime concerns. By establishing SPACE's position I have been able to chart the changes in emphasis which occur as "the SPACE approach" moves further from researcher control and closer to the classroom.

3. The Nature of Primary Science

Alexander (1992) argues that teaching in primary schools has been based upon belief systems rather than empirical evidence of how children learn, leading to the prevalent view that children learn by doing. In the early years of schooling this view is even more prevalent (e.g. Johnston, 1996), and Anning (1991) is one of the few writers to use research to counter the accepted orthodoxy. In primary science the learning by doing approach has been justified by taking the view that children should learn science in the way scientists do, through investigation and experiment. This approach, Harlen (1992) argues, enables children to develop an accurate picture of the nature of science by experiencing the creation of knowledge through the development of their own provisional ideas. This perspective conforms to an inductive view of science, that particular observations form the basis of testing and are then generalised into theories. However, particularly in combination with a constructivist approach as advocated by SPACE, inductivism limits the scope for children to access the currently accepted body of knowledge of science, restricting their opportunities to *learn science* as well as to *learn about science* (Hodson, 1993a). A more deductive approach, in which general theories are established and used to test specific cases of knowledge is necessary in order for children to learn the knowledge of science, and this approach is more in line with a socio-cultural standpoint than constructivism.

4. Teaching Strategies and Effective Teaching

In 1986, Shulman advocated a reconsideration of the importance of subject knowledge to teaching. His itemisation of subject knowledge and its classroom-active form, pedagogical content knowledge, has led to research which highlights links between effective teaching and teaching strategies (e.g. explanation) which are dependent upon subject knowledge. Because the range of strategies employed is related to the teacher's attitude to science teaching (Wolfe, 1989) then the level of subject knowledge is likely to affect the style of teaching and therefore learning in which children can engage. In order for constructivist teaching to happen, then, a teacher must have an appropriate attitude to science teaching and must possess the requisite science knowledge to enable them to make an informed choice of approach.

5. The Primary SPACE Project

The Primary SPACE Project ran from 1987 to 1992 and was based at Kings College London and Liverpool University. The aims of the Project were to:

- find out what ideas children held in a range of science concept areas
- help children to develop their ideas in a direction which would make them more scientifically useful.

Over time, the SPACE Project became established as largely classroom-based research. I was closely involved with the teachers who were working with us, and I planned and ran the majority of the INSET (inservice education and training) which accompanied the Project. The teachers collected qualitative data from their class using instruments which we designed to make this feasible; they undertook some analysis of their data, with assistance from the research team; they selected appropriate experiences to facilitate the children's conceptual development; and they collected follow-up data to determine how successful the learning experiences had been. The wealth of classroom-generated data supported the findings from the individual interviews conducted by the research team, ensuring that the Project was very successful with regard to its first aim, establishing the range of ideas held by children, and inferring where these ideas might have come from in the children's everyday experiences.

However, it was less obviously successful with regard to its second aim, of developing children's understanding, partly, I suspect, because there was no researcher-generated data against which to compare the classroom data: the specific learning experiences were determined exclusively by individual teachers rather than researchers and were therefore not reliably replicated. The considerable degree of teacher collaboration in the Project led to attendant and initially unanticipated developments in teacher practice. These trends laid a firm foundation for a curriculum development initiative to run alongside the research, resulting in the production of the

Nuffield Primary Science (*NPS*) materials, which were published in 1993, and which its authors viewed as a vehicle for disseminating the ethos of the SPACE Project more widely.

6. *Nuffield Primary Science*

While I was intimately involved with SPACE for three years, I had no links with the development of *NPS*. The *NPS* materials consist, in their second edition (1995), of a Science Co-ordinator's Handbook (SCH), Teachers' Guides (TGs) and pupils' books. The SCH is intended to assist schools with their planning and the implementation of "the SPACE approach". The two series of TGs, one at each of key stages 1 and 2, address all the areas of science addressed in the National Curriculum (DfE, 1995) by providing key ideas for teaching, the likely spectrum of children's ideas, suggested practical activities and background science. The pupil books are referred to in the TGs but are supplementary and do not form the focus of the majority of science work envisaged for the classroom. The focus of the classroom work is therefore clearly the TGs in which exemplar activities are provided for teachers to adapt as appropriate for their classes. It might be expected, then, that the activities as modelled in the TGs would be clearly related to "the SPACE approach" as advocated in the SCH and as portrayed in the SPACE research reports.

I was interested to determine the extent to which *NPS* is built upon SPACE, and any ways in which it differs from the advocated approach. This relationship is very important to establish since education in Britain aims for children to acquire particular knowledge and understanding whilst at school. As SPACE was not notably successful in enabling the children to develop such understanding, then, assuming *NPS* to be a useful set of curriculum materials which can help teachers in this regard, any changes which have been made to the role of the teacher in the development from SPACE to *NPS* should have important messages for the science education community about the nature of effective science teaching.

7. The Structure of the Thesis

As constructivism forms the theoretical underpinning for my research, I begin in Chapter 2 with a detailed exploration of the debates surrounding constructivism. One of my principle aims is to look at the range of theoretical positions which is encompassed by the term and to assign more precise labels to each so that it is possible (in chapter 5) to locate SPACE within the constructivist paradigm. A second aim is to explore the ramifications for science teaching of the dichotomy between children's ideas being considered as either scientific theories or everyday ways of knowing. Ideas as scientific theories would clearly need to be developed in accord with the processes of science, while everyday ways of knowing can be acknowledged as such and not made the object of teaching. In terms of teaching I conclude that the latter perspective offers more opportunities for children to develop their knowledge of science, as well as enabling children to function socially since their intuitive ideas mirror society's linguistic structures and are necessary for effective communication.

The majority of the constructivist research has been conducted with secondary children so, in order to locate SPACE within constructivism in the primary school, chapter 3 considers recent developments in primary science education. I begin by contextualising primary science as an aspect of primary education rather than simply on a continuum with secondary science. I contend that the nature of primary science has evolved because of prevalent views concerning "good primary practice" which can then be supported by an inductivist view of the nature of science rather than vice versa. This leads to primary science being characterised by learning through investigation, though recent research in line with socio-cultural perspectives on teaching challenges the link between doing and understanding, giving more prominence to discussion-based activities.

As primary science has an ideological basis, it is important to compare the teacher roles advocated by Harlen, for example, with the research on effective teaching. Chapter 4 takes a broad view of the factors which influence effective primary science teaching so that the efficacy of those aspects of constructivism which set it apart from other approaches to teaching and learning can be evaluated. I contend that, despite what has been said to the contrary, teachers need a good understanding of science in order to be able to teach children science in a coherent manner. This teaching needs to be in the context of a clearly understood framework for science teaching and learning so that children have appropriate expectations for the nature of the work they undertake. In this regard, curriculum materials should provide teachers with useful support for teaching science. I have inspected the structure and content of a range of curriculum materials and conclude that, while the manual accompanying materials usually has clear ideas about the nature of primary science, the pupils' materials provide too much structure to enable them to be used in the manner intended. For a scheme to impact on classroom practice there needs to be investment in teacher development alongside the materials. I therefore end the chapter with a look at how practice in primary science can be developed, comparing perspectives on teacher development which reveal that teachers need the motivation to change and a period of time over which to do it.

Having thus contextualised the study from three perspectives, chapter 5 focuses upon the Primary SPACE Project, exploring its methodology and methods of analysis. In particular, I define the role of the SPACE teacher as one who enables children to articulate then test their ideas in a supportive environment. The analysis of SPACE enables me to locate it within the constructivist paradigm, in the field of personal constructivism (Osborne and Wittrock, 1983; 1985) and within the particular approach of building on children's ideas (Harlen and Osborne, 1985).

In order to compare the constructivism of SPACE with that described as "the SPACE approach" in *NPS*, in chapter 6 I present the results of a textual analysis of the *NPS* materials (the SCH and the TGs for one topic, sound and music) which establishes that the role of the teacher in the SCH is very similar to that in the SPACE Project. However, by analysing all of the questions and drawing inferences about the role of the teacher from the exemplar material contained in the TGs, I conclude that the TGs do not necessarily model a constructivist teaching approach and can be interpreted as being more in line with the 'guided discovery' approach to science teaching in which children are encouraged to learn one particular right answer through open-ended investigation.

Chapter 7 draws on my analysis of the role of the SPACE teachers in order to illustrate the classroom-based work which became the hallmark of the Project. I comment on the different phases of the research cycle in relation to the teachers' growing confidence and competence in using constructivist techniques in the classroom. The teachers' development did not, though, proceed as anticipated from the earlier discussion on teacher development, and I suggest a model to account for the difficulties inherent in adopting a philosophically different approach to working while at the same time trying to master new skills and knowledge.

Chapter 8 moves into a classroom to observe one teacher using the NPS materials for the first time. My analysis of her teaching - using the framework provided by the teacher role definitions in the SCH - shows that she is more directive than would have been expected for a guided discovery approach and that the substantial discussion with which she concludes each session contains characteristics relating to a socio-cultural approach to teaching.

In Chapter 9 I combine previously unanalysed material in order to draw clear comparisons between SPACE and *NPS* in relation to constructivism and effective teaching. This analysis serves to reinforce those in chapters

7 and 8 in that the SPACE teacher is seen to accept the children's ideas to such a great extent that no challenge or development is evident at all. In comparison, the *NPS* teacher is initially accepting of a range of ideas but becomes systematically more expecting of science ideas as she strives to reinforce the children's developing understanding. I conclude that the differences between the two teachers largely relate to the degree to which each of them is trying to modify the accepted social culture of the classroom.

In Chapter 10 I draw conclusions about the developments which contribute to effective primary science teaching, based on evidence from the *NPS* and SPACE teachers of what were the strengths and limitations in their practice. The importance of subject knowledge is reinforced, as is the setting of clear learning objectives and the repetition of key ideas throughout the topic. Importantly, these effective features relate very comprehensively to the findings of earlier research into successful science teaching. While I do not support constructivism as a way forward for primary science it is important to recognise the contribution of personal constructivism, SPACE and *NPS* to the current debate, particularly with reference to an acknowledgement of the existence of children's ideas and their contextual significance for everyday understanding.

Chapters 11 and 12 look forward to future developments in research and teacher education primarily in relation to teachers' subject knowledge of science. These developments will contribute to a secure research basis for primary science.

CHAPTER 2

DEBATES IN CONSTRUCTIVISM

In this chapter I survey the current thinking on constructivism, looking at how the theory has developed and how the term has come to be used as an umbrella notion to embrace a wide range of methodological and philosophical approaches. I categorise these approaches in order both to differentiate between them, and to locate constructivism as it is interpreted in primary science within the paradigm. In particular, I consider the social dimension of learning in relation to constructivism and place the socio-cultural perspective apart from constructivism. I present the two contrasting perspectives on the nature of children's ideas as either scientific theories or everyday ways of knowing, and argue that the former viewpoint is more compatible with constructivism and the latter with socio-culturalism. By comparing different approaches to teaching for conceptual change I form the opinion that constructivism is a useful way of describing learning but that socio-culturalism is more appropriate as an approach to teaching. My analysis concludes with the generation of the working definition of constructivism which I use in this thesis.

1. Defining Constructivism within the Literature

The recent wave of research in constructivism began in 1978 when Driver and Easley produced their paper describing adolescent concept development in science. A simple definition of constructivism would embrace the notion that individuals are active learners who generate theories about the world around them through their interactions with it, and that these theories may be idiosyncratic and context-dependent. That much everyone would be able to agree on. Beyond that, definitions become more complicated since, as Solomon (1994) points out, constructivists appear to have no problem in accommodating a whole range of contradictory views under the one umbrella concept, without modifying or expanding the label "constructivism". For example, over a period of eleven years, Driver has written about constructivism with differing emphases. The following quotations illustrate these differences, while I acknowledge that one quote could be unrepresentative of the tenor of her writing. Initially, Driver (1983) appears to be seeking ways of teaching children the principles of science more effectively by acknowledging their starting point in terms of ideas:

> "pupils may have some strongly held ideas or beliefs about the phenomena they study in science lessons. These ideas influence the observations pupils make in their experiments, as well as affecting the explanations they give for them. They can also persist in a range of situations and be resistant to change....If we wish children to develop an understanding of the conventional concepts and principles of science, more is required than simply providing practical experiences. The theoretical models and scientific conventions will not be 'discovered' by children through their practical work. They need to be presented. Guidance is then needed to help children assimilate their practical experiences into what is possibly a new way of thinking about them"
> (Driver 1983, p.33, p.9)

Five years later, she gives more weight to these ideas, suggesting that children are acting as scientists to develop their own theories, and that these should be taken seriously:

> "The process by which knowledge is constructed by the learner is broadly surmised to involve a process of hypothesis testing, a process whereby schemes are brought into play (either tacitly or explicitly), their fit with new stimuli is assessed and, as a result, the schemes may be modified...There is an epistemological implication of this view of knowledge as constructed which has yet to be taken seriously by educators, and that is that to know something does not involve the correspondence with an external authority but the construction by the learner of schemes which are coherent and useful to them." (Driver 1988, p.135)

Six years later again, she and her colleagues appear to build on the notion of coherent theories by acknowledging that these will be influenced by the views of other children in the classroom, thus suggesting that peer validation has an important role in school science learning.

> "It is recognised that learning about the world does not take place in a social vacuum. Children have available to them through language and culture ways of thinking and imaging...Whether an individual's ideas are affirmed and shared by others in classroom exchanges has a part to play in shaping the knowledge construction process." (Driver et al 1994, p.3)

Over the eleven years, there is a marked shift from making curriculum delivery more effective by being aware of ideas to using children's ideas as the basis for knowledge construction, and therefore presumably curriculum delivery. Because constructivism appears to be such an evolving entity it could be considered to be a moving target for critics. However, among constructivist researchers and critics this evolution and broadening appears to be considered unproblematic. The result is that critics have aimed their fire equally broadly, both camps failing to identify the increasing inconsistency of definition. For example, Osborne (1993) focuses on the umbrella concept of constructivism for his critique, leading him to suggest a commonality of definition which does not accord with the range of positions held by researchers in the field. In order to try to untangle the various standpoints within constructivism, I will describe different viewpoints in the following paragraphs and, where possible, add a descriptor to the label "constructivism" in order to enable more precisely focused discussion to follow.

Bell and Gilbert (1996) categorise constructivist theories under five headings. Their categorisation is worth considering because it begins to impose some order upon the field of constructivism. Their sub-groupings are as follows:

- Personal construct theory (Kelly, 1969)
- Piaget (1953; 1974)
- Personal constructivism (Osborne and Wittrock 1983, 1985)
- Radical constructivism (von Glasersfeld, 1991)

- Social constructivism (Berger and Luckmann, 1966)

Of these five, the two which have underpinned the majority of constructivist research projects are Piaget and Osborne and Wittrock. The five categories will be described in the order listed, with more detail given to those models from which ideas will be pursued.

1.1 Personal construct theory

Kelly (1969) derived his theory from his work as a clinical psychologist studying the concepts which adult patients developed. He considered that a person would construct their understanding of concepts from their experience and continually test their understanding against reality in order to make it more realistic. While the range of constructs which could be formed was not limited in any way, except by the individual's imagination, Bell and Gilbert consider the weakness of this theory to be the ease with which an individual can develop or modify their own constructs as this is at odds with the finding that children's ideas are resistant to change.

1.2 Piaget and personal constructivism

Piaget (1953) considers concept acquisition and development to involve the mind in a quest for equilibrium. Where a new experience can be allied by the learner with a previously experienced phenomenon then it will be accommodated within existing mental structures. Where it cannot, the mental structures will be in a state of disequilibrium and will need to adapt so that the new experience can be assimilated and equilibrium returned. This articulation of a process of mental growth is independent of Piaget's (1974) stage theory of intellectual development. However, the criticisms of the stage theory in terms of: its focus on context-free, abstract thought; the implication that there is a particular 'given' view that the individual has to adopt (O'Loughlin, 1992) and the focus on linear progression through stages (Donaldson, 1978) have affected the manner in which Piaget's ideas are used to underpin science education.

Osborne and Wittrock's (1983; 1985) Generative Learning Model (GLM) avoids the pitfalls of a stage model and uses terminology from cognitive psychology to describe an essentially similar process of concept development in which attention is paid selectively to stimuli as a result of the interaction of sensory inputs with existing ideas. Links are then generated between the stimulus and ideas in the memory store in order to generate meaning. These meanings can then be tested out against other items of the memory store in order to enhance their validity. This active testing of ideas using mental processes is an essentially individual process which leads to the construction of individual understanding, which might follow orthodox scientific understanding or be more idiosyncratic, dependent on previous experience. In their 1983 paper, Osborne and Wittrock strive for the former by suggesting highly structured teaching approaches drawing on psychological principles such as retrieval cues and advance organisers. By their second paper in 1985 they are more tolerant of the latter and advocate more ownership for the learner of the process, according the status of theories to the children's ideas. By mirroring what some consider to be the process of knowledge acquisition in science, this approach is inherently attractive as a model for science education. However, its focus on sensory inputs as the data for concept development suggests an inductive model of science (Driver, 1983), which can lead to little learning of the accepted science viewpoint.

Many terms are used to describe these idiosyncratic theories: "children's ideas" (Osborne, Bell and Gilbert, 1983), "alternative frameworks" (Driver and Easley, 1978) or "misconceptions" (Posner et al, 1982) are commonly found. I will use the term "children's ideas" to describe any or all of these. The nature of children's ideas will be described in section 2 of this chapter.

1.3 Radical constructivism

Von Glasersfeld (1991) describes radical constructivism so as to make it the ultimate explanation in terms of individual learning. He describes how each individual creates their own construction of reality from their experiences. While this relates very closely to Kelly's, Piaget's and Osborne and Wittrock's ideas, he pursues this notion of the individuality of understanding with the consequence that he considers a shared reality to be impossible since every person will have their own perceptions and their own interpretations of them. O'Loughlin (1992) and Olssen (1996) dispute this relativist viewpoint, claiming that there is a shared reality which takes the form of agreed understandings about knowledge and society and is created through the interactions of individuals in a social situation. Were Von Glasersfeld's views to be accepted, the aims of education as a process would need to be changed so that the acquisition of a knowledge base became unimportant.

1.4 Social constructivism

The area in which the four previous models place least emphasis is the social domain and its impact upon an individual's cognitive functioning. Berger and Luckmann (1966) argue that our notions of reality are influenced by the context in which we encounter them and are thus socially determined. This viewpoint has received far more attention in recent years, perhaps partly in response to Solomon's consistently argued position on the issue, and partly because of the growth of popularity of the notions of Vygotsky (1962). Building on Vygotsky's ideas, Solomon (1983) describes how children's ideas in science are part of their 'life-world view' which is formed as a result of interactions with everyday experiences, rather than their 'science-world view' which is formed as a result of formal science teaching. The implication of this theory is that there is an explicit acknowledgement that the social setting in which individuals function will impact upon their intellectual development, and that different social settings will lead to different perceptions of the world.

Bell and Gilbert list a number of terms relating to social constructivism which they consider to be equivalent and which different authors use to refer to similar notions. These are: social cognition, everyday cognition, situated cognition and learning, cognitive apprenticeship, common sense ways of knowing, learning in context and socio-cultural views of learning. However, there are two distinct issues which are conflated here. Firstly, there is the idea that society has ways of understanding everyday life which impact (for example through language use) upon our understanding of the world, and which might be different from the view of the world which school science learning seeks to portray. Secondly, there is the notion that all knowledge is mediated by social interaction and that, to learn to culturally agreed norms, the learner has to interact with a more knowledgeable other who can aid the learning process. Bruner's (1960) analogy for this process is "scaffolding", which uses modelling as a way of gradually enabling a child to take over a co-operative task from their teacher. Socio-cultural views of learning, as espoused by Vygotsky (1962) develop each of these notions, while situated cognition and cognitive apprenticeship bridge the two, aiming to enable learners to locate their school understanding in a real-life context in order for it to be immediately useful and meaningful in everyday life.

1.5 Conclusion: the socio-cultural perspective

The main draw-back of each of the categories of constructivism is that they emphasise learning at the expense of teaching. As the purpose of schooling is to educate children into the ways of society then emphasising the individual's viewpoint at the expense of a wider perspective is counter-productive. Returning to the three quotes from Driver, it is possible to locate them within the different constructivist perspectives. In 1983, her position was akin to Osborne and Wittrock's (1983) initial vision of generative learning, with teaching to society's mores taking precedence. Her 1988 writing is more suggestive of the personal constructivism of Osborne and Wittrock (1985) and the most recent quote, while emphasising a social dimension to learning, appears to do so from a standpoint closer to radical constructivism than socio-culturalism as it is the individual's ideas which are being socially validated rather than society's. The initial difference between Driver and Solomon appears to have been in the status of the children's ideas in relation to teaching, but it has widened to embrace perspectives on the purposes of education.

While constructivists appear happy to lay claim to the range of views of learning which acknowledge the social dimension, as has been shown in Driver's (1983; 1994) definitions, there is a noted absence of the term "constructivism" in the socio-cultural literature researching this area. Where Bell and Gilbert (1996, p.56) see constructivism as "the only credible alternative available if teachers wish to reject a behaviourist view of learning", I consider the problem to be defined rather more complexly in terms of a range of approaches to teaching and learning. In line with this position, I have sympathy with Howe's (1996) suggestion that, while the two perspectives of constructivism and socio-culturalism are distinct, education would be better served by blurring the distinctions and merging the two so that children's ideas would be elicited not in order to be challenged, but in order to establish the starting point for teaching, the position initially established by Osborne and Wittrock in 1983.

2. The Nature of Children's Ideas

Children's ideas have been the object of intense research interest over the last twenty years, and their existence is not in dispute. However, as I illustrated in the preceding paragraphs, their status with regard to children's science learning is contested. The contrasting views giving respectively the positions of Driver and other constructivist researchers, and Solomon and other socio-cultural researchers, are presented here: either children's ideas are scientific theories or they are everyday ways of knowing.

2.1 Children's ideas as scientific theories

It has become clear that similar ideas are used to explain the same phenomenon across different populations and in different countries. Additionally, there seem to be common developmental pathways (conceptual trajectories (Driver et al, 1995)) for ideas in particular areas, suggesting that these ought to be taken into account in curriculum planning. These research findings have led to children's ideas being characterised as theories which are generated as a result of observations. As children's observations are not widely generalised from one situation to another they explain phenomena in ways which are context-dependent (Engel Clough and Driver, 1986) and therefore of limited explanatory power, differing from the scientific view of the world. To compound these inconsistencies, it has been widely noted that the ideas are very resistant to change, due to their taking on the status of beliefs which leads to contrary evidence being ignored (Head, 1985; Gunstone, 1991a).

McClelland (1984) is dubious of the status of these ideas, doubting that many of them has the status of a theory, and suggesting that poor teaching of concepts and lack of motivation to engage with the scientific ideas might be responsible for their development and persistence. However, his interpretation does not explain the existence of idiosyncratic ideas in young children (Russell and Watt, 1990) who have had no formal science teaching.

The characteristics of context-dependency and persistence lead constructivists to determine that these ideas are detrimental to formal school science learning, though the context-dependency can be minimised if teachers interpret the ideas by looking beneath the surface features to the scientific principles which implicitly underpin the view (Minstrell, 1991; Johnson and Gott, 1996). From a constructivist's perspective, children have to be persuaded away from their views so that school science learning can be more coherent and productive. This 'persuasion' is known as "conceptual change" in the research and curriculum development literature.

2.2 Children's ideas as everyday knowing

Solomon (1983), while not disputing the existence of children's ideas, challenges the notion that they need to be modified to enhance science teaching and learning. She proposes that individuals think in two separate but parallel domains, "life-world" and "science-world" and that some individuals find switching between the two domains much harder than others, with the life-world domain being more accessible. In fact, Barnes (1989) proposes that children who fail at school do so because they can only access the life-world domain. While Freyberg and Osborne (1985) are concerned that holding two unrelated perspectives simultaneously impedes the process of children making sense of the world, Solomon proposes that children's ideas in the life-world domain are necessary for individuals to function socially in the everyday world as many ideas are reflected in social language use, e.g. the sun rising, the sun going behind a cloud. She suggests that school science learning can co-exist with life-world thinking by being located in the science-world domain. This changes the nature of the problem from one of trying to change the children's ideas to one of triggering the more appropriate domain for particular occasions.

Not only is this view consistent with thinking in other academic disciplines such as anthropology and linguistics (Bourdieu, 1977; Halliday, 1978, as cited in Solomon, 1995), but there are research findings to support it: students are able to perform far more scientific investigations when presented with a science-world context than they are when presented with a life-world context which leads to more qualitative decisions being made (Solomon, 1983, 1988). Surprisingly, this critique has not been received by the constructivist movement as such, but embraced as another facet of the phenomenon which is worthy of research. Recent writing by Driver (Driver et al. 1995) shows signs of Solomon's views being incorporated into her perspective.

2.3 Conclusion: children's ideas and the socio-cultural perspective

When children's ideas are accepted as theories and therefore accorded the respect which that status merits, there is the dilemma of balancing out the competing demands of children learning and teachers teaching. Not only would teaching be governed by endeavouring to change ideas, but children as a result would be deprived of their means both of functioning socially according to societal linguistic norms and of developing the scientific knowledge base of society. Viewing children's ideas as everyday knowing means they can be treated with respect and that teaching of science ideas can take place using approaches consistent with the socio-cultural perspective. Children can thus learn the science which society deems to be relevant while being helped to understand how those ideas are constructed.

3. Elicitation of Children's Ideas

Leach et al (1995) describe the two main approaches which have been developed to explore the content of children's ideas, retitling the categories which Driver and Easley (1978) described seventeen years earlier. For the sake of completeness, Driver and Easley's terms are included in parentheses. Both of these approaches are concerned with eliciting the ideas of children, but from very different standpoints, and each of these is considered in the following paragraphs.

3.1 Conceptual approach

A conceptual (or nomothetic) approach involves the researcher in finding out what the child knows about a particular scientific concept by using variations of the technique of "interview about instances" (Osborne and Gilbert, 1980). The interview probe is in the form of a stick diagram with associated questions and involves ascertaining how the child understands particular scientific terminology, e.g. 'energy' or 'force', in a situation which may relate to either scientific or everyday contexts. For example, "A golfer hitting a golf ball. Are there any forces here?" This approach can be considered to be top-down, starting from the accepted science view and finding out how closely a child's description compares with it. This approach has been used extensively in 'alternative frameworks' research in areas of secondary school physics, for example by the Children's Learning in Science (CLIS) Team (CLIS, 1987) and by Gilbert, Watts and Osborne (1982). It is relevant as a tool for determining both "children's ideas as scientific theories" and "children's ideas as everyday knowing".

3.2 Phenomenological approach

A phenomenological (or ideographic) approach is more bottom-up, starting with an example in either an everyday or a scientific context, and establishing which constructs the child employs to describe the phenomenon (e.g. interview about events, Osborne, 1980). No scientific language is used to cue the elicitation, leaving the child able to use any explanation they consider appropriate. This approach has, until recently, been less widely used but is the predominant method adopted by the SPACE Project research and is now used by the CLIS team. Clearly, proponents of this approach consider children's ideas to be theories.

3.3 Relationship of elicitation approach to domain use

Using Solomon's domain explanation, the conceptual approach should be better at cueing children to the science-world domain than the phenomenological approach because it is using technical vocabulary which will have been encountered in school science. The context of the elicitation would also have a bearing, and a scientific context should be more effective at cueing science thinking. So, a conceptual approach in which the context was scientific would be most likely to cue scientific thinking (Brook and Driver, 1984), followed by a conceptual approach using an everyday context or a phenomenological approach in a scientific context. Least effective at cueing science, and most effective at cueing everyday thinking would be a phenomenological approach in an everyday context. The inefficacy of this last combination has been corroborated by Russell et al (1989) who found that children did not associate certain everyday stimuli with the phenomenon being explored. For example, in the context of evaporation, a slice of bread left to dry was considered to have 'gone hard, stale', making no mention of water, presumably because the children did not associate water with bread.

An additional variable which might be anticipated to have an effect on domain use would be experience of school science. Thus, children who have studied science at school would be more familiar with both its language and contexts than children who have limited experiences. Using either approach with young or inexperienced children would therefore lead to a greater use of life-world notions than with older or more experienced children. CLIS (Leach et al, 1995) have shifted their research probes from being conceptual to being phenomenological, and from scientific to everyday contexts. They have also begun to say that the children's everyday ideas do not have to change. With these changes in position, it is interesting to speculate about why they are continuing to carry out this research if they are acknowledging the need to contrive the contexts, and if they are not aiming to develop children's ideas through teaching.

3.4 Critiques of elicitation

As mentioned in section 2.1, Johnson and Gott (1996) have recently criticised the constructivist movement for trivialising children's ideas by taking insufficient pains with the collection and interpretation of data. They contest the meaningfulness of data which may be neither reliable nor valid. By focusing on the surface characteristics of the children's responses there are two unknowns which are unacknowledged. Firstly, there is no way of knowing how the child has interpreted the question which the researcher asked (either in an interview, or as part of a questionnaire), and secondly, there is the issue of how the researcher interprets the child's response. They suggest that it is important to acknowledge that interpretation has taken place, and to triangulate data. When the researcher interprets the data, they advise that this should be done using the child's frame of reference since it is this frame which should be the target of future teaching rather than the particular idea. This notion has resonances with the work of Minstrell (1991) and the "facets" of knowledge he has identified as containing evidence of the underlying science basis to the idea.

3.5 Conclusion: Interpretation is central to elicitation

Elicitation serves different purposes depending on whether children's ideas are considered according to a constructivist or a socio-cultural perspective. From a constructivist perspective, phenomenological probes in an everyday context are better because they give access to children's considered theories. Interpretation of these ideas will counter criticisms about focusing on the surface features of the ideas. From a socio-cultural perspective, conceptual probes in a science context are better for revealing the science-world ideas children have learnt, but the child needs to give an explanation to support the response to ensure that true understanding is being represented. In either case, inviting children to provide explanations and examples will go some way towards meeting the challenges to elicitation by enabling more interpretive analysis to take place.

4. Conditions for Promoting Conceptual Change

Conceptual change is a term coined by constructivist researchers and curriculum developers for the process of developing understanding by changing concepts. There are two levels at which conditions for promoting conceptual change need to be discussed: conditions within the learners themselves; and conditions within the classroom, as set up by the teacher and the school system. Each of these levels is considered in turn.

4.1 Necessary conditions within learners

Posner, Strike, Hewson and Gertzog (1982) describe in detail the processes they consider a learner must go through in order to be prepared to change their idea. These involve the learner in becoming dissatisfied with their own idea and so rejecting it in favour of a more scientific conception. Specifically, the four conditions necessary before conceptual development can occur are:

1. The learner must feel dissatisfaction with their existing ideas;
2. The learner must have access to a new concept which is intelligible to them;
3. The learner must find the new concept initially plausible as an explanation;
4. The learner must be aware that the new idea offers fruitful avenues for further research and development.

These criteria have been generated from a consideration of the philosophy of science, building on the hypothesis that the process of conceptual development in an individual child is a reflection of the extension of science knowledge by scientists, the position questioned in section 1.2 by Driver (1983) as being naively inductivist.

This teaching approach which focuses on the learner makes demands on them to which they will be unaccustomed (White, 1988a). If children are expecting to be passive recipients of knowledge (Tasker, 1981, as cited in Gunstone, 1991b) they will change the task so their role fits their expectations. Posner et al's four conditions would therefore need to be supplemented to provide for a re-orientation of the child's perception of learning: the learner must understand and accept that they are actively in control of their own learning.

4.2 Necessary conditions within classrooms

At the level of the classroom, several researchers have identified factors which are important precursors of conceptual development. These are:

1. Creating a social environment in which ideas are valued, and change in ideas is considered as a positive feature (Hollon et al, 1991; Scott et al, 1991; Biddulph and Carr, 1992);
2. Establishing problems which will engage children in scientific thinking, that are personally meaningful and can be vehicles for the mastery of science knowledge (Hollon et al, 1991);
3. Ensuring that concepts have application in real world situations (Russell et al, 1989; Hollon et al, 1991);
4. Having a clear focus on the concepts to be developed (Osborne and Wittrock, 1983; Bentley and Watts, 1994; Osborne and Simon, 1996; Summers et al, 1996)
5. Teacher confidence in the subject matter to be taught (Summers et al, 1996)
6. Grouping children so that those with different ideas were working together (Howe, 1995)
7. Being aware of the children's perception of the context in order to know what they expect to learn from the situation (White, 1988a)
8. Being aware either of the children's ideas or of the likely content of their ideas (Driver and Easley, 1978; Osborne and Wittrock, 1983; Harlen and Osborne, 1985; Biddulph and Osborne, 1984; Russell et al, 1989; Scardamalia and Bereiter, 1989; Scott et al, 1991; Howe, 1995; Howe, 1996; Summers et al, 1996)

9. Being able to facilitate the creation of dissatisfaction in the children's minds with their existing ideas (Posner et al, 1982; CLIS, 1987; Roth et al, 1987)
10. A curriculum with a much reduced content (Posner et al, 1982; Driver, 1983; Hollon et al, 1991; Bell and Gilbert, 1996)

From this list there appears to be one main point of consensus about how to develop a child's thinking: being aware of children's ideas or their likely content. It is not possible to say this is so, because different writers consider that criterion to be important for different reasons. For example, Russell et al's (1989) teacher needs to know in order to help the child test out their idea. On the other hand, Scott et al's (1991) teacher needs to know so they can devise appropriate challenges to the children's thinking.

The ten conditions do all have one thing in common: they enable the teacher to have control over the teaching process and to be able to work towards the achievement of a particular learning goal (Mercer, 1995). Were conceptual change truly a learner-centred process, as suggested in 4.1, then there would be no guarantee that the change would be in the required direction (Osborne and Wittrock, 1983). However, because of the teacher intervention, the individual learning process becomes directed and constrained, and thus it becomes manageable in the classroom.

4.3 Conclusion: conceptual change and the socio-cultural perspective

The constructivist approach is clearly making demands on both learners and teachers which are at odds with the established classroom culture. These issues will be explored in more depth in chapter 4, section 2. Teaching from a socio-cultural perspective is more in keeping with cultural expectations. The teacher will still want to know the children's ideas, but for the purpose of selecting the appropriate starting point for teaching by devising cues which are likely to lead to the retrieval of science-world rather than life-world understanding. Thus, changing children's ideas is the wrong place for a teacher to start when conceptual development can be otherwise achieved.

5. Approaches to Teaching for Conceptual Change

Scott et al (1991) review the teaching strategies which have been described in order to implement a constructivist approach in the classroom. They divide these into two main camps; cognitive conflict and developing children's existing ideas. These two camps appear to complement the two approaches to eliciting children's ideas, with the former corresponding to the conceptual approach to elicitation, and the latter to the phenomenological approach. As with the two schools of finding out children's ideas, far more attention has been given to the former approach than the latter, and that might explain why, half way through the paper, Scott et al appear to redefine 'developing children's existing ideas' as 'the development of ideas consistent with the science viewpoint' which seems to come from a socio-cultural standpoint. Thus, having started the paper with two approaches they finish it with three. Through personal communication with Scott (1997) I established that the intentions of the paper were to explicate the cognitive conflict and the socio-cultural perspectives, suggesting that 'developing children's ideas', the second category, was simply worded ambiguously. I will consider all three approaches separately because they each define a distinct approach to teaching for conceptual change.

5.1 Cognitive conflict

Approaches to cognitive conflict all involve the child being made to be dissatisfied with their existing idea in relation to the scientific view, a strategy which is in line with those interpreters of Piaget who consider equilibration to be the resolution of externally imposed conflict. To this end, there are four main stages to the process, each of which is accorded different status by the various researchers in the field. Because it has attracted such vast amounts of research interest only a sample is compared, selected as far as possible from those who have conducted at least some of their research with primary school children. The four stages are: elicitation of children's existing ideas; the testing of the children's ideas; the introduction of the science view and the application of the science view in everyday contexts. A comparison of each of these four phases enables some of the major differences between researchers to be identified.

1. Elicitation of ideas is part of the programme for all researchers. It is either an end in itself, providing the teacher with insights into the children's ideas (e.g. Summers et al, 1996; Posner et al, 1981) or it can either lead into (e.g. CLIS, 1987; Bentley and Watts, 1992) or be an integral part of (e.g. Roth et al, 1987; Nussbaum and Novick, 1981) the second stage;
2. Testing out the children's ideas is a less widely employed stage in which children are encouraged to generate predictions, hypotheses and explanations based upon their own idea (CLIS, 1987; Bentley and Watts, 1992; Nussbaum and Novick, 1981; Roth et al, 1987). This stage could be considered to have a particular drawback in that it makes the children spend a long time working with their own ideas before being presented with the scientific viewpoint. In the CLIS case, the children spend three lessons exploring their own ideas in order to practise their process skills, which is as long as is spent subsequently in considering the science view. This is likely to have the effect of making the idea more persistent by reinforcing the idea in the child's mind as worthy of study in school science lessons (Solomon, 1995);

3. The introduction of the science view can be either explicit (e.g. Hollon et al, 1991; Roth et al, 1987; CLIS, 1987; Rowell et al, 1990; Summers et al, 1996) or implicit, through the use of an anomalous situation (e.g. Posner et al, 1982; Nussbaum and Novick, 1981). It is at this stage that the cognitive conflict is introduced. This conflict can either be handed over to the children for them to compare their own views with the science ones (e.g. CLIS, 1987; Nussbaum and Novick, 1981; Bentley and Watts, 1992) or controlled more closely by the teacher

reinforcing the important concepts through the use of explanation using analogies, metaphors and models (Bentley and Watts, 1994; Hollon et al, 1991; Roth et al, 1987; Summers et al, 1996).

4. Application of the ideas in everyday contexts is the last step which serves to provide both practice in the use of the understanding and its generalisation to a wider range of contexts. (Roth et al, 1987; CLIS, 1987; Hollon et al, 1991).

5.2 Developing children's existing ideas

"Building on children's views" is first introduced as a phrase by Osborne, Bell and Gilbert (1983) to refer to the process of cognitive conflict. It therefore appears that this phrase is even more ambiguous than suggested by my discussion with Scott (1997), being used to label each of the three approaches to conceptual change at different times. However, I am using the phrase to refer to the process of establishing children's ideas and then helping them to test these through investigation in order to make them more explanatory. Thus, in line with the phenomenological approach to elicitation, the starting point for teacher intervention is what the child currently knows rather than what they do not know.

By a detailed inspection of papers relating to the Generative Learning Model (Osborne and Wittrock, 1983;1985; Harlen and Osborne, 1985) it is possible to trace the development of this particular approach. Osborne and Wittrock (1983), as mentioned in sections 1.2 and 1.5, describe a very structured teaching approach similar to socio-culturalism, in which the teacher establishes the children's ideas in order to be able to target their teaching more closely: cueing retrieval of ideas from memory; using examples, explanations, questions etc. to teach a more scientific perspective and show the children their ideas are inadequate. Osborne and Wittrock (1985) has a less overtly psychological flavour to it, making more reference to the philosophy of science and "the child as scientist" evaluating evidence scientifically and literally building on their own ideas, a far more child-centred perspective than two years previously. The concluding paragraph of this latter paper suggests that the more suitable intervention approach would depend on the age of the child: primary children should test their ideas through investigation, while upper primary or secondary children should be challenged. Primary constructivism therefore became testing children' ideas, a position derived from Harlen and Osborne (1985), and discussed in section 3 of the next chapter.

Head (1985) sees a focus on children's own ideas as increasing the personal dimension in science, and it is compatible with the prevalent primary school ethos of process-focused, child-centred heurism. This approach can easily fall into the trap articulated by Johnson and Gott (1996) as teachers are likely to engage the children in meaningless, trivial investigations testing out the surface characteristics of the idea rather than interpreting it in terms of its frame of reference. As mentioned in Chapter 1, this approach is considered to help the child to develop a greater understanding of the nature of science, particularly as Freyberg and Osborne's (1985) proposed aims for science education lead to a greater emphasis on developing curiosity and self esteem than on necessarily promoting conceptual change in a particular direction.

5.3 Developing ideas consistent with the science viewpoint

The third approach to teaching for conceptual change, the development of ideas consistent with the science viewpoint (Solomon, 1995, Treagust et al, 1996, Sutton, 1992, Rowell et al, 1990), is described in the latter half of Scott et al's article, and has been referred to earlier in this chapter as the socio-cultural approach. These authors recognise the importance of children's ideas as indicators of the current level of understanding, but do not endeavour to change the ideas. Rather they are concerned with finding effective strategies for teaching children the scientific view, and with finding ways to cue children's recall of ideas within the science-world domain rather than their life-world ideas. This approach clearly puts the teacher in control both of the ideas being taught, and of the teaching process, which may reflect principles of scaffolding (Askew, Bliss and MaCrae, 1995). It is consistent with Osborne's (1993) view that acculturation is a necessary part of science education rather than an over-reliance on sensory experience and empiricism.

This 'active teaching' towards the accepted science view seems very similar to the position alluded to by Driver in her earlier writing (e.g. 1983). However, it is not the message in her later publications, in which her emphasis appears to have shifted towards radical constructivism and the individual development of ideas, i.e. away from the pre-eminence of developing society's accepted viewpoint. This shift is surprising given the focus of the majority of critiques of constructivism in recent years, which has been the neglect of the social milieu of education, a criticism easier to level at Driver et al (1994) than at Driver (1983).

5.4 Conclusion: the status of children's ideas in the development of understanding

The three approaches to conceptual change described here differ in terms of two main factors: the status of children's ideas, and the children's age. Cognitive conflict and developing ideas consistent with the scientific viewpoint have the same aim, i.e. developing the "correct" science idea, either describing the children's ideas as theories (the former) or as everyday notions (the latter). In common with the former, building on children's ideas considers the ideas to be theories, but adopts a more "child as scientist" approach because the age of the children is considered to make manipulation of ideas difficult. The problem seems to be the treatment of idea as theory. With that variable removed, a socio-cultural teaching approach could be used to present and explain science ideas in ways relevant to children of different ages and levels of experience.

6. Conclusion: A Theory of Learning or a Theory of Teaching?

The theory that children, as individuals, learn through their own experience seems very attractive as an explanation of concept development, as it did to Piaget who modelled his theory on the processes of science, i.e. the collection of evidence in order to test a hypothesis (O'Loughlin, 1992). As soon as children's ideas are acknowledged as important and potentially obstructive to the learning of school science, it becomes important to develop teaching strategies to make children change their minds.

By persuading children to abandon their ideas in order to adopt more scientific thinking, not only is society shaping the individual's world but, by endeavouring to impose one particular right answer on the child, a view of science as a deductive enterprise is being presented. However, Driver (1983) is at pains to explain that a constructivist approach should involve "teaching consensus without turning it into orthodoxy" (Ziman, 1968, as cited in Driver, 1983). Whatever the intentions, given curriculum constraints, science can easily be portrayed as consisting of one right answer, rather than as a set of provisional tenets waiting to be disproved. This, Harlen (1992) suggests, is one reason why building upon children's ideas should be a preferred approach to cognitive conflict, since there is no imposition of a science view. However, as Biddulph and Carr (1992, p.193) describe one of the roles of the teacher as to guide children's interests "in a subtle, but seemingly natural, way to consider key aspects of the topic" it would appear that one of the differences between the two approaches could be reduced to a covert as opposed to an overt acknowledgement of the supremacy of the scientific viewpoint.

However, the process of individual learning is far removed from the process of education, in which there are prescribed tenets of knowledge which children are to learn (Mercer, 1995). Talk of a learner-centred curriculum is just as reductionist as that of a teacher-centred one, in that it only considers the learner's side of the teacher - learner equation. By placing the onus on the child to change their understanding, not only does the role of the teacher become an even more demanding one (Scott et al, 1991) but that of the child ceases to look like the role ascribed to children implicitly through the hidden curriculum of schooling. As White (1988a) says, the major determinant of the outcomes of a learning process is the child's perception of the context in which the learning is taking place, and if children have a transmission view of learning then it must be important to consider the sense the children are making of the process and endeavour to develop the children's conceptions of learning (Gunstone, 1991b).

Driver's writing (1983, 1988, 1994, 1995) acknowledges the place of social context in children's learning in a manner which changes greatly over time. In her earlier writing she discussed the society of scientists and their consensual world of knowledge, which is in line with current thinking. However, her assertion (1988) that there can be no body of knowledge for children to learn because all knowledge is subjective, and that the curriculum should be a programme of learning tasks from which children create their own understanding seems related to von Glasersfeld's notions, and is fundamentally flawed. There self-evidently is a body of knowledge which is called science, which has been socially created and is acknowledged by scientists as being provisional. By endeavouring to empower the individual child in this way, the role of the teacher becomes untenable. Teaching is about the process of interaction between teacher and learner, and the teacher is responsible for passing on to the learner that knowledge which society has constructed and values (Cobern, 1996). By interacting with society and its knowledge base in this way, the individual is empowered by learning about society from within by negotiating meaning, rather than isolated by trying to learn about it from outside (O'Loughlin, 1992). In a similar vein, Sinclair (1989) states that an individual can never learn the same concept as the person from whom they are learning because each individual passes on the understanding which they themselves have constructed from what they heard or experienced. The implication here is that generating understanding must always be a social rather than an individual activity, and that by siting it within the public domain, society's view of knowledge will become consensual. Only by seeking a collective understanding can there be the possibility of generating theories about the world which are generally explanatory (Olssen, 1996).

The socio-cultural agenda for teaching and learning in science proposed by Solomon and others, in which children's ideas are acknowledged and valued as life-world knowledge, and in which science learning for understanding is considered to be a teacher-intensive process in which teachers strive for success of teaching rather than being preoccupied with reasons for failure in learning (Leinhardt et al, 1991) is more useful. If this thesis uses the term constructivism in a similar ever-expanding and mutating way as the research literature, then socio-culturalism would come under its umbrella, and a teaching as well as a learning theory could be described. However, it seems more intellectually honest to define constructivism in a manner which accounts for the vast wealth of research data concerning children's ideas and their nature. For this reason constructivism is defined as:

> ***a learning theory which requires children's intuitive ideas to be changed so that a unitary view of the world can be established.***

Where a specific form of constructivism is discussed, a descriptor will be appended, e.g. personal constructivism; social constructivism.

7. Summary

The intense research interest in children's ideas has led to a common range being identified across different populations, and to them being defined as context-specific, based upon everyday understanding and resistant to change. These ideas have been seen by constructivists as impediments to children's school science learning and therefore to be changed. Constructivist research has been divided into five main areas by Bell and Gilbert (1996), but within the research literature the term 'constructivism' tends to be used generically and with varying definitions. Each of these five areas acknowledges that individuals play an active role in constructing their own understanding, but they differ in the relationship of the individual to society's knowledge base. Constructivist research appears to change its nature as fast as its critics can generate criticisms. There has recently been a move towards the use of techniques which are more likely to generate everyday thinking in order to look at progression in ideas and from which the findings should be more valid and reliable because of the greater interpretation of children's underlying constructs. Researchers have elucidated what they consider to be the conditions necessary within the learner and within the classroom for children to undergo conceptual change. However, because of the range of methodological and definitional differences between researchers, and because no-one has asked the children about their views of learning in science, it is not possible to identify a definite range of factors.

The three main approaches to teaching for conceptual change have very different implications for the nature of children's learning, and also for the nature of teaching. Firstly, through cognitive conflict, children's ideas are challenged in relation to the accepted scientific viewpoint, requiring teachers to present the scientific view as more convincing than the children's alternative views. Secondly, through building on children's existing ideas, children as scientists are encouraged to develop their own understanding by testing out their ideas, requiring the teachers to ensure that the testing of ideas is fair. Thirdly, by developing ideas consistent with a scientific viewpoint, children's ideas are not changed but signal the appropriate starting point for the active teaching of science understanding. The second approach is particular to primary science and conforms closely to the prevalent ethos of child-centred learning by doing. The third view is more akin to socio-culturalist thinking, according to which it would not be considered to come under the constructivist heading.

Recent constructivist writers have placed increasing emphasis on the social dimension of learning, but their embracing of a social dimension to constructivism seems unreciprocated by the socio-cultural researchers who do not use the term constructivist to describe their work. Now there is more of a consensus, particularly within the socio-cultural camp, that these everyday ideas should exist alongside science-world ideas because they are necessary for normal social functioning in society.

Society's aims for science education are to ensure that children acquire an understanding of science related to currently accepted tenets of knowledge. Given this position, constructivism either disadvantages children by allowing them to explore only their own ideas without access to the scientists' views, or it covertly introduces science ideas to them. A socio-cultural perspective in which ideas are presented and explained in a structured way by teachers is more appropriate as it conforms to cultural norms about the purposes of schooling.

Having explored the whole area of constructivism in order to analyse its important features, chapter 3 focuses on science in primary schools and locates constructivist primary science within the recent developments in the curriculum area.

CHAPTER 3

RECENT DEVELOPMENTS IN PRIMARY SCIENCE EDUCATION

Science is a comparatively recent addition to the established curriculum of the primary school. In fact, it is only since the advent of the National Curriculum in 1989 that it has become part of every child's entitlement to a broad and balanced education. In this chapter, I consider primary science as primarily an aspect of primary education, reflecting "good primary practice" which, fortuitously, conforms to inductivist notions of the nature of science and to the "building on children's ideas" approach to personal constructivism. I describe the effect of the National Curriculum on primary science in the classroom and determine that, while science now has a greater prominence , the broad knowledge base needed by teachers is affecting how effectively it can be delivered. I conclude with the view that constructivist primary science should have little place in the primary curriculum, beyond alerting teachers to the existence of children's intuitive ideas, because these developments are not leading to the sort of successful primary science practice that would be hoped. Challenges to the place of practical work in science should be taken seriously.

1. The Practice of Primary Science

In order to understand the nature of primary science and its development it is important first to explore its place in relation to the primary curriculum as a whole.

1.1 The wider context: "good primary practice"

Alexander (1992) writes at length about the ideological positions upon which primary education is based: the class teacher system inherited from nineteenth century elementary schools; the view that primary education should centre around the child rather than the curriculum and the notion that children should learn through first hand experience in order for it to be meaningful. Applying these principles to primary science, the class teacher should be responsible for its teaching, regardless of their expertise; developing the children's ideas and skills should be central to teaching rather than conveying any body of knowledge and this development should be mediated by children engaging in practical activities. These positions are supported by very little empirical evidence, as Anning (1991) showed in her analysis of early years education. Not only does she come down in favour of the importance of *teaching* as the means of ensuring children develop, but she questions how teachers can implement open-ended activities if they have neither the experience nor knowledge in that curriculum area. Unfortunately, Alexander's and Anning's analyses have yet to influence some teacher educators, let alone some classroom teachers, since Johnston's (1996) "Early Explorations in Science" is still advocating young children learning through unstructured science activities which enable meaningful individual learning and involve the teacher principally in the role of resource organiser.

Edwards and Mercer (1987) argue strongly that concentrating on learning through experience encourages children to generate understanding which is limited to one context and is thus more likely to lead to misconceptions, an argument similar to McClelland's (1984, chapter 2, section 2.1). However, as "good primary practice" is based upon teachers' beliefs and values, its existence is likely to be as persistent as children's ideas (Head, 1985; Gunstone, 1991a, as cited in chapter 2, section 2.1) and unlikely to be disproved by contrary evidence.

> "Classroom strategy can never be merely an enacting or an extension of educational belief. Yet this is exactly how good practice has frequently been defined in primary education. First work out your 'philosophy', then construct your practice to fit it: if the philosophy is right, the practice will be sound." (Alexander 1992, p.188)

It is within this context of "good primary practice" that primary science has developed. Child-centred heurism is evident in the way the subject is defined, as I demonstrate in the next section.

1.2 The nature of primary science

> "This rationale [for primary science] can be provided by starting, not from some general 'aims of primary science' but from a vision of the way in which we want children to learn and the kind of learning we wish to promote." (Harlen and Osborne 1985, p.133)

Definitions of the nature of primary science are very much in line with these sentiments of child-centred heurism. Wenham (1995, p.4) summarises the nature of primary science as, "largely concerned with investigating through first hand experience and helping children to understand the world around them". This definition is similar to that given by Squires (1980) and Harlen (1993), though Wenham's expansion on that definition is in accord with the latter rather than the former author's argument. Whereas Squires emphasises the fact that, "each pupil has to make his own journey" (Squires 1980, p.12), both Harlen and Wenham advocate the value of investigations in terms of introducing children to the activities of the scientist: in developing knowledge; understanding; the ability to investigate competently; insights into the nature of science and science as a human activity which is therefore tentative and has limitations. What on the surface appear to be similar conceptions of primary science have evolved over time from one in which a Piagetian model of learning is espoused in accord with "good primary practice" to a more precisely articulated pragmatic viewpoint which has the Generative Learning Model (GLM) as its underpinning. However, the GLM is such that it enables Harlen and Wenham to offer a definition which is compatible with an inductivist view of the nature of science, thus providing a justification for learning by doing as the children will be modelling the science process. Thus the picture of primary science teaching and learning as practical activity remains unchanged despite different justifications of its form from these teacher educators and researchers.

A similar rationale for practice is found when teachers are asked for their views on the nature of primary science. Russell et al's (1995) evaluation of the implementation of the science National Curriculum exposes the views of the sample teachers through exploring the reasons why some science topics are being under-represented in their coverage. Apart from teacher subject knowledge, the two reasons given are that abstract concepts are out of the reach of children in primary schools, and that children should learn by doing rather than being told. These views suggest that at least some teachers see teaching in science as either based on practical activities or transmission of knowledge with no alternative conceptions of the teaching process. These views seem more in accord with Squires' ideas than with Harlen's or Wenham's, suggesting that there is a time lag between the articulated views of teachers in the classroom and researchers and writers. In support of this time-lag, neither Russell et al nor Newton (1992) found any evidence of more contemporary views of science, e.g. a constructivist or socio-cultural view of learning and teaching, espoused by teachers in their samples.

2. Changes in Approach to Primary Science

From the preceding paragraphs it is clear that, despite science's comparatively recent emergence as a main-stream part of the primary curriculum, there are already different approaches to its teaching. The development of these differences is the focus of this section.

2.1 The development of 'process science'

In the early 1970s, science was the subject of two major curriculum development projects which espoused a very different approach to science teaching from the information-giving model which up until then was more likely to be practised in primary classrooms. *Nuffield Junior Science* (1967, as described by Wastnedge, 1983) was followed by the Schools Council project, *Science 5-13* (e.g. Ennever and Harlen, 1972). These schemes built upon Piagetian principles of cognitive development. They advocated learning by doing, and espoused learning through guided discovery as the means by which children should be helped to learn science: children were provided with activities which guided them to discover particular scientific principles. This approach is clearly consistent with "good primary practice". It is worth speculating about how the primary ideology came to combine with science. *Nuffield Junior Science* was developed by scientists in dialogue with teachers. It is therefore likely that the scientists saw links between the approach teachers advocated in primary schools and their own understanding of science based on their professional practice. As scientists rather than teachers the authors would have been in no position to challenge the accepted orthodoxy.

Science 5-13 was evaluated from its inception by Harlen (1975). This evaluation was interesting because it was formative and influenced both the development of the teaching materials and later aspects of the evaluation itself. Harlen began by assessing the difference between the children's starting points and their products to provide indicators of their learning. However, she found these proved less useful indicators than classroom observations and teachers' records as a picture of what was happening in the classroom. It is possible to surmise that the before and after measures of understanding were less useful because they were revealing little development, despite clear evidence of purposeful scientific activity by the children. This shift in data collection reflected a change in the focus of the research from assessing product to using process (i.e. evidence of the use of particular forms of thought, or mental processing) as a measure of learning. As children were considered to be learning through practical activity, it followed that evidence should be gathered through observation of children investigating.

As Harlen (1975) said, this shift embodied an assumption which should be tested: that, if certain processes were present in the classroom, the required learning would automatically follow. In fact, there are two assumptions here: firstly that processes are linked directly to learning, and secondly that practical activity is necessary for meaningful learning to occur. The first assumption, however, was not and still has not been tested, though as Harlen (1993) points out there must be an interaction between the two because processes such as observation are evidently theory-driven, ensuring that we can interpret our observations from within our conceptual frameworks. Only the growing acceptance of socio-culturalism led to the second, the place of practical work in the learning of science, being seriously explored (see section 4.1 in this chapter). Reference back to section 1.1 shows that in the broader context of primary education there is evidence that practical activity is not sufficient for learning to occur.

Despite *Science 5-13* having little impact in the classroom (Black, 1980), which given later criticisms may be fortunate, it was the process objectives from *Science 5-13* upon which later work was based, with the result that the emphasis on content was reduced (Russell et al, 1995). The endpoint of a process science investigation was often the identification of a data pattern, without any attempt to interpret that pattern in terms of what it explained. This position is hardly surprising given, for example, Harlen's (1993) words of caution about encouraging children only to draw conclusions for which they have direct evidence. Furthermore, a teacher who is not very secure in their science content knowledge would be likely to stop at the pattern rather than risk going any further. Books such as *Taking the Plunge* (Harlen, 1985) were used as reference points for teachers who wanted to learn to use a process approach to science, even though they were written to help teachers understand their role in helping children to develop their understanding through investigation. Maybe the separation of chapters into 'skills and processes' and 'children's ideas' facilitated a selective use of the material.

Given my earlier argument about the impact of "good primary practice" on the nature of primary science education, it is not surprising that the process emphasis was popular. However, I will explore whether there might be other contributory reasons for its popularity. Firstly, it could have been a reaction against didactic science teaching which involved children copying down facts and remembering them as it would be far more motivating for the children, and thus more enjoyable to teach. Secondly, and importantly, it might be that teaching science through children's investigations was less problematic for teachers in terms of their own subject knowledge. Clear messages were conveyed to teachers that they did not need to know any science and that they could learn alongside the children (Biddulph and Osborne, 1984; Kerry and Tollitt, 1987). So, in addition to it being consistent with teaching and learning in other areas of the curriculum, it would be a far more feasible approach for generalist teachers lacking a background in science. Process science therefore became the predominant approach which was advocated for those practitioners who were keen and interested in pursuing current developments in science education.

2.2 The contribution of the Assessment of Performance Unit

The Assessment of Performance Unit (APU) conducted its first survey in 1980 in order to provide a national picture of children's abilities in science and many of today's professors of science education were part of the APU teams, e.g. Paul Black, Rosalind Driver, Richard Gott, Wynne Harlen and Terry Russell. Teams of teachers up and down the country were trained by the researchers as APU assessors which involved them in working with individual children to explore their understanding of science, its processes, concepts and attitudes. As Qualter et al (1990) point out, because the survey was an assessment exercise the different aspects of science were teased apart so they could be separately assessed. This therefore made the testing process unlike the teaching one with the result that, for example, to assess children's understanding of the process of investigation, there were minimal demands on content knowledge.

I intend to propose a mechanism by which this assessment exercise became very influential in the development of primary science in the classroom. Not surprisingly, many of the APU assessors later became advisory teachers for science, and many of the researchers became science educators. In this way, the APU investigations which were designed to assess children's science processes would have become a natural part of the teacher educators' repertoire in working with teachers. Thus, investigations which were designed to test children's understanding of science processes while making minimal demands on them conceptually came to be used to help teachers develop their understanding of variables and fair testing in primary science. It would be understandable if teachers with little or no experience of teaching science in a practical way then transferred these investigations (e.g., "Which kind of paper will hold the most water?" (DES, 1985, as cited in Qualter et al, 1990)) into their classrooms and used them as models from which to develop further science activities, thus perpetuating the "trivial" science content which has become synonymous with process science (Russell et al, 1992).

2.3 The resurgence of content

The development of the National Curriculum (NC) in the late 1980s led to a sudden requirement to delineate the processes, knowledge and understanding which constitute primary science. As Harlen (1992) observed, the development of the classroom teaching of primary science has not been shadowed by a research movement which can identify those elements it is necessary for children to learn, and by which approaches it can most effectively be taught. There therefore ensued a battle between science educators and the National Curriculum Council in order to ensure that current ideas about teaching and learning in science, based in "good primary practice" as they were, were recognised within the Curriculum (ASE, 1987) and portrayed in the non-statutory guidance (1989). The processes of science were given an attainment target of their own (AT1 or Sc1), and it was weighted heavily in order to ensure that content did not become pre-eminent in the primary school. However, despite these intentions, AT1 was but one of 17 in the original Orders (DES, 1989), and is still one of four (DfE, 1995). These other ATs are heavily knowledge-based, with a focus on fragmented knowledge, potentially leading children to develop as little understanding of science as through many process-based investigations.

There is therefore a mismatch between the knowledge requirements against which children are being assessed and the model of science education which underpins the structure of the NC. As a result of the NC, many teachers focus on the delivery of content knowledge, with the amount of investigative work on offer being much reduced from before (Russell et al, 1995). As well as the sheer volume of content, one factor leading to the change of approach is the requirement to ensure content learning. Where teachers themselves have either inadequate subject knowledge, or inadequate understanding of current views of the nature of science, then investigative work with defined content objectives is beyond reach. Personal communication with a local advisory teacher suggests that, in her experience, it is this formulation of content objectives which is the biggest stumbling block to teachers being able to deliver an effective science curriculum (Jowett, 1996).

2.4 Conclusion: No justifications for particular approaches

This prescription of a content for primary science has forced a reappraisal of the nature of primary science, and of appropriate teaching strategies to ensure effective curriculum delivery. While, as Harlen (1993) says, the prescription of content should not let teachers abandon their ideas about why and how science should be taught, neither should an under-researched vision of the child as scientist be allowed to dictate the structure and delivery of the curriculum.

3. The Advent of Constructivist Primary Science

Chronologically, the development of constructivist primary science predates the NC, but in terms of classroom impact it comes later. This is in accord with the time lags noted earlier in this chapter (section 1.2) between curriculum developments and classroom practice.

3.1 A generative model for learning primary science

Harlen and Osborne (1985) applied Osborne and Wittrock's (1983) Generative Learning Model to primary science. In so doing, they acknowledge two major constraints on their thinking. Firstly, they assert that young children need to interact with stimuli because of their limited range of prior experience and their immature processing strategies making more abstract tasks difficult. In other words, they justify young children learning by doing because of their age. Secondly, the teachers' lack of knowledge in science content and processes necessitates them taking a more organisational role in which children's ideas rather than science knowledge are the focus for learning. Even without more detailed explication of their model, it is clear that an acceptance of these constraints results in a constructivism with a very different nature from that espoused by Osborne and Wittrock, in which the prime aim of science teaching is to help children understand the accepted science view.

Table 3.1 on page 49 shows that the primary GLM has the same underlying premises as the secondary version, that mental processes are used to construct meaning from sensory inputs, making the child an active participant in their own learning. However, in opposition to the active role of the teacher in the secondary version, the primary teacher is defined as a facilitator of the learning process. The primary teachers' role is intended to move beyond providing first hand experiences, "to promote interactions of children with materials *and with the ideas of others*" (my italics) and the criteria for evaluating learning include "children seeking out, listening to and reading about the ideas of others". However, these aspects relating to the accepted science view are not only outweighed by those concerned with children developing their own ideas through investigation, but are the most difficult for teachers to implement as they require an understanding of the science being investigated. For a teacher to help children to relate the three aspects of: their ideas, their first-hand evidence and the ideas of others without an understanding of the appropriate direction of learning is very unlikely to succeed. The teaching processes involved are at least as complex as those necessary to use explanations and models to teach children the accepted science view.

Similarly, the role assigned to the young learner is more active than that assigned to the older children in Osborne and Wittrock's model. According import to discussing and weighing up evidence produced through their own investigation assumes their investigation will be appropriate and be furthering their science understanding. In the absence of an informed teacher, this is by no means guaranteed.

Surprisingly, the framework for teaching sequences (table 3.2) makes little mention of the role of the teacher, strengthening the impression that teaching in science is about facilitating child-centred learning rather than aiming towards the science view. However, Harlen and Osborne's suggestions for a content for primary science clearly refer to the development of scientifically accepted notions, and the criteria they suggest for the selection of content for primary science are balanced. Children should be encouraged to generate ideas which:

- have significance for making sense of everyday events;
- can be generated by many primary children at their level;
- can be related by children to their own prior knowledge and experiences;
- can be placed in a socially meaningful context;
- will help rather than hinder further learning in science; and
- can be tested by children through simple investigations (including referring to books and experts about the findings of others).

<u>Table 3.1 A Generative Model for Learning Primary Science</u>

(from Harlen and Osborne 1985, p.137)

view of learning

Learning through children
- generating new views of the world which enable children to make better sense of their world
- developing the processing strategies which enable children to more effectively and efficiently interact with things about them and the ideas of others

aim of primary science

to help children construct effective, and useful ways to view their world and to develop effective ways of learning

learning experiences

- children actively seeking evidence through their own senses and thinking about the evidence in terms of prior experiences and memory
- children listening to, reading, and thinking about the ideas of others in relation to both their own ideas and the evidence available
- children interacting with things to try out ideas and reconsidering them in the light of evidence
- children seeking more effective ways of organising information and testing ideas

classroom roles and procedures

<u>children's role</u>
- to become involved in developing their own ideas and ways of processing information and to realise that this is something they must do for themselves

<u>teacher's role</u>
- to find out the children's ways of viewing the world and provide experiences which help children to build more effective ones
- to help children ask, and attempt to answer, their own questions
- to help children reflect on their ideas and on their ways of thinking
- to help children test out their ideas in a fair manner
- to promote interactions of children with materials and with the ideas of others

<u>role of resources</u>
- to provide opportunities for children to investigate and manipulate things in their environment
- to arouse curiosity and interest in the ways things behave
- to provide information to help children construct useful ideas

evaluation criteria

<u>children's learning</u>

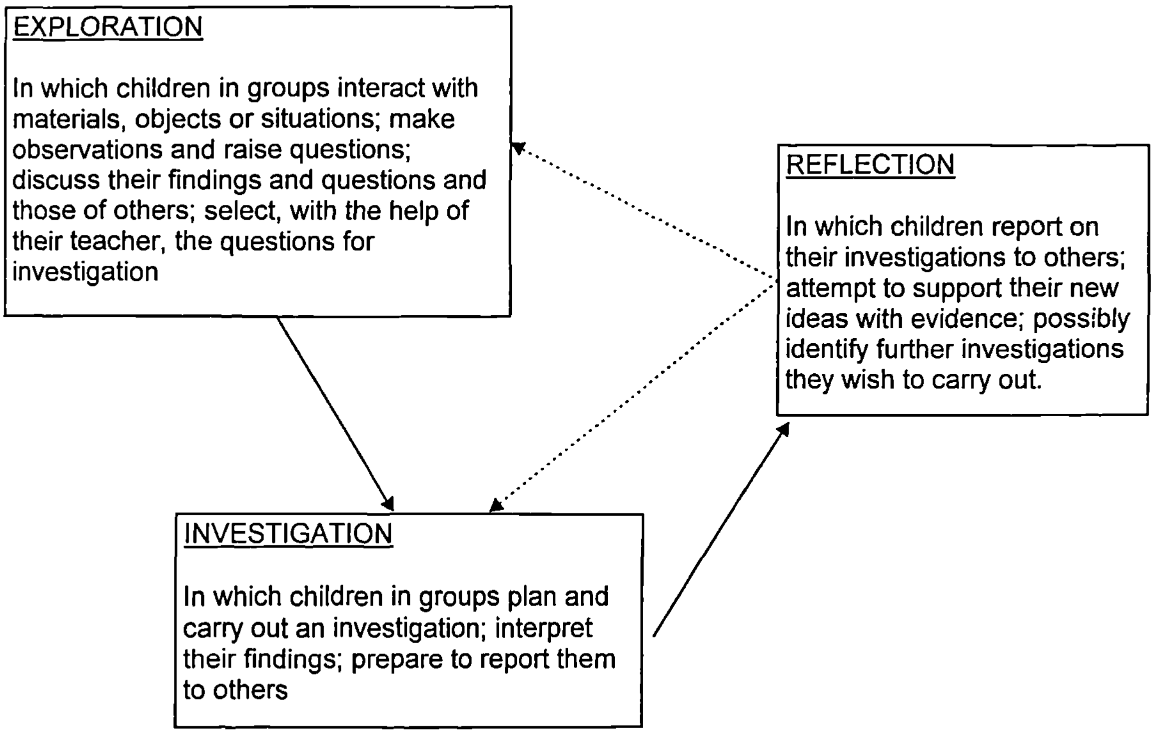
the extent to which possible indicators can be identified, such as:
- seeking out new ideas
- questioning new ideas
- relating new to existing ideas
- basing statements on evidence
- trying to explain new situations

<u>learning opportunities</u>

the extent to which the learning environment provides opportunities such as:
- working on own questions
- defining own problem
- devising fair tests
- basing conclusions on evidence
- relating finding to previous experience

<u>Table 3.2 Framework for Teaching Sequences</u>

(from Harlen and Osborne 1985, p.142)



The tensions throughout this paper appear to be a desire to provide a structure which teachers with little science knowledge can use while at the same time conveying a clear notion of what science should be learned by children, and a mechanism by which it can occur. These two positions seem irreconcilable as it would take an understanding of both the knowledge and processes of science to be able to assist children in investigating towards particular goals.

3.2 Classroom constructivism

Since the SPACE Project, the existence of children's ideas in primary science has had a major impact on research. However, despite small-scale studies by teachers into their own children's ideas (e.g. Braund, 1996), constructivism has had only limited impact upon classroom practice. One reason for this was the introduction of the National Curriculum in 1989, as discussed in section 2.3. Gibson (1996) sheds light on another possible reason by stating that research rarely goes beyond an elucidation of children's ideas to report how those ideas can be developed. The time lag in the production of curriculum schemes which utilise current approaches is also influential, ensuring that Nuffield Primary Science was not published until 1993. Perhaps it is not surprising, therefore, that neither Newton (1992) nor Russell et al (1995) found teachers using constructivist approaches in the classroom.

3.3 Children as scientists?

As considered in chapter 2, the children's perceptions of the constructivist learning process need careful appraisal. If teenage children find it difficult to learn for themselves (Gunstone, 1991a), and they would be working with a teacher who had some background in science, children of primary age will be more dependent on the teacher for direction as to their intended role. Without a background in science, the primary teacher is unlikely to have a clear understanding of *why* the children are investigating. My experience suggests that, for teachers, investigations are to develop skills and have no link with understanding. This lack of clear direction is likely to be compounded by the inappropriate selection of topics for investigation due to the focus on surface features rather than the underlying scientific principles (Johnson and Gott, 1996). This lack of focus will lead to children having no real understanding of the nature of science and the purposes of investigation.

3.4 Challenges to primary constructivism

As shown in section 1.2, the 'building on children's ideas' approach to personal constructivism is peculiar to primary constructivism. It seems to be a natural extension of the prevalent process approach, meaning that primary constructivism is synonymous with an inductivist approach to science education. A logical extension of "good primary science practice" would, on the face of it, seem highly desirable. However, there are three convincing arguments why this might not be the case. Firstly, Driver (1983) is at pains to distance constructivism from a process approach to science, saying that an over-reliance on practical work leads children to focus on sensory experience as a source of understanding, thus depriving them of conventional models which are not accessible to that approach. Secondly, the use of investigations may make science learning inefficient by overloading children by asking for concept acquisition, skill development and the use of procedural understanding all at the same time (Qualter et al, 1990; Gott and Duggan, 1995). Not only is this demanding in practical terms, it is asking children to take ownership of their learning, a position at odds with the school culture which places knowledge in the hands of the teacher (Mercer, 1995). Thirdly, I have quoted from Harlen and Osborne (1985) in section 1.2, that primary science has been "the subject of swings in ethos and practice" which they then set out to counter by proposing a rationale based on "a vision of the way we want children to learn". Substituting one ideological position for another does not constitute evidence of effective approaches to teaching primary science. These challenges to the accepted structure of primary science as investigative-based activity need more detailed exploration, and I consider them further in section 4.1.

4. The Nature of Practical Work in Primary Science

It is tempting to assume that, because young children do not have a sophisticated command of language, their learning can more effectively be mediated through their own practical actions. However, it is important to give careful consideration to *how much* practical experience is necessary in relation to a particular phenomenon before a child is able to consider it in a more abstract manner. The following sections address this issue in relation to primary science.

4.1 A typology of practical work

Gott and Duggan (1995) have identified different types of practical activity which each contribute to the learning of science in different ways. These are:

- skill development (to acquire and practise particular skills);

- observation (to use a conceptual framework to relate real objects to scientific ideas);
- enquiry (to 'discover' a particular concept / law / principle);
- illustration (to verify a particular concept / law / principle)
- investigation (to use concepts, processes and skills to solve a problem).

This typology identifies investigations as the means of testing a child's learning through their ability to apply their understanding in a new context. Thus, investigations would not be considered as the means by which new understanding should be generated. An acceptance of this approach to teaching science would enable teachers to be more honest with their children about the nature of practical activities in science. They would explain the objectives of an exercise to children so they would be aware of whether they were, for example, trying to find a particular answer in order to exemplify a principle, or to consolidate their own understanding by testing out a hypothesis (Nott and Wellington, 1996).

4.2 Questioning the link between "doing" and "understanding"

From a similar perspective to Driver (1983), Sutton (1992) challenges the amount of practical work in which secondary school children engage because he considers that the intellectual processes can be developed more effectively through discussion than through investigations.

> "Good telling and good puzzling can both gain greater prominence, while 'doing' should be derived from these and made more purposeful by that connection, and less time consuming."
> (Sutton 1992, p.71)

Sutton is of the opinion that, as language is an interpretive system, individuals should strive to reach an agreed understanding through discussion rather than finding out practically. A reliance on practical work implies that "the right answer" is something which is observed, and science becomes an activity devoid of the human dimension of discussion and negotiation. This position contrasts well with Harlen's (1993), that practical work from children's own observations and therefore their ideas helps them to understand the provisional nature of knowledge because they are modifying their own ideas as a result of contrary evidence.

The difference in position between Sutton and Harlen could be due to the type of practical activity under discussion. Harlen is referring to investigation and Sutton to enquiry and illustrative work. Using Gott and Duggan's typology from section 4.1, the definitions for both enquiry and illustrative activities need little dependence on practical activities as concepts/principles and laws need not be based on observable features, and can more accurately be determined via other methods. Investigations could more appropriately use practical activities. Harlen and Osborne's exploration phase (shown in fig. 3.2) is constructed to enable discussion to precede practical activity. However, given the importance of developing *coherent* frameworks, the teacher input to the exploration phase would need to be both well informed and substantial in order to avoid the problem of developing ungeneralisable, context-specific pieces of knowledge.

There is a prevalent view that young children cannot manipulate ideas with sufficient dexterity to develop ideas other than through practical activity, while older children have more options available to them. An initial first-hand experience is necessary for anyone to be able to engage with a phenomenon, however old, and the issue is then whether young children are less able to build on a practical experience through discussion than older ones.

As Nott and Wellington expound, the power relations which exist within the scientific community at large, and also within the classroom, do not allow children to claim new knowledge, therefore making their position as 'scientists' untenable. They are in the position of learning society's best guess at science knowledge and the mediation of this socially constructed knowledge can best be done through discussion.

4.3 Conclusion: The development of understanding in primary science

Hodson (1993a) considers the aims of science education to be three-fold: firstly, to learn science by accessing society's body of science knowledge; secondly, to learn about the nature of science by conducting investigations in the context of the public body of knowledge and thirdly to learn to do science by developing skills. Harlen's and Wenham's advocacy of combining these three aspects so that learning science is done through investigation, at the same time as learning how to conduct a fair test, leads to an approach to science teaching which is untenable because it demands three types of learning from the one procedure. This over-load is likely to lead to less understanding being gained. Furthermore, by using children's own ideas as the starting point for investigation, constructivist primary science is depriving children of access to society's body of knowledge. Without access to accepted explanatory models children may be able to conduct investigations but they will be unable to converse as scientists. In order to make use of a range of practical tasks as well as discussion related to important issues, it seems that teachers will need to have a good understanding of science themselves. The implications of this for primary science education are considered in the following chapter.

5. Conclusion: What Should be the Place of Constructivism in Primary Science Education?

Harlen (1992) indicates that the problem with primary science is that its growth as a curriculum subject has not been matched by a systematic research movement, meaning that it is open to the vagaries of fashion and trend. Constructivism has certainly been fashionable in recent years, but the research base which is now developing in primary science suggests that the emphasis on learning through investigation which is present in primary constructivism does not maximise children's learning either *of* science or *about* science. Though Harlen and Osborne clearly intended "investigation" to be interpreted more widely than planning, carrying out and evaluating fair tests, the wider focus of exploring the ideas of scientists which would give children access to the accepted science view is far less likely to be developed by teachers with no background in science. The narrower interpretation, testing children's ideas, will not only deprive children of gaining science knowledge, it will expect children to take responsibility for their learning within a school culture which does not allow children to claim new knowledge. Thus, however well constructed the practical investigation, without the necessary interaction with the ideas of more knowledgeable others, they will neither be developing their science knowledge nor their understanding of science as a discipline.

According to the National Curriculum the aims of primary science education are to give children more explanatory power so that their ideas can become useful concepts through: understanding key concepts; using scientific methods of investigation; appreciating the contribution science makes to society and understanding that learning in science contributes to personal development (NCC, 1993). However, according to the level descriptions for AT1 (experimental and investigative science) it is not until level 4 that pupils are expected to begin to relate the conclusions of their practical work to scientific knowledge and understanding. This might suggest that primary science should be concerning itself solely with the development of scientific methods of investigation. However, the level descriptions for ATs 2, 3 and 4 contain statements of knowledge and understanding which children are to acquire, suggesting that primary science is expected to do that using methods other than scientific investigation. The messages being conveyed here are consistent with the stated aims of the National Curriculum for science education, but are inconsistent with a model of science education which suggests that children should develop understanding through investigation. A personal constructivist approach combined with heurism would therefore not be compatible with National Curriculum science, though a socio-cultural approach could be.

As the edicts of the NC are "a top-down, best guess" (Russell et al, 1995), the absence of a research base make its prescriptions no less ideological than the stand-points the Government was presumably seeking to replace, such as constructivism. Authors who have listed aims of primary science education (e.g. Freyberg and Osborne, 1985; Harlen, 1993) have done so from within the constructivist tradition, so while constructivism would clearly have an essential place within that framework, there is no more of a research base underpinning that view of science than there is the National Curriculum. It is worth noting Driver's (1983) views on how a heuristic approach to learning in science came about:

> "Incidentally, it would be incorrect to suggest that psychologists and philosophers of science have been influential in shaping the science in our schools. Rather, the community of science educators has invoked such theoretical 'support' as is necessary to give credibility to 'common sense' views about the nature of science and of children's learning" (Driver 1983, p.75)

Her argument states clearly that the primary ethos of learning by doing precedes and dictates the formulation of primary science as the "young child as scientist", and that inductivist views of the nature of science are then used to justify this formulation. As constructivism, which itself has no research base, builds on the heuristic process science tradition, there can currently be little justification for its place as an underpinning for primary science.

6. Summary

The model of "child as scientist" which has underpinned primary science owes its origins to the child-centred primary ethos of learning by doing and finds support in the inductivist philosophy of science. By assuming the validity of children learning by doing, Harlen and Osborne (1985) proposed a primary model for learning in science based on Osborne and Wittrock's (1983) Generative Learning Model. Thus primary constructivism came to have its particular character, apart from secondary constructivism.

At first glance primary science may appear to have come full circle, back to the content emphasis of the early 1960s. Rather, it has come in a spiral, with a renewed emphasis on content, but with a different view of learning underpinning it. Teaching is no longer considered to be about transmission of knowledge but about the development of socially agreed understanding, mediated by active processing. It is therefore difficult to ascribe a place for personal constructivism in primary science because of its emphasis on both the development of personal understanding and investigation, making the attainment of the science view unlikely. Current research suggests that active processing can take many forms, but need not necessarily be either hands-on "doing" or investigation.

The discussion of primary science in general, and primary constructivism in particular, has raised issues of central importance to the teaching of primary science such as classroom culture, children's expectations of learning and teachers' subject knowledge. I pursue these themes in more depth in chapter 4 in a consideration of factors which affect primary science teaching.

CHAPTER 4

FACTORS INFLUENCING TEACHING IN PRIMARY SCIENCE

In this chapter I focus on various factors which contribute to effective teaching in primary science, exploring research concerning teacher attitudes towards science, classroom ethos and teacher subject knowledge. Where possible, I cite research conducted in the context of primary science. However, as such research is limited, I make use of findings from other subject areas, and concerning older children, with the assumption that there is at least some degree of commonality between either teaching science to older children, or teaching other subjects to primary school children, and teaching science to primary school children. I survey the structure and content of primary science curriculum materials to establish how they contribute to practice. I consider the issue of teacher development with particular reference to primary science and conclude the chapter by suggesting that the current 'best guess' about effective teaching in primary science is influenced profoundly in all aspects by teacher subject knowledge.

1. Teachers' Understanding of the Nature of Science

Stodolsky (1988) found that elementary teachers adopt different teaching approaches for different subjects that they teach. She claims that her finding supports that of Shulman (1986), that children will learn that they learn differently in different subjects. A corollary of this is that teachers will be conveying messages to children about the nature of science through their approach to teaching, and through their interactions with children during science lessons. This position is supported by Benson (1986, as cited in Hodson, 1993b) that children in the same class have similar views about science, and views which are different from those of children in other classes. All other things being equal, it is reasonable to infer that a teacher's approach to science teaching is indicative of their own understanding of the nature of science. For these reasons, I present a typology of teacher attitudes and relate these styles to the response to curriculum innovation.

1.1 A typology of teacher attitudes to science teaching

Wolfe (1989) sets out to test the hypothesis that teachers convey messages about the nature of science through their teaching by observing their approach to teaching science. However, she does not ask the children what they think science is about, so there is no way of knowing how the teachers' messages are received and used within the classroom. Carré and Ovens (1994) refer to the typology produced by Wolfe which typifies three different attitudes towards science teaching. These, from Carré and Ovens but with Wolfe's titles, are:

<u>Sensationalist</u>

Encouraging children to be autonomous and work independently
Helping children to ask productive questions
Offering initiatives to children
Refraining from giving clues or science information to children
Providing motivating materials for hands on enquiry

<u>Formalist</u>

Transmitting content clearly within a framework provided by the teacher
Thinking mainly about the product. Providing clear tasks to produce it
Preventing aimless activity by directing investigations
Showing and demonstrating
Scientific vocabulary deliberately incorporated into lessons

<u>Rationalist</u>

Negotiating understanding and helping pupils to reshape their knowledge
Planning for pupil's misconceptions
Challenging pupils to predict, explain and justify their use of evidence
Providing ways of applying new concepts
Eliciting ideas by setting up new dialogues

Given the differences between these three typologies, it is clear the science experienced by children taught according to each typology will be qualitatively different. The sensationalist teacher is presenting a view of science as inductive activity, with principles generalisable from observations; the formalist teacher is presenting science as the reception of a body of knowledge; and the rationalist teacher is presenting science as socially determined deductive activity. While such typologies are undoubtedly helpful as a way of highlighting differences between approaches to teaching science, there is a danger that it will lead to over-simplification since most teaching approaches use some strategies from each heading. For example, a socio-cultural perspective is predominantly rationalist but makes use of formalist strategies like showing and demonstrating; personal constructivism as applied in primary science is predominantly sensationalist but with rationalist elements, for example planning for misconceptions, challenging children to predict, explain and justify their use of evidence.

1.2 Typological response to curriculum innovation

The extent to which teachers conform to particular typologies influences their response to curriculum innovations in different ways. In the absence of training, the *Science 5-13* and the LISP materials are used successfully only by teachers who already hold the sensationalist / rationalist view of children's learning which is compatible with the scheme's (Harlen, 1975; Biddulph and Carr, 1992). Similarly, teachers are more likely to be successful at adopting rationalist conceptual change strategies if they already hold a formalist rather than a sensationalist approach (Smith and Neale, 1991). According to Carré and Ovens' definition of a formalist teacher, it is likely that their product orientation, and therefore familiarity with aiming for a particular learning outcome, enables them to adapt to conceptual objectives with greater ease. Evidence which supports Smith and Neale's finding comes from Appleton and Asoko's (1996) case study of "Robert". He was a sensationalist teacher whose main difficulties with a conceptual change approach came from his planning work which involved the class in interesting activities rather than in tasks with learning objectives which matched the required concepts. His planning thus lacked a clear focus for children's conceptual learning, consistent with his sensationalist approach, hampering him from developing a more rationalist approach.

1.3 Conclusions: Subject knowledge constraints on teaching approach to science

So far, I have implied that teachers' attitudes to science teaching are freely chosen. There are, though, other constraints at work here, one of which is subject knowledge. A rationalist stance involving negotiation of understanding is impossible without a sound understanding of science, and is an approach only an expert teacher can pursue (Scardamalia and Bereiter, 1989). At the same time, Tobin and Garrett (1988) suggest that the problems of purposeless process science are the result of inadequate content knowledge. They consider that effective teaching in secondary science classrooms, characterised by tasks of high cognitive demand, would be desirable in the primary classroom. I would speculate that at least part of "Robert's" preoccupation with process rather than product was a manifestation of a lack of subject knowledge, as was his planning by activity rather than by objectives (Osborne and Simon, 1996a), both of which are impediments to the adoption of a more rationalist approach to teaching. By directing activities, formalist teachers ensure that children cannot venture beyond the bounds of their subject knowledge (Harlen, 1996). It is possible, then, to appreciate Osborne and Simon's (1996a) argument for restricting the content of primary science to that with which teachers feel secure, thereby enabling them to develop their preferred approach to science teaching rather than having to use one by default.

2. The Culture of the Classroom

I referred in section 1 to children learning from the teacher how to behave in particular subjects (Stodolsky, 1988; Shulman, 1986) and in the previous chapter to children's expectations of classroom learning. The issue of children's understanding of classroom culture is important to explore more broadly to establish whether there is evidence that children can adapt not only to different organisational styles but also to approaches with different theoretical underpinnings, e.g. constructivism. This section explores the culture of the classroom in terms of children's understanding of ethos and the learning process.

2.1 Classroom ethos

Whatever a teacher's attitude towards science teaching, it will be reflected in the manner in which science is organised and managed in the classroom. As science is part of the broader curriculum, it will inevitably need to conform to the unspoken rules and ideologies of schooling (Hollon et al, 1991). However, many curriculum developers appear to ignore this constraint and assume that the intentions behind their approach to learning will be perceived accurately by both teachers and children. This is particularly an issue in relation to constructivist teaching approaches in which the children's ideas become the conceptual focus of teaching in a way which my experience suggests is likely to be incompatible with teaching and learning approaches in the rest of the curriculum, and which requires teachers to adopt unfamiliar teaching strategies.

Olson (1981) asks teachers who have recently introduced the student-centred Schools Council Integrated Science Project to describe what they and the children are doing. It transpires that teachers used to "high influence" activities, for example lecturing and demonstrating, modify the "low influence" roles to retain their position of control in the activities. For example, they describe themselves as 'directors' or 'navigators' rather than 'facilitators'. In related research, Fraser (1978) found teachers interpreting low influence roles as ones with zero influence, so that independent learning by students was exactly that, with no offer of teacher support. White (1988a) describes this phenomenon in terms of lesson 'scripts' which are based on generalised episodes of previous lessons and which therefore set out expectations of what will happen. For teachers to adopt new roles within the science lesson, both they and the children need to develop new 'scripts', which takes time, particularly if the learning outcomes are still to be measured in the same way as previously, i.e. by the recall of knowledge through exams. Similarly, where teachers are asked, as in a constructivist approach, to value children's ideas, this approach needs to be learnt and accepted by both teacher and children.

The importance of this two-sided acceptance is shown by Rudduck (1980) who found that pupils can neutralise the effect of any change simply by maintaining their established forms of behaviour. In one of the few pieces of research to ask primary school children about their teachers, Bentley (1985, as cited in Bentley and Watts, 1992) found that children are extremely adept at interpreting non-verbal communication from teachers, and that these interpretations determine how the children respond to the teacher. She found that children would be open and discuss their ideas if they perceived the teacher to be warm, enthusiastic and interested in children and their ideas. By extrapolation, were a teacher who was viewed as unenthusiastic required to adopt a constructivist approach, it is unlikely that their non-verbal communication would be convincing, and therefore children would be unlikely to develop this new way of working.

Edwards and Mercer (1987) describe how these classroom rules ensure that the teacher is the purveyor of knowledge, and how the associated ideologies which value experiential, inductive learning ensure that children are unlikely to develop real understanding but to gain "ritual and procedural knowledge". They cite the example of a teacher who introduces the context for an investigation and undertakes a "cued elicitation" with the class, in which the children proffer variables to explore which are ignored or modified until they correspond with the variables which the teacher has pre-planned that the children will explore. In so doing, the teacher ignores hypotheses which, if tested, would lead to real scientific understanding, in favour of pre-planned superficial hypotheses which do not help learning. Not surprisingly the children, when asked, have no understanding of why variables should be controlled in terms of scientific principle. They are learning another school procedure rather than gaining experience in generating understanding.

Mercer (1995) goes further in attacking the 'learning by doing' which is prevalent in primary science, and states that the school constraints in terms of a curriculum to be taught must be acknowledged and balanced against giving children freedom to explore. This is very resonant with Nott and Wellington's (1996) plea for teachers to be honest with students about the stage-managed nature of the majority of practical work in which students are engaged. Having this knowledge empowers students to be able to take greater control of their learning because the hidden control of the teacher is removed and replaced with an explicit structure. Further, by making the demands clearer, teachers may become more able to operate at the higher intellectual level which they are asking of children rather than focusing on lower level management issues (Stodolsky, 1988). This would certainly concord with the perspective of secondary students, that effective teachers should be knowledgeable and enthusiastic, sympathetic to students' understanding but expecting of high standards, and competent managers (Woolnough, 1994).

2.2 Children's understanding of science learning

When Woolnough (1994) asked students (in Y13) what they considered to be the important characteristics of school science they said they liked doing investigations, but they preferred well-structured, teacher-directed lessons to having to plan from their own initiative. This finding suggests a mismatch between teacher and student interpretations of the nature of open practical work. Either teachers are providing insufficient structure for investigations (for which there is evidence from other research, e.g. Fraser, 1978) or, as Edwards and Mercer suggest, they are failing either to convey an understanding of the nature of science learning through investigation, or to take into account sufficiently the students' understanding of the nature of school learning. Gunstone (1991a) considers this latter dilemma and cites two pieces of earlier research which shed light on the problem: Tasker (1981) determined that students held a passive view of learning which meant they were unaware of why they were engaged in particular activities. Simply structuring tasks to make students take an active role would, in that context, be unsuccessful because they would change the nature of the task to make it less demanding. This parallels Olson's findings of teachers reinforcing their position of authority by redefining their role. Macdonald (1990) found this problem could be addressed by helping them to develop an appropriate metacognitive vocabulary to discuss their own learning.

2.3 Conclusions: The influence of subject knowledge on classroom culture

While this research is located in secondary schools, recent primary research has echoed Fraser's and Macdonald's concerns, and suggested an additional interpretation of Edwards and Mercer's work. Simon (1997), in a comparison of two case study classes, found that children in one class were far more often unaware of what they were meant to be learning in science than in the other class. She concluded that the children had much clearer ideas about the purposes of activities if the teacher had introduced the activities in a manner related to clear learning objectives, had selected appropriate activities, and if the classroom organisation facilitated teacher - child interaction. These conditions were met in the class which had a teacher with good subject knowledge, but not in the other. This research again raises the issue of teacher subject knowledge because if teachers are to select appropriate activities, organise and present them well, they must understand what they are doing. This understanding would, whatever the power relationship in the classroom, help to avoid children learning ritual and procedural knowledge at the expense of developing scientific understanding.

3. Teachers' Subject Knowledge

Each of the previous sections in this chapter has concluded that teacher subject knowledge is influential in primary science teaching. Since 1985 there has been a growing body of research, originating in the United

States, which has been exploring the issue of subject knowledge in teaching. This research has been spearheaded by Lee Shulman (1986; Grossman, Wilson and Shulman, 1989) and has led to the definition of different forms of subject knowledge. These types will be defined and exemplified so that the ideas can be used to inform later argument.

3.1 Types of subject knowledge

Grossman et al (1989) propose that subject knowledge is composed of four dimensions: content, substantive and syntactic knowledge, and beliefs about the subject matter. Content knowledge relates to the discipline-based concepts; substantive knowledge to understanding the knowledge structures of the discipline, i.e. how the concepts inter-relate; syntactic knowledge to how knowledge is created, i.e. the methodology of the discipline. Within the particular context of science, Shulman (1986) exemplifies the terminology in terms of biology. The content of biology can be organised into a range of substantive forms, each of which will be applicable in particular cases: a biochemical perspective focusing on cell function and building up to a whole organism; an ecological perspective looking at systems within an environment or a zoological perspective focusing on organisms. Whichever perspective is applied, the syntactic rules by which new knowledge can be accepted as valid are the same and governed by the scientific process of objective testing. Of particular relevance in a study relating to constructivism and socio-culturalism, Carlsen (1991) supplements Shulman's four dimensions with a fifth, pragmatic knowledge. This recognises that knowledge is context-dependent and useful for different purposes, meaning that both substantive and syntactic rules will be applied differently in an everyday as opposed to a scientific context.

Understanding how the different parts of science work together to form the unique subject of science is in itself insufficient to enable teaching to be successful. Shulman (1986) articulates the need for subject knowledge to be transformed into "action-relevant" knowledge which can be used appropriately within the classroom context to inform decisions about choice of activity (curricular knowledge) and mechanisms for conveying meaning (pedagogical content knowledge). McDiarmid, Ball and Anderson (1989) discuss how the teacher can thus select representations (examples, analogies and metaphors) to use in teaching which will be both comprehensible to the student and provide realistic portrayals of the nature of the subject to assist students in developing their scientific literacy (Harlen 1996, p.7), a term recently coined by the American Association for the Advancement of Science to signify "that essential science understanding which should be part of everyone's education".

3.2 Primary teachers' understanding of science knowledge

It has long been recognised that teachers in primary schools lack a background in science, and it has been posited that such knowledge might give them the necessary understanding and confidence in science to enable them to teach the subject effectively to primary school children (e.g. DES, 1978; Black, 1980). Russell et al (1992) contend that it should be possible for every primary school teacher to acquire the amount of content knowledge needed "given the means and the opportunity", suggesting that very little knowledge is necessary in their view. Moreover, they consider the assumption that science teaching would automatically improve with this knowledge to be flawed. This latter position would be shared by anyone who has found the ideas of Shulman and his colleagues to be useful in illuminating the role of subject knowledge in teaching. Russell et al's former assertion would also probably go undisputed - were it not that "the means and the opportunity" are not available for the majority of teachers (Ovens, 1988), for whom science is but one of nine subjects, all of which need to be taught to children according to the prescriptions of the National Curriculum (DfE, 1995).

Harlen and Osborne (1985), writing from within a personal constructivist framework, suggest that teachers should focus on understanding the range of ideas children are likely to bring to their science learning and how these can be developed rather than learning accepted science: that is, focusing on pedagogical content knowledge rather than content knowledge. However, putting the emphasis on pedagogical content knowledge in the absence of content knowledge would involve teacher in having to make curricular decisions in a vacuum. Where teachers themselves lack a framework of knowledge, they lack the ability both to explain anything to children from a position of understanding (Bell, 1994) and to interpret the children's ideas in terms of underlying understanding (Johnson and Gott, 1996). It would therefore be very unlikely that children would be able to develop any sort of coherent picture of science as they would need the teacher's help in developing their own framework for science.

This argument about the inter-dependence of content and pedagogical content knowledge stems from a socio-cultural perspective on teaching and learning, and it corresponds closely to the manner in which Harlen (1996) used interviews (known as "collaborative explanations") with teachers as a forum for both eliciting and developing their understanding. By talking with teachers about various "big ideas" in science, the interviewers were able not only to probe their understanding, but to provide a non-threatening forum for discussion during which the teachers were assisted in developing their understanding in the target areas.

3.3 Teacher subject knowledge and classroom teaching

Recent research initiatives concerning teacher subject knowledge in primary science used a range of methodologies to explore this issue. The Primary School Teachers and Science (PSTS) Project (e.g. Kruger et al, 1990) used constructivist techniques to elicit teachers' understandings of science and find them very similar to children's ideas. This approach, using interviews-about-instances (Osborne and Gilbert, 1980), has resulted in newspaper articles decrying the level of understanding of primary teachers, without providing any evidence that the classroom practice of those teachers with low levels of understanding was qualitatively different from others. Had this evidence been available, then the research base about the effects of subject knowledge upon classroom practice would have been usefully augmented. Some evidence which does support the hypothesis that a good understanding of science relates to good science teaching comes from Osborne and Simon (1996) who provide case studies of the practices of a small number of teachers who have a good understanding of science and those who do not, as measured by their degree specialism. "Fiona", a science graduate, was able to:

- create and sustain open dialogue;
- identify the important features within a topic for children to learn;
- use more and better analogies;

while "Carol", a non-science graduate, could not do these things, making judgements about what science content was relevant by selecting curriculum activities which seemed appropriate for the children's age. It cannot be assumed from these case studies that science graduates will necessarily make better science teachers because they might not have appropriate pedagogical content knowledge to support their content knowledge. However, where the two co-exist, the teachers' knowledge framework will be a substantial advantage. Similar characteristics of informed practice are found in student teachers (Carré 1993).

The PSTS project is now collecting classroom-based data in the form of case studies in order to establish how successful their INSET aimed at improving content and teaching knowledge (Shulman's content and pedagogical content knowledge) is at improving understanding in a group of children taught outside the classroom by the teacher. While the rigours of the classroom context itself are much diminished in this approach, the results of the children's learning seem positive according to a pre/post-test measure of understanding. In the post-teaching interview the teacher, who did not have a background in science, considered the success to be due to a number of factors (Summers, Kruger and Mant, 1996):

- having clear objectives for the children's learning enabled a clear focus to be kept on the required concepts.
- having increased confidence in subject matter enabled her to use demonstrations rather than relying upon the children discovering the concepts
- establishing the children's ideas and then explicitly introducing the 'scientific' view as the focus for teaching
- having appropriate teaching knowledge in order to anticipate and refute children's ideas; to use models, analogies and language effectively
- checking the children's thinking and understanding through questioning
- involving the children in activities and discussions

Many of these strategies are ones which would be used by teachers without thinking in other areas of the curriculum in which they have more experience, suggesting that content and pedagogical content knowledge are crucial for successful teaching. This is further supported by the above-described teacher's assertion that her knowledge base had increased enough for her to be able to do demonstrations, but not far enough for her to feel that she did not need to control the children's learning, something else which demonstrations allowed her to do.

3.4 Conclusions: Teacher confidence and teacher subject knowledge

It should be anticipated that there is a link between a teacher's level of subject knowledge and their confidence in teaching science. Holroyd and Harlen (1996), in a survey of 514 primary teachers, largely confirm this premise by finding that teachers are more confident about skill development than concept development because they are unsure about their own subject knowledge. Interestingly, Harlen (1996) found an anomalous group of teachers with low subject knowledge but high confidence in teaching science. She found that these teachers use a range of strategies in order to cope with the teaching. These are: avoidance by teaching as little science as possible; selecting from a limited range of topics which they consider easier; restricting discussion to teacher-controlled question and answer sessions; stressing process rather than concept development and sticking to prescriptive workcards or textbooks. Similar findings come from several sources: Louden's (1991) extended participant observation in the classroom of a creative arts specialist shows she uses science as a vehicle for developing independent study skills in order to circumvent her own perceived inadequacies in both process and content knowledge; Goodrum (1987) and Whitby (1994) show that the quality of teacher questions is related to confidence in science knowledge.

4. The Structure, Content and Impact of Curriculum Materials

In terms of teacher confidence and subject knowledge, curriculum materials should be able to provide good support. In this survey of recent materials I found them to vary according to two dimensions: emphasis on process or content, or an interaction between the two; and the degree to which the activities are structured for the children. In order to inform the later discussion of *Nuffield Primary Science* (chapter 6), I compare the degree of congruence between the teachers' guide for each scheme, and the materials produced for children. Each of these areas is considered separately.

4.1 The approach to science advocated in curriculum materials

The relationship of schemes to the two dimensions of process and content can be traced to the prevalent climate in primary education at the time. As mentioned in chapter 3, the *Nuffield Junior Science* and *Science 5-13* belong to a guided discovery tradition, in which children are encouraged to follow their interests and to use science processes in order to find answers to their questions. The materials are therefore left unstructured so that teachers can select from them according to the interests of their children. While according this autonomy to teachers was based upon the best intentions of current educational thinking, Black (1980) observed that these materials were not well used because teachers lacked both the knowledge and experience of science to enable them to make the necessary curricular decisions. In response to these schemes there followed the production of materials aimed explicitly at redressing what the authors perceived to be earlier imbalances in both content (*Look! Primary Science*, Gilbert and Matthews, 1981) and teacher support (*The Young Scientist Investigates*, Jennings, 1986). Necessarily, these materials are much more structured with attendant differences in how the nature of science is conveyed to children.

The late 1980s and early 1990s saw the publication of a large number of new schemes, all of which have one thing in common: every teachers' guide proclaims clearly that, "children learn through being involved in practical activities" (Bailey and Wilcock, 1987; Showell, 1989; Ginn Science, 1989; West Sussex County Council, 1991; Hopkins and Hunter, 1990; Howe, 1991; Davis, 1991). This statement heralds a renewed emphasis on learning through investigation, linked to the rise of 'process science'. Discovery learning is not the underpinning message; children need to be given experience in developing the skills necessary for carrying out competent investigations. The understanding which should be generated from these investigations is not prominent at all, and the identification of data patterns is often an end in itself, as evidenced by the lack of specificity in content objectives and the prevalence of process objectives (e.g. Howe, 1991). The scheme's authors appear to do little more than provide the context for the investigation for which practical and intellectual skills are the main focus.

Here is further evidence of the time lag between research and classroom practice, as mentioned in chapter 3, section 1.2, as 'process science' was no longer in prominence by the time these schemes were produced. *New Horizons* (West Sussex County Council, 1991) and *Q Science* (Davis, 1991), on the other hand, separate out knowledge-developing activities from process-developing activities. This approach is far more in line with that advocated by Gott and Duggan (1995) and Qualter et al (1990), as mentioned in chapter 3, section 4, with the intention that investigations should consolidate knowledge gained in other ways. It would be interesting to know how many of these curriculum materials are written by advisory teachers for whom science as process has become the main focus of science. Certainly *Nelson Science* reads as if the text of the teachers' guide comes from a book written in the mid 1980s, e.g. *Taking the Plunge* (Harlen, 1985):

> "Action questions are the 'what happens if' questions which can always be truthfully answered...After sufficient activities provoked by the type of questions just described, children become ready for a new type of question: the more sophisticated 'can you find a way to' question....Breaking up children's 'how' and 'why' questions into manageable 'what happens if' questions and 'let us see how' observations may try the children's patience, but will provide necessary experiences to make understanding possible. In any case, it is good science education." (Elstgeest in Harlen (ed.) 1985, pp.39, 43)

> "Many of the questions children ask are complex 'how' and 'why' questions. The teacher needs to encourage this but at the same time help children to frame investigable questions. The explanation-seeking 'how' and 'why' questions need to be turned into information-seeking 'What happens if...' and 'I wonder whether...' questions which can be answered through actions. The child will then be able to reach towards understanding by reasoning on the basis of his/her own experience and the evidence from his/her own investigations." (Hopkins and Hunter 1990, p.18)

All the schemes in the above paragraphs, with the exception of *Longman Scienceworld* (Bailey and Wilcock, 1987), were published after the introduction of the NC but, given the time from inception to publication, they would have been under development before the NC was in force. The schemes which have been published since then (e.g. *Bath Science*, 1993; *Oxford Primary Science* (Axten and Axten, 1993); *Nuffield Primary Science*, 1993) all make science knowledge and understanding more prominent, while still emphasising the role of process. Interestingly, all three of these schemes make either overt or covert reference to research in primary science and use that to inform their development, an aspect not previously prominent.

Schemes which have been published in 1996 or are due for publication in 1997 again cover the whole spectrum of approaches to primary science from knowledge-based presentations (Hall, 1995) to process-based presentations (Coltman, Peacock and Richardson, 1997). Neither of these, nor the more balanced *Bath Science* (edition 2, 1995) has sufficiently focused learning objectives to lead to concept development as opposed to fragmented knowledge and understanding. There is one new scheme which does stand out, and that is based on the research which has been carried out at Durham University under the auspices of Gott and colleagues, as mentioned in chapter 3, section 4. Feasey, Gott, Phipps and Stringer (1996) have produced materials containing very structured tasks which are clearly based on a scaffolding as opposed to an investigatory approach. This is an example of a scheme which is in line with current research thinking, and is therefore likely to be ahead of classroom practice. It will therefore be interesting to see what its uptake is amongst both teachers and science educators.

4.2 The relationship between teacher guides and pupil materials

Authors use a range of approaches to provide support and guidance for teachers. Schemes fall broadly into three camps; those which provide no pupil support materials for practical activities (e.g. *NPS*, *Science 5-13*); those which provide 'recipe' activities for children in order to help teachers to build their own confidence (e.g. *Look! Science*, *Oxford Primary Science*) and those which provide a clear framework for children to work in (e.g. *Collins Primary Science*, *Learning through Science*). Only the second and third categories can be discussed in this section as there can be no relationship if no pupil materials exist. The teachers' guide for each of these schemes shows clearly that the authors not only understand the nature of science, but also have an appreciation of the practical and intellectual constraints to which teachers are subject in regard of primary science. However, the materials as presented to children vary considerably in the extent to which they enable them to learn about the nature of science and the process of construction of scientific knowledge (Gott and Duggan, 1995).

The schemes which provide structured pupil activities to give children all the guidance they need state clearly in the teachers' guides that there is an expectation that teachers will modify the activities as they gain in confidence. However, as the work cards contain prescriptive, illustrative activities under the guise of investigations, it would not be easy for teachers to change these, leaving the children with a process-impoverished selection of activities to work through. Should the teachers read the teachers' guide they would begin to understand their role in children's learning, but should they not read it, their perceptions of science and their role as a teacher would be very distorted and unlikely to help the children to learn science.

The more open pupil materials contain an explicit framework to guide the children through the investigative process, and are often less open than they at first seem since they contain pictorial cues. However, most of these frameworks stop short of encouraging the children to draw conclusions from their data to develop or consolidate understanding. Again, these materials require the teacher to understand what science the children are meant to be learning so they can ask pertinent questions of the children.

The pupil materials, whether structured in an open or a closed manner, are all intended to give the teacher support in teaching science. However, it is very hard for teachers to be in control of the learning process, particularly if they have a low knowledge base themselves, because there is an almost universal lack of clear learning objectives for knowledge and understanding within the teachers' guides. Osborne and Simon (1996) found, not surprisingly, that a teacher with a low knowledge base chooses unconnected 'interesting' activities for children to do, and the children's understanding of the purpose of the science activities appears to be related to the teacher's understanding (Simon, 1997). As Jowett (1996) states that the construction of learning objectives is what teachers find hardest, this suggests that those materials intended to support teachers are not doing so with the necessary level of specificity. Rather than supporting teachers, they may be lulling them into a false sense of security.

4.3 The impact of curriculum schemes on classroom practice

As suggested by Simon's research above, if schemes are not providing the support which teachers need to gain confidence and experience in teaching primary science, they are unlikely to impinge in a positive way on classroom practice. Baird (1988) considers the lack of impact of curriculum development on classroom practice to be due to the lack of effort expended on related teacher development, which concurs with the findings of Harlen (1975), Biddulph and Carr (1992), Fraser (1978) and Olson (1981) described earlier in this chapter. An alternative explanation is provided by Olson and Eaton (1987). They have found that teachers "cannibalise" innovations by using only those aspects which they can incorporate into their existing practice. In that way they can ensure that they remain competent practitioners, gradually incorporating more new ideas over a period of time. Symington and Osborne (1985) recommend involving teachers in understanding the roles, and in turning their 'self-concerns' (from Fuller, 1969) into concerns for the learner. As can be seen, the introduction of curriculum materials utilising unfamiliar approaches will affect both teaching and learning within the classroom.

4.4 Conclusion: maximising the impact of curriculum materials for teachers

Black (1980) suggested that teachers did not have sufficient experience, knowledge or confidence to use schemes which left the decisions to them. Seventeen years on, his message is still topical if only because the NC has required teachers who would otherwise not have done so to teach science. It is therefore important to use curriculum materials to provide support for teachers and this should be done in a number of ways. Firstly, as it cannot be assumed that teachers will read any teacher materials, the pupil materials must be structured so that they both stand alone and can be used in a manner consistent with the thinking behind the scheme. Secondly, as a teacher's knowledge of science cannot be assumed, a clear framework for developing children's knowledge, understanding and mental processes should be provided in the form of key ideas and skills, and accompanied by clear learning objectives for activities so that teachers can know their intended purpose. Thirdly, where schemes advocate an approach to teaching which may not be familiar to teachers, extended support should be provided in the form of teacher development. As science is probably only just becoming familiar to a large number of teachers, this support should extend across all schemes. White (1988b) eloquently writes:

> "Theory cannot be launched at practice like a missile; rather it has to be cultured and nurtured like a plant." (pp.129-30)

5. Developing Practice in Primary Science

HMI (DES, 1978, 1984) clearly subscribe to the view of science education as the use of science processes and skills to develop understanding, that is, the view which is prevalent in the literature of the time - but which was scarcely evident in schools. During both surveys, HMI comment on the slow progress made in classrooms compared with the time, money and energy invested in curriculum development. Both surveys pointed to the lack of science knowledge in teachers as a major factor in this state of affairs, knowledge of both content and process. As solutions to this, the deployment of specialist teachers (DES, 1978), training courses for science co-ordinators (DES, 1984) and the prescription of some content (DES, 1984) were proposed, amongst other things. Each of these suggestions came to pass, in the form of science advisory teachers, 35-day courses and the National Curriculum. As teacher subject knowledge is so important in science teaching, it would seem a sensible place to target teacher development work. However, much INSET has been targeted on earlier models of science teaching which make fewer demands on content and more on understanding the nature and processes of science. This section reviews teacher development initiatives and considers models of professional development derived from their evaluation.

5.1 Government-funded training

Pre-National Curriculum, teachers who were enthusiastic about teaching science were able to avail themselves of many INSET opportunities offered or validated by the Association for Science Education. However, partly because of the poor state of primary science teaching generally and teacher subject knowledge in particular, other training opportunities were made more widely available, and these were funded at a national level. The Education Support Grant (ESG) teachers were seconded to advisory posts for an initial period of three years to work alongside teachers in their classrooms, meaning that whole staffs could work in their own, familiar context with an expert science teacher. As discussed in chapter 3 section 1.2, the pre-eminence of hands-on activity became the norm for primary science, especially amongst teachers who worked with advisory staff. Again, the reasons for the enthusiasm for a process approach may be that it skirts around the issue of content knowledge for both the advisory teachers and the classroom teachers.

The advent of the National Curriculum had such a large resource implication for primary school teachers that it is hardly surprising that the editorial of the Primary Science Review, the magazine of the primary members of the Association for Science Education, was repeatedly calling for a resource allocation to match the size of the task (e.g. Ovens, 1988). By the end of 1987, Ovens stated that 1350 science co-ordinators had been able to benefit from a 35-day science course. At that rate, he estimated that it would take until the year 2053 before every school had a representative who had attended such a course. These courses were required to be developed jointly by local education authorities (LEAs) and higher education institutions and were scaled down to 20 days in 1990, and again to 10 days in 1994. As these courses were becoming shorter, concurrent initiatives from the Education Reform Act (ERA) meant that funding was being devolved from LEAs to schools. This devolution in funding resulted in a dramatic decrease in the number of advisers and advisory teachers which meant that the necessary support to introduce science to teachers who had never taught it before was not there in all areas of the country. For example, in one LEA during the academic year 1992-3, the advisory staff were instructed to reduce the amount of time spent on development work by 40%, leaving only 20% of their time for such work. The remainder of time was given to quality assurance via inspection (Evans and Penney, 1994). While the change in scale and role of the advisory service began in 1993, four years after the introduction of the National Curriculum, Platten (1993) and others argue that the intervening years served to enable teachers to come to terms with the Orders sufficiently for them to be at the stage of being aware of what particular help they need in interpreting and delivering the National Curriculum in the classroom. Thus, by the time the teachers' curricular knowledge is sufficiently developed for them to be receptive to suggestions regarding content and pedagogical content knowledge the opportunities for such support are much reduced (Kirkham and Towns, 1993).

5.2 Outcomes of teacher development

The use of ESG teachers was evaluated by Kinder and Harland (1991) who have subsequently used their data to generate a hierarchical typology of the outcomes of the INSET in one LEA. They found that individual teachers received different outcomes from the same INSET, but that for the INSET to be successful and result in changed classroom practice all of the possible outcomes were necessary. The outcomes, starting with the lowest order, were:

Third order

Provisionary - the teacher gained materials from the course, e.g. worksheets and equipment;

Information - the teacher gained an awareness of curricular and organisational requirements;

New awareness - the teacher changed their understanding of the nature of science;

<u>Second order</u>

Motivation - the INSET generated enthusiasm in the teacher;

Affective - the INSET generated a positive emotional experience in the teacher;

Institutional - the INSET generated support and collaboration amongst the teachers;

<u>First order</u>

Value congruence - the extent to which the teacher and the INSET deliverer have similar views about good practice in teaching;

Knowledge and skills - the teacher gained a deeper understanding of content and processes of teaching and learning.

These outcomes seem realistic and plausible. The second and third order outcomes could conceivably be achieved in a one-off INSET course, while the first order outcomes would need a longer period of contact between teacher and INSET provider for that understanding to develop. The more sustained contact is something ESG teachers were able to provide, and which helped them to overcome the acknowledged limitations of 'hit and run' INSET. An alternative approach to first order development was formulated by Russell et al (1995) who instigated action research groups to enable teachers to evaluate the content of the NC from the angle of pedagogical content knowledge. By virtue of the action research, teachers were engaged in a collaborative enterprise over a period of time, providing mutual support for each other.

> "They discovered, invented and shared amongst themselves a range of techniques and strategies for exposing pupils to the prescribed content. Where they could not find the means to make ideas accessible, they concluded that the curricular agenda would need to be changed." (Russell et al 1995, p.487)

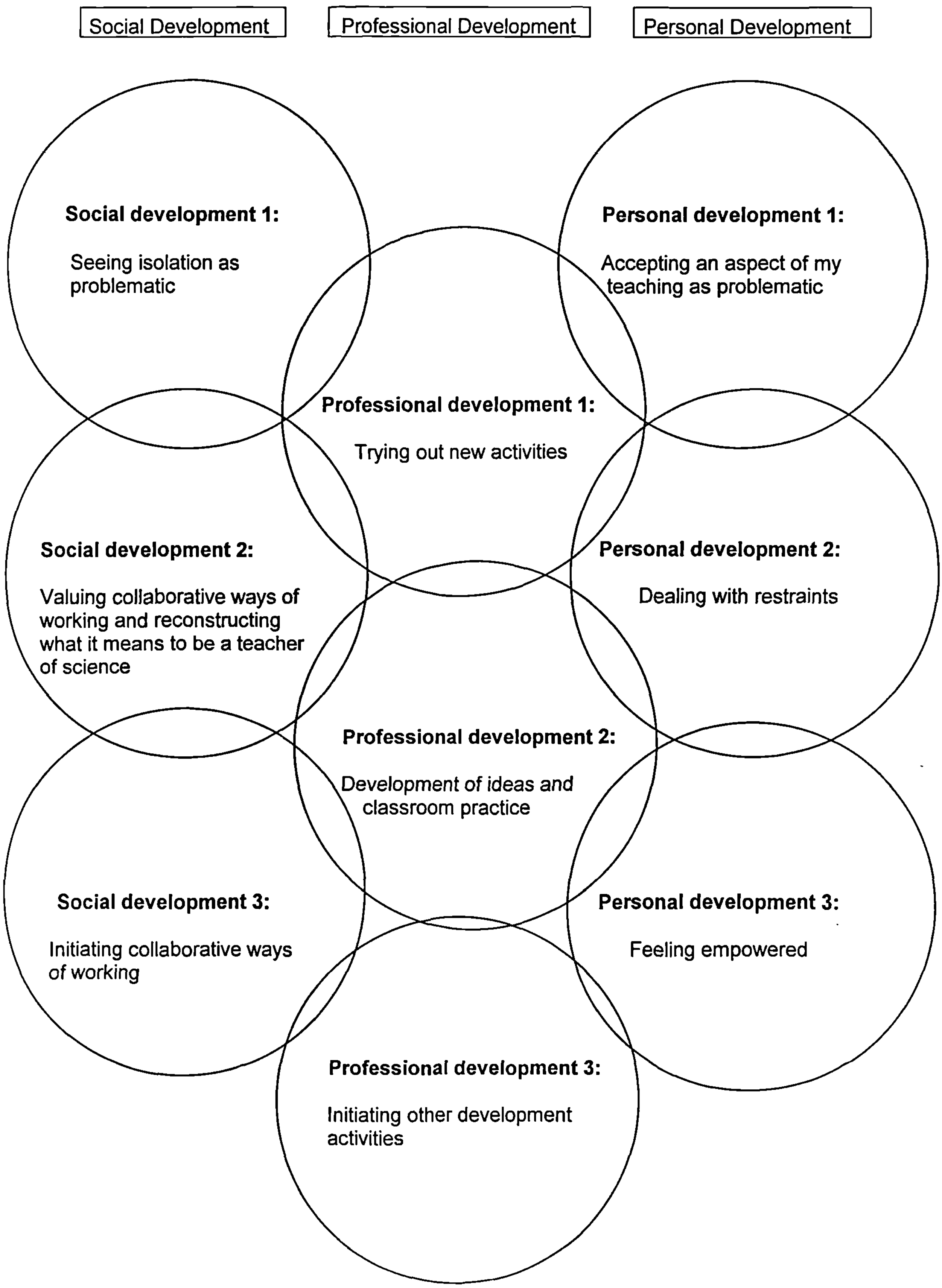
One of Kinder and Harland's first order outcomes is improved teacher knowledge, both content knowledge and pedagogical content knowledge. The development of the "20 day" courses should therefore have been a laudable aim, except that the courses had a remit specifically to develop teachers' understanding without addressing approaches to classroom teaching. In order to circumvent the Government restrictions on the content of the courses, many institutions decided to model on the teachers the approach to teaching they would advocate in the classroom, that is, a constructivist approach. Such courses (e.g. Ritchie, 1995) did improve the knowledge base of the teachers and were able to have some effect on classroom practice as long as they were carefully structured, and initial attempts at using the approach with children were with small groups and with a supportive observer to give feedback (see also Hollon et al, 1991; Smith and Neale, 1991; Summers et al, 1996).

5.3 Models of teacher development in constructivist primary science

There have been other, more substantial, attempts to introduce teachers to the use of a constructivist approach to teaching (Symington and Osborne, 1985; Ovens, 1993; Bell and Gilbert, 1996). These researchers have identified essentially similar components to the change process as Kinder and Harland, though they have labelled them differently. The one aspect which constructivist professional development represents in a substantially different manner is the first order outcome referring to the degree of congruence between INSET deliverer and teacher in terms of their beliefs about teaching and learning. In Bell and Gilbert's model (fig. 4.1) the teachers would not even be able to begin the process of development unless they had accepted that an aspect of their practice was problematic (stage 1 of personal development).

Table 4.1: Bell and Gilbert's Model of Teacher Development

(from Bell and Gilbert 1996, p.16)



The ideological assumption in constructivist teacher development, conveyed clearly by Bell and Gilbert (1996) and Russell et al (1995) is that constructivism as an approach to teaching is right and every other view is wrong. Rather than observing teachers who are considered to be effective in achieving the requisite aims for science education and analysing how they are doing that, these researchers are looking for matches to their ideal teaching approach, even where there might be equally or more valid routes to the same goal. Such a position would be acceptable were there evidence to support its efficacy as an approach but, "No properly evaluated teaching research so far set up has supported constructivist assumptions about teaching" (Solomon 1995, p.148).

According to Adey (1994) such assumptions about effective teaching and learning frequently underlie INSET, making any evaluation of the INSET itself problematic since a failure to produce improved learning may equally be due to the inadequacy of the teaching method being advocated. Where constructivist INSET works, the evidence from authors' reports could equally be interpreted in terms of second order motivational and affective concerns. Firstly, teachers are shifting from a didactic approach in which children are bored (Bell and Gilbert, 1996) to one in which the children's ideas are the centre of the teaching process. Given such a scenario, it would be surprising if the children were not more motivated and engaged. Secondly, in Russell et al's training, the teachers "relished the constructivist approach" because it was more motivating for them:

> "What was particularly productive in the action research mode of operating was that teaching was confirmed as an imaginative and creative interactive activity, far removed from the formulaic delivery mode which some had feared to be the National Curriculum expectation" (Russell et al 1995, p.488)

It would be necessary to compare the success of constructivism against another interesting approach to science teaching in order to establish its efficacy as a means of promoting learning.

5.4 Reflective models for teacher development and subject knowledge

Relating this science-specific research to more general teacher education research, it is interesting to see that similar frameworks for analysis appear. Handal (1990, as cited in Day, 1993) described teachers being able to reflect at three different levels in order to effect change. At level 1 classroom teaching is refined to meet externally determined goals; level 2 involves the teacher in using practical, contextual and theoretical considerations to inform the nature of teaching; level 3 requires moral and ethical justifications for the nature of teaching being undertaken. Fullan (1991) refers to educational change in a manner compatible with Handal's three levels of reflection. He describes change as a "dynamic inter-relationship" between the three dimensions of: new use of teaching materials (level 1); new teaching strategies (level 2); and new beliefs about education (level 3).

These levels of reflection map well onto Kinder and Harland's typology and, since most teachers regularly operate at level 1 (Day, 1993) and most school INSET is also at that level, then operation at level 3 requires teachers to operate at a level not normally required. All these typologies refer to quality of thought, rather than attempting to model the change process. Nevertheless, the time involved might also be expected to be considerable since case studies (e.g. Ovens, 1993) suggest that it takes a year to move beyond level 1 changes. Bell and Gilbert's model of the change process has a 'time' dimension built in, thus explicitly acknowledging that change does take time to happen. As they identify the second stage of social development as involving reconstructing what it means to be a science teacher and the second stage of personal development as involving dealing with restraints (sic), then time must be allowed for teachers to meet the very extensive cognitive demands early in the change process.

Implications of these models of teacher development for increasing the efficacy of science teaching are clear. Improvements in teachers' command of content knowledge cannot be expected to happen within a short time span. Only once teachers are clear about the science they are teaching and its nature can they implement their science teaching in a considered manner. Thus, children will receive science teaching which reflects the teachers' true attitude to science and in a constructive classroom ethos only once the constraints of inadequate subject knowledge have been removed.

6. Summary

Different approaches to the teaching of science have been delineated in terms of the attitudes to teaching science which they reflect. The three approaches are sensationalist, rationalist and formalist. While the typologies should not be seen as discrete and non-overlapping, they provide a useful framework for relating practice to underlying features such as subject knowledge. It is suggested that, while formalist and sensationalist approaches can be used without an adequate knowledge base, the same is not true of rationalist teaching, which is the approach most closely allied to a socio-cultural perspective.

The unspoken understanding of the processes of teaching and learning as they occur in classrooms is well established. In order for teaching and learning to take place efficiently the same understanding must be shared by both teacher and children. Approaches to teaching science which give children more ownership of the process, e.g. a personal constructivist approach, are likely therefore to be reinterpreted by both teachers and children in line with agreed views of teaching and learning unless both parties can learn new roles. In primary school classes there is beginning to be some evidence that children's understanding of the purposes for science learning are influenced by the level of the teacher's subject knowledge.

From small-scale studies which have remarkably consistent findings, it appears that teachers who have good subject knowledge are able to:

- use their semantic knowledge in order to identify those aspects of science topics which were important for students to learn
- use their pedagogical content knowledge to construct a powerful set of explanations using appropriate representations
- engage children in open discussion, making use of the students' questions and contributions in order to develop their understanding
- use their curriculum knowledge to select activities which provided opportunities for the students to learn the identified concepts

Conversely, teachers with poor subject knowledge characteristically:

- close down discussions and activities in order to stay within the bounds of their knowledge of the subject
- emphasise aspects other than concept development - either process development or study skills
- choose activities which do not provide opportunities for learning important concepts

The development of curriculum materials has paralleled the development in views about the nature of effective science education. Thus, they have had an emphasis on discovery learning, developing process skills and knowledge development in turn. Recent schemes are beginning to advocate a mixed, structured approach making use of a wider range of teaching approaches, in line with current research. However, they need to place more emphasis on structuring knowledge for teachers by giving them clear aims and objectives for topics and activities. In order to obtain a clear picture of the intentions behind the schemes it is important to read the teacher guides since the pupil materials often bear little resemblance to the authors' espoused intentions. This in effect means that, while schemes are designed to support teachers, without knowledgeable use by teachers they are unlikely to deliver a coherent science education. Science curriculum development has been found to have little impact on classroom practice, suggesting that teacher' guides, whether used or not, are insufficient without a programme of INSET to support them.

The Government started training teachers in science knowledge, but with a specific embargo on help with classroom science activities and approaches. This led to initiatives using constructivism as their theoretical underpinning in order to be able to model a classroom approach for teachers. This approach did lead to some changes in classroom practice, but whether these were due to first order learning due to the approach, or to second order affective learning is unclear. However, all models of teacher development agree that change in classroom practice takes substantial periods of time to happen. Only when the constraints of inadequate content and pedagogical content knowledge have been removed will teachers be able to develop their science teaching in line with their preferred style, leading to a classroom ethos which children can interpret consistently.

Chapters 2, 3 and 4 have shown that a large number of factors need to be taken into account when considering primary science teaching. Having thus contextualised the study, chapter 5 explores the Primary SPACE Project, its development and its location within the paradigm of constructivism.

CHAPTER 5

THE PRIMARY SPACE PROJECT

This chapter outlines the rationale behind the SPACE Project, and the procedures it used, using material from SPACE research reports which were written by myself. I conclude with an analysis of SPACE, the aim of which is to locate SPACE accurately within the constructivist paradigm. Much of the written material relating to the Project (e.g. Watt, 1987; 1988; 1989; Russell, Harlen and Watt, 1989) has been produced in Liverpool, and therefore tends to reflect the methodological preferences of that team. The two research reports which support this thesis are clearly written from that perspective. As the *Nuffield Primary Science* materials obviously draw on these written materials in their rationale, it is necessary in this thesis to take "The SPACE Project" as implying "the Liverpool team of the SPACE Project" unless stated otherwise. The exemplification of the data collection and analysis is drawn from the range of techniques used by the class teachers in order to provide a clear picture of how the Project was contributing techniques for teaching. These examples are in the appendices to the thesis. The role of the teacher developed by the SPACE team is defined by extracting its essence from both the 'Sound' research report and accepted criteria for good questioning practice (Watt, 1992). As a founder member of the research team it is at times difficult to know which of the following ideas are being expressed by me because of my understanding of and involvement in the research process but should be attributed to other authors from within the Project team.

1. Personnel

Members of the Project team were based at both King's College, London University and Liverpool University. I was a member of the Liverpool-based team from January 1987 to August 1989, and for that period I was the only full-time researcher for the Project, thus being responsible for much of the day-to-day running of the Project. Since I was working on the Project from its outset I was heavily involved in its development, and the steering committee (composed of all the involved parties from both King's and Liverpool) met regularly in order to make final decisions about ways forward. A detailed breakdown of my specific contributions to the SPACE Project is in Appendix 1. Names of all the Project personnel are in Appendix 2.

2. Rationale

As cited in the introduction to each SPACE research report (e.g. Russell and Watt, 1990), the main aims of the Project were two-fold:

1. To establish the ideas which primary school children have in particular concept areas;
2. To ascertain the possibility of helping children to modify their ideas in a direction which makes them more scientifically useful, through relevant experiences.

These aims suggest that the emphasis of the Project was firmly upon children's learning, with teaching only mentioned implicitly as the source of "help" and "relevant experiences". This approach is clearly allied to the 'developing children's existing ideas' tradition of research, as defined in section 5.2 of chapter 2. The location of SPACE at two centres enabled the team to diversify and explore the efficacy of different techniques for data collection and analysis, and to follow particular methodological preferences. To this end, the London team developed conceptual probes as elicitation strategies, and the Liverpool team developed phenomenological probes. This led to the development of intervention strategies which also differed, with the London team placing more emphasis on cognitive conflict and the Liverpool team building on children's ideas.

The Liverpool-based members of the SPACE team were keen to adopt a phenomenological approach because we prioritised accessing children's considered ideas by using their likely out-of-school experiences of scientific phenomena as elicitation probes. We were also keen to conduct research in the context available to class teachers so that the children's ideas were not elicited by virtue of one-to-one contact in a quiet corner between a child and a researcher but would have validity within the normal classroom environment. As someone who was, until a month before the Project, a practising primary school teacher, I felt strongly that this latter aspect was important in order for the research to be seen as credible by teachers. I was aware that teachers considered much research to be irrelevant and therefore ignored its messages, and was keen that the SPACE research should not be similarly viewed. I am sure my position on this issue was influential in determining the Project stance.

This desire for credibility had wide implications for the research and influenced every aspect of it: the development of data collection instruments and teaching strategies for subsequent intervention; their application in the classroom and the data analysis and the relationship with Project teachers. As a result, the teachers who were working with the Project had much greater involvement in the research activity than had been originally anticipated by the Project Directors, or than had occurred in earlier research (e.g. CLIS, 1987; Biddulph and Osborne, 1984). The possibility of increasing research credibility without impacting on reliability and validity needs exploring, and I consider the relationship between credibility, reliability and validity in section 3.4 of this chapter.

3. Methodology

The sections from the introduction to the SPACE research reports which are in Appendix 3 provide a succinct description of the way in which the Project work was arranged in classrooms, the data collection instruments and the strategies for developing children's understanding. I will now clarify various methodological points raised by the text of Appendix 3. These points are either unexplicated in the research reports or can now be elaborated with the benefit of hindsight.

3.1 Sampling the children

Details concerning the selection of classes for involvement in the Project, and of individuals within those classes for interview, are absent from the SPACE reports. We had no control over the selection of teachers within the schools, and therefore could not select children of particular ages to be involved. Coincidentally, there was a reasonably even spread of ages from five to eleven years across the Project classes. We were, though, in a position to control the sampling of the children for individual interviews, and the selection was made according to the variables of gender and teacher assessment of children's achievement. Thus, we interviewed three girls and three boys from each class, one each of high, middle and low levels of achievement, as judged by the teacher. We were not in a position to stipulate the measure of achievement teachers should use, so some judgements were intuitive while others were based on English or mathematical classroom groupings. Only one teacher used achievement in science as the measure of selection.

We intended the achievement stratification to enable us to make comparisons between schools. However, the lack of a reliable means of establishing achievement meant that only rough comparisons could be made: if children were selected because of their positions in their own classes, there was little likelihood of these positions being equivalent across the schools.

3.2 The rationale for the exploration / elicitation / intervention packages

The exploration/elicitation/intervention packages as presented in the introduction to the SPACE reports may appear to lack a coherence of approach because it is a compilation of those used by the Liverpool and London teams. Thus the London team, who kept much tighter control of all research activities, were the only ones to: use 'completing a picture' as an elicitation technique; develop a discrete pack of equipment and intervention activities and test the science idea alongside the children's own ideas. The nature of these activities is clearly more closely related to the conceptual / cognitive conflict approach to constructivism than the other techniques, which are in accord with Liverpool's phenomenological / building on children's ideas approach.

The use of everyday contexts for the exploration / elicitation phase was particularly compatible with the phenomenological approach, and also with the range of topics explored in Liverpool, for example 'evaporation and condensation', 'growth' and 'sound'. 'Electricity' and 'light', two of the London topics, would have been much harder and less appropriate to locate exclusively in everyday contexts. While Osborne and Wittrock (1983; 1985) advocate the use of everyday contexts for the research activities, these have been shown to reduce the likelihood of older children accessing their science knowledge (Solomon, 1983) and, by implication, to increase the chances of them expressing their own ideas, thus maybe leading to an under-representation of the science viewpoint. As SPACE was not operating within a socio-cultural framework, the two domains of knowledge were not considered and there could thus have been such an under-representation, particularly in the Liverpool sample. However, as we were careful to interpret the children's ideas according to underlying understanding rather than surface features - ahead of Johnson and Gott's argument - science ideas, even if expressed in everyday terminology, were interpreted as portraying the science view.

3.3 Innovation: Classroom application of SPACE materials

A positive advantage of working in collaboration with teachers is that they can often use their creativity to help the Project, as illustrated in the following example. Anne Hall, one of the Project teachers, tried out annotated drawings with her class and I subsequently incorporated the idea into the collection of strategies on offer to teachers (Appendix 4). These classroom-based, teacher-implemented elicitation strategies had not been used in constructivist science research before at either primary or secondary levels of education, though drawing and writing / dictating was used in health education research a few years earlier (Williams, Wetton and Moon, 1985, as cited in Williams, Wetton and Moon, 1989).

CLIS (1987) introduced posters as a means for children to explore their ideas, but as part of their teacher curriculum materials rather than their research, which relied upon individual interviewing and APU pencil and paper tests. Similarly, LISP (Osborne, 1980) relied on individual interviews for research data, and focused on children's questions as a curriculum elicitation activity. These innovations ensured that each teacher was able to establish the ideas of their entire class, ideas which were found to be consistent with those expressed in interviews. This immediately gave SPACE a dissemination advantage over other projects because teachers could learn about the Project then go back to their classrooms and try the ideas out for themselves. In this respect, the desire for credibility was fulfilled.

I suggested that teachers themselves annotate the diagrams of children for whom writing was not easy, after first checking with the child, because I was aware of how children's lack of fluency in writing can inhibit their expression of ideas. As it was the ideas we wanted rather than the writing, this suggestion showed teachers that we understood the practicalities of the classroom, thus enhancing both the quality of data collected and the Project's credibility.

The production of a framework of intervention strategies and an accompanying ideas sheet (Appendix 5) was a particularly innovative feature which enabled teachers to implement the intervention strategies in their classrooms. We asked teachers to use the children's drawings and the preliminary analyses of the interview data in order to assess which intervention strategies would be most appropriate for the children in their class. The framework explicitly labelled each strategy so as to make the functions of each one clear. For example, 'Making the imperceptible perceptible' embraced analogous examples of imperceptible phenomena (allied to 'anchor' examples of Clements et al, 1987, as cited in Scott et al, 1991), such as the perfume spray mentioned in the SPACE research report introduction, but also a time-lapse video recording of a plant growing. Thus, the framework was defined by strategic function as opposed to cognitive pathway along which children's ideas would develop.

By empowering the teachers in this way, we were helping them to develop appropriate pedagogical content knowledge within a clear structure. Each teacher developed in an individual way from their particular starting point, the precise nature of the intervention activities being determined by the teacher within an agreed area of learning.

This again gained the Project credibility, but it lost it both reliability and validity since it was not possible to attribute development in ideas to any particular intervention as we could not be sure exactly what had taken place in any one classroom. However, had we prescribed activities these would still have been implemented differently due to the teachers' different levels of understanding of the constructivist approach to teaching. We thus turned the potential problem of implementing a set of activities in idiosyncratic ways into an opportunity for teacher development.

Our assumption that it was possible for teachers to use Project approaches merely by providing them with a 'package' or a 'framework' needs to be questioned, even though INSET was available. Because the materials were designed largely by myself, a recently practising teacher, they had teacher-child interaction as central to their construction. As the way teachers interact with their class is dependent on their beliefs about the nature of teaching (Wolfe, 1989), we were effectively requiring the teachers to apply the Project constructivist rationale within part of their practice, which may well have had a different view of teaching and learning associated with it. For teachers for whom accepting any statement a child made without giving feedback was anathema, this must have placed enormous strains on their ability to practice effectively with their classes. Our approach therefore shared some features with other constructivist curriculum development (e.g. Bell and Gilbert, 1996; Russell et al, 1995) in which the assumption of efficacy was allowed to determine the required teaching approach. Detailed descriptions of the classroom application of the pre-intervention elicitation work and the intervention strategies are included in chapter 7, accompanied by a brief commentary.

3.4 Classroom credibility or research validity?

Wiliam (1996) presents a four-facet framework for validity (based on Messick, 1980) in which he discusses the notion of credibility under the heading of "within-domain consequences" of assessment. He argues that the value implications of assessment, that is, the extent to which the assessment is considered to be educationally valid, needs to be considered alongside the other three facets: within-domain inferences (construct validity - the extent to which a test measures what it is intended to measure), beyond-domain inferences (the extent to which future performance can be predicted from the assessment) and beyond-domain consequences (impact - the extent to which external judgements will be based on the assessments). The recognition of the importance of credibility is thus not without precedence. However, the huge reliance which SPACE placed on the teachers in terms of the presentation of assessment tasks made both within-domain inferences and reliability (the replicability of the test in measuring what it is designed to) very difficult to judge. It is impossible to make categorical statements about reliability because it is difficult to ensure exact replication of teachers' oral questions used as part of teaching. It can be surmised, however, from the narrow range of responses individual children gave during the researcher-conducted interviews that the questions themselves were able to elicit similar responses, suggesting they were quite reliable, as long as they were asked in a consistent manner.

It was certainly not possible to make judgements about the teaching which the children received in order to help them develop their ideas because, except for occasional visits to the classrooms, the teachers worked unobserved and we were dependent on their notes to outline what they did. However, the teacher meetings were structured in such a way as to engage the teachers in discussing what they were doing and developing a party line. Paradoxically, this was made more successful by delegating responsibility further to the teachers and asking them in groups to agree on common approaches. Thus, the ideas sheet (Appendix 5) which helped individual teachers plan the first intervention did not need to be included for the second phase because the teachers had discussed and agreed their own ideas. In order for credibility to have been balanced with reliability and validity, interventions planned and conducted by researchers should have been carried out as triangulation alongside the teachers' interventions (Robson, 1993). Further discussion of teacher development sessions is included in chapter 7.

4. Analysis

As we had access to data from both classrooms and interviews, we had a very rich source of children's ideas to analyse and interpret. The analysis of the children's ideas was entirely carried out after the data were collected, i.e. the data categories were generated by inspecting the data and were not imposed upon the data. This type of categorisation has the advantage of being responsive to the actual ideas of the children rather than necessitating the fitting of the ideas into some pre-determined framework. The process of imposing order on the children's ideas, enabling general statements to be made, is illustrated for the topic of 'sound' by the interpretive analysis of the children's drawings in Appendix 6 and the interview analysis in Appendix 7. Appendix 8 contains a summary of the children's ideas both pre- and post-intervention.

The analysis in Appendix 6 makes sense of the children's ideas in a way which seems entirely reasonable. However, any analysis which is based on the interpretation of children's words and pictures must be inspected with care since interpretations cannot be other than subjective. The data can be substantiated in several ways: firstly, triangulation of products enables interview responses to be compared with classroom-based elicitations such as children's drawings; secondly, triangulation of interpreter means that teacher annotations of children's work can be compared for reasonableness with the interviewers' transcripts. These double-checks, however, do not address Johnson and Gott's (1996) points about the need to interpret the data from the child's perspective in order to access the framework upon which the ideas are based, rather than focusing on the surface features of the ideas themselves.

The generation of the super-ordinate categories relating to sound production, transmission and reception enable this to be done, and Appendix 9 shows the changes in thinking of individual children which can be established using this framework. The super-ordinate categories ensure that the relationship of the children's ideas to the important factors at each stage, namely presence of vibrations, presence of a medium, and presence of vibrations respectively, is ascertained. However, we have no way of knowing whether teachers picked up on the surface features of the children's ideas or were able to extract the scientific essence except for some audio-tapes of teacher-led discussions which suggest that on the whole they were unaware of significant ideas. This was despite sessions both in content knowledge, during which the organising framework of super-ordinate categories was presented, and in understanding the difference between an observation and an idea. This lack of awareness would have contributed to any imprecision in the way the teachers implemented the intervention strategies because they could have suggested investigations which tested trivial relationships rather than underlying ideas. This problem could only have been circumvented by researcher allocation of intervention activity, since giving teachers a specific range of activities would not have ensured a more in-depth interpretation of the children's ideas.

5. The role of the teacher in the SPACE Project

The SPACE research report for 'Growth' describes the SPACE style of teaching as "a teacher-directed, pupil-centred, management of learning" (p.92). However, nowhere in any of the reports is there an expanded account of what this means in practice, other than cameos of teachers using strategies in ways we considered to be effective. I have therefore used a combination of sources to derive a picture of a SPACE teacher, principally the SPACE research report for 'sound', and the criteria for good questioning practice (Appendix 10) which I compiled from the existing literature in order to evaluate the efficacy of the SPACE INSET on the teachers' questioning (Watt, 1992, as summarised in chapter 7).

5.1 A picture of an effective SPACE teacher

The SPACE research report for 'Sound' contains both descriptions of the classroom elicitation and intervention strategies and guidelines for their implementation. A combination of these two features and my knowledge of the content of the teacher INSET days gives a picture of how we envisaged the role of the teacher. This can be summarised as follows, with the source of the statement identified in brackets. A SPACE teacher should:

1. Have an understanding of the important concepts in the area of study (SPACE teacher INSET);
2. Find out children's ideas in an informal and accepting manner, using everyday examples of the concept under investigation (SPACE report for 'Sound' Appendix III, my Appendix 4);
3. Interpret the children's ideas to establish their current understanding (SPACE teacher INSET);
4. Use a range of intervention strategies to help children develop their ideas from their current level of understanding (SPACE report for 'Sound' Appendix V, my Appendix 5);
5. Encourage children to test out their ideas using fair testing (SPACE report for 'Sound' Appendix V, and SPACE teacher INSET);
6. Monitor children's understanding in order to see how their ideas have changed (SPACE research report for 'Sound', Appendix V, my Appendix 5).

5.2 Criteria for good questioning practice

The criteria for good questioning practice (Watt, 1992) are set out in Appendix 10. While the criteria were designed to apply to questioning behaviours, they embrace all the features necessary for teachers' constructivist classroom interaction with children. This confirms what is well known, that teachers spend a very large proportion of the time in the classroom asking questions, at the expense of other forms of dialogue (e.g. Brown and Edmondson, 1984). This combination of questioning behaviours and the teaching strategies outlined above ensure that pedagogical content knowledge as well as semantic and syntactic content knowledge are included in the definition of SPACE practice.

6. The Location of SPACE Within the Constructivist Paradigm

In chapter 2, I outlined five different approaches to constructivism: Kelly's personal construct theory, Piaget's stage theory and model of conceptual development, Osborne and Wittrock's personal constructivism, Von Glasersfeld's radical constructivism and social constructivism (within which I identified socio-cultural perspectives on teaching and learning as a particular viewpoint). Further, I explored the nature of children's ideas as either scientific theories or everyday ways of knowing, and different approaches to elicitation. I have already considered the last of these three areas with respect to SPACE, leaving the former two to be addressed now, working back from the elicitation approach.

6.1 The elimination of alternatives

In respect of different elicitation approaches, SPACE employed predominantly phenomenological probes in everyday contexts, thus increasing the likelihood of children expressing their own ideas. As these ideas were used as the starting point for intervention it can be inferred that the children's ideas were considered to be theories. Were they alternative ways of knowing, they would not have been accorded the status they were within the intervention. As the accepted scientific viewpoint was clearly in the minds of the researchers, radical constructivism with its emphasis on personally exclusive knowledge development would not seem to be appropriate, as would neither personal construct theory (because of the ease with which it suggests new ideas can be developed) nor Piaget's stage theory (because no stages were proposed). The non-interventionist role for the teacher in which giving explanations did not figure shows that SPACE places less emphasis on societal expectations of knowledge acquisition than does social constructivism, though the presence in the teachers' minds of desirable outcomes for the children suggests a degree of inclination towards socio-cultural ideas. The weight given to individual idea development determines that the predominant approach is the primary personal constructivism of Harlen and Osborne's (1985) application of Osborne and Wittrock's (1983) Generative Learning Model (GLM) to primary science.

6.2 SPACE and the generative model for learning primary science

There are three comparisons to make between SPACE and the primary GLM: the proposed structure of the learning process; the role of the teacher and the proposed view of learning. I will address each of these in turn.

In chapter 3, fig. 3.2, I portrayed Harlen and Osborne's teaching sequence which is composed of three phases: exploration, investigation and reflection. These phases have clear parallels with the SPACE research outlined in Appendix 3, particularly the exploration phase which even has the same name. Thus, there is a period of observation and thought, the exploration, which precedes and determines the investigation to develop ideas and the reflection in which evidence for particular ideas is shared with others. While SPACE has no separately identified reflection phase, the actions suggested within it are incorporated within the SPACE intervention phase. The focus on children's ideas in the primary GLM is less overt than SPACE, partly because it has been emphasised in SPACE for research purposes and partly because the primary GLM emphasises children using their ideas to help them raise questions for investigation whereas the SPACE teacher raises the questions for children to consider. However, the focus on children developing their own ideas is present in both.

As alluded to briefly above, the role of the teacher contains subtle differences between the primary GLM and SPACE, in terms of both the locus of control for raising the investigable question and the status of the accepted scientific view. At first glance, it seems that the science idea is more prominent in the primary GLM than SPACE in which, though 'testing the right ideas alongside the children's' is one of the intervention strategies, in practice the investigations were related to testing the children's ideas. Given the status of teachers' understanding of science, it is unsurprising that this was the emphasis. However, if the other SPACE intervention strategies are included, then encouraging generalisations, developing vocabulary and making the imperceptible perceptible can all be considered to be strategies leading children towards the science idea.

The view of science conveyed by the personal constructivist approach is inductive, that children's understanding is based on their personal experience, and learning is explained in terms of children developing their own ideas. As conveyed in chapter 3 section 1.1, this particular approach to personal constructivism, of building on children's ideas, is closely linked to "good primary practice" involving learning by doing. Both sections 5.1 and 5.2 above show clearly that we asked the SPACE teachers to operate within a personal constructivist framework, while acknowledging the influence of the social environment of the classroom on learning. Using the criteria for good questioning practice, there is an understanding that children can learn through social interaction with other children (criterion 5), and that the teacher's interaction with the child can have a great effect on learning (criteria 1, 2, 3, 8, 10, 12). The teacher is therefore responsible for providing support, facilitation and challenge to develop children's ideas. The teachers should use their knowledge of science to ask questions and set up scenarios in which children are more likely to encounter and be persuaded by the science view.

On balance, then, SPACE can be considered to be an interpretation of the generative model for learning primary science developed by Harlen and Osborne (1985).

7. Summary

The Liverpool team of the SPACE Project extended the boundaries of personal, phenomenological constructivist research by providing the first example of a large-scale project in which teacher collaboration was a major component. In so doing, we formalised the role of the teacher in the research; we developed new data collection instruments and a range of intervention strategies for classroom use. We expanded and capitalised on teachers' insights into children's learning for the sake of the research, increasing even further than anticipated the credibility of the procedures. However, there must at the same time have been a considerable sacrifice in terms of reliability and validity since it was impossible to gather data about the relative efficacies of different teacher intervention strategies, or to determine the precise nature of teacher delivery. The research falls within the definition of personal constructivism allied to Harlen and Osborne's (1985) interpretation of Osborne and Wittrock's (1983) Generative Learning Model, and adopts the "building on children's ideas" approach to conceptual change which is suggestive of "good primary practice".

It has been necessary to describe SPACE and to locate it precisely within constructivism so that subsequent changes in message or emphasis can be clearly identified. I am therefore in a position in chapter 6 to analyse the *Nuffield Primary Science* curriculum materials in relation to SPACE and primary constructivism.

CHAPTER 6

THE NUFFIELD PRIMARY SCIENCE MATERIALS

The *Nuffield Primary Science* curriculum materials (*NPS*), as described in the introduction, were developed as a result of the success of SPACE. A congruence should therefore be anticipated between the view of learning and teaching developed in the SPACE Project and its portrayal in "the SPACE approach" of *NPS*. In this chapter I test this hypothesis by analysing the text of the Science Co-ordinators' Handbook (SCH) and the Teachers' Guides. As a specimen, I use the "sound and music" Teachers' Guides for KS 1 and 2, making the assumption that the tenor of each Guide in the scheme is the same. I begin by considering how the structure of the Teachers' Guides relates to Harlen and Osborne's (1985) constructivist teaching sequence. Following that, three analyses illuminate the role of the teacher in *NPS*: firstly, the teachers' role from the SCH is described; secondly, the questions used in the activities are analysed and thirdly, the teachers' role as modelled in the Teachers' Guides is compared with that espoused in the SCH. These analyses enable me to compare the theoretical underpinnings of SPACE and *NPS* and conclude that the Teachers' Guides present a different view of learning from either the SCH or SPACE.

1. The portrayal of the constructivist process in NPS

The generative model for learning in primary science (Harlen and Osborne, 1985) presents the constructivist teaching and learning process in three phases, exploration, investigation and reflection. These are represented as four phases in the SPACE research, with the exploration and intervention phases each being followed by an elicitation, separately identified because of the importance of the elicitation for research data collection. The *NPS* Teachers' Guides suggest four phases, "finding out children's ideas", "children's ideas", "helping children to develop their ideas" and "assessment". The first and third of these phases corresponds clearly to those of Harlen and Osborne and SPACE; the second enables teachers to find out about the likely content of children's ideas, as Harlen and Osborne exhort teachers to do, and the fourth relates to SPACE's elicitation phases. The Teachers' Guides use the same phenomenological approach to elicitation as SPACE, utilising many of the stimuli and questions from the research reports. The Teachers' Guides also draw heavily on SPACE for the second phase, using examples of the data - children's drawings and quotations from interviews - to provide very good, concise summaries of the categories of ideas which are likely to arise. While it is appropriate for *NPS* to build on the SPACE analysis, the focus on description is likely to disadvantage teachers in developing a constructivist methodology though analysis linked explicitly to the NC level descriptions is in the assessment chapter. The third phase is less homogeneous. It contains a small number of charts which appear to be modelled on the discussions SPACE teachers had to develop their intervention strategies. These charts suggest how different ideas can be developed through activities. It also contains a much larger number of exemplar activities which are not obviously linked to children's ideas but which can be used to develop skills and understanding. Similarities between these activities and constructivism are harder to detect.

Structurally, then, *NPS* is consistent with a constructivist approach. However, even this overview suggests that the content is not as consistent. The following sections look in more detail at the content of both the SCH and the Teachers' Guides to establish the verity of this position.

2. The Role of the Teacher in "the SPACE approach"

The SCH defines the role of the teacher in "the SPACE approach" (p.34). It has five aspects to it:

1. finding out what children's ideas are;
2. reflecting on how children may have arrived at their existing ideas and how far they have progressed towards developing more scientific ideas;
3. helping children develop process skills so that they test and apply their ideas scientifically;
4. providing opportunities to test or challenge ideas, perhaps leading to changes;
5. assessing the extent of any change in ideas and in process skills which may have resulted.

In order to expand on the meaning of each of these headings, I analysed the text of the SCH to discover the most important characteristics of each aspect of the teacher's role by identifying the most frequently mentioned behaviours. For each aspect of the teacher's role I identified skills, knowledge and understanding and attitudes which the teachers need to possess. A fuller description of the teacher's role is characterised in table 6.1, overleaf.

Table 6.1 Relative Frequency of Teaching Behaviours in the SCH

NPS role	Categories derived from the *NPS* Science Co-ordinators' Handbook		Total
	Areas of behaviour	Specific behaviours	
1	Elicitation strategies	Questioning	14
		Listening	4
		Watching	1
	Classroom context	Engaging interest with real stimulus	7
	Teacher attitude	Non-directive attitude	24
2	Managing conceptual development	Monitoring understanding	8
		Guiding children towards wider application	2
	Understanding conceptual development	Starting with children's ideas	9
		Knowing intended direction of learning	11
	Teacher attitude	Ideas accepted as provisional and serious	6
3	Guiding children in testing ideas	Developing and assessing skills	7
		Assessing proficiency in investigating	2
		Guiding investigations	6
	Classroom context	Facilitating children's communication	4
	Teacher attitude	Care and thoroughness	3
4	Intervention strategies	Challenging/questioning	9
		Listening	1
		Discussing	1
	Intervention activities	Facilitating sharing of children's ideas	3
		Encouraging reappraisal of ideas	9
		Providing sources from which to find out	7
		Providing opportunities to test/apply ideas	3
	Teacher attitude	Supportive attitude	12
		Facilitating children's ownership of learning	7
5	Summative assessment	Planning for assessment	5
		Assessing	9

Using the totals in table 6.1, I identified the specific behaviours which were mentioned repeatedly and used them to augment the definition of the teacher's role in the SCH. For example, in relation to finding out children's ideas, the two behaviours 'questioning' and 'non-directive attitude' were mentioned more frequently than the other behaviours so they were incorporated to expand the definition. The more detailed role is:

1. **finding out what children's ideas are** through questioning and exhibiting a non-directive attitude towards the children's contributions;
2. **reflecting on how children may have arrived at their existing ideas and how far they have progressed towards developing more scientific ideas** through knowing what the children's ideas are, treating them seriously and using that information to determine appropriate activities in order to ensure that future learning is in the required direction;
3. **helping children develop process skills so that they test and apply their ideas scientifically** through helping children to develop skills and guiding them through their investigations;
4. **providing opportunities to test or challenge ideas, perhaps leading to changes** through supporting children as they are challenged to reappraise their ideas;
5. **assessing the extent of any change in ideas and in process skills which may have resulted.**

The roles of the teacher as stated in the SPACE research reports and espoused in the SCH are very similar, though there are slight differences in emphasis, as acknowledged in the SCH. There are different ways of viewing the desired scientific understanding which will be developed by the end of the teaching on a particular topic, with *NPS* placing less emphasis on testing ideas and more on challenging children to rethink their ideas in the direction of the accepted science view. This greater emphasis on challenge still falls well short of "cognitive conflict" because the science view is neither introduced nor applied, and it is justified in terms of teachers needing to plan activities in advance to whole school schemes of work. However, this shift has implications for the view of science portrayed by *NPS*, as it is moving from one in which the status of science knowledge is represented as provisional to a position where there is one correct view which is paramount (Harlen, 1992). It cannot, though, be considered to be a move away from a purely inductivist approach to one which is more deductive because the challenges are likely to be based upon observable evidence. It is now important to look at whether the role set out in the SCH is what appears in the Teachers' Guides.

3. An Analysis of Questions Written in the *NPS* Teachers' Guides

The criteria for effective questions in constructivist primary science education (Appendix 10; Watt, 1992) were constructed in order to handle all questioning behaviours which personal constructivist teaching could generate. It is therefore reasonable to expect these criteria to account for all, or at least the majority, of the questions which are included as examples in the Teachers' Guides, as *NPS* has a constructivist underpinning.

Given the constraints of working with written questions which do not allow non-verbal cues to be taken into consideration, the categories referring to tone of voice and emphasis of wording (criteria 1 and 2) are not applied, neither are those which require a question to be part of a dialogue in order to be able to interpret its meaning (criteria 4, 5, 9 and 10). Having eliminated these criteria, there is still a substantial group of questions which cannot be categorised. These questions relate to the observations children make as part of their science activity. In order to accommodate these observation-based questions I have added to the criteria by further subdividing the categories concerning clarification of a child's meaning (criterion 6b), and extension of a child's answer (criteria 7a and 7c). The new categories are:

6bO Seek clarification by checking a child's observations

7aO Extend by asking a child to make observations which encourage them to find relevant evidence

7cO Extend by asking a child to make observations which will encourage them to generalise

Examples of these categories are:

6bO "What do you notice about the sound?" (KS1 Teachers' Guide, p.19)

7aO "What happens to the sound if you use a different elastic band?" (KS1 Teachers' Guide, p.18)

7cO "Is there always some vibration / wobbling / shaking when a sound is made?" (KS2 Teachers' Guide, p.43)

Table 6.2 shows the frequency with which different question types are used in the NPS Teachers' Guides for 'sound'.

<u>Table 6.2 Analysis of Written Questions in *NPS* Teachers' Guides</u>

Categories of questioning behaviour (which are assessable from written questions)		KS1 teachers' guide			KS2 teachers' guide		
8	Word questions so that the intention behind them is clear	10 - *			5 - *		
3a/ 3b	Give ownership of an answer / Cue a child to the response by, "What do you think....?"	13			25		
11	Ask questions according to a considered sequence	1					
12	Use a child's answer as the basis for the next question	9			23		
6b	Seek clarification by asking the child what they mean	P 5	C 1	O 22	P	C 8	O 2
7a	Extend by asking for a hypothesis or for evidence to support one	P 1	C 31	O 21	P 13	C 54	O 34
6c	Seek clarification by reflectively rewording the child's response to them	P	C		P	C 3	
7b	Extend a child's answer by challenging their hypothesis.	P	C		P	C 5	
7c	Extend a child's answer by asking them to generalise.	P	C 5	O 5	P 1	C 9	O 5

* The "-" indicates that the numbers in those cells reflect the number of questions which have <u>not</u> had clear wording
P Question asked in the context of process development
C Question asked in the context of concept development
O Question asked in the context of observation development

3.1 Questions relating to observation

Taking the KS1 Teachers' Guide, three quarters (22/28) of questions in which a child's meaning is being clarified are based on checking observations; nearly half (21/53) of the questions in which a child's answer is being extended are asking for observations and half (5/10) of the questions encouraging generalisations are directing children to make relevant observations. In the KS2 Guide the same features are found, but in a less pronounced manner. One fifth (2/10) of the questions in which a child's meaning is being clarified are based upon checking observations; one third (34/101 and 5/15 respectively) of questions in which a child's answer is being extended are asking for observations.

These questions clearly promote an inductivist approach to science teaching in which theories and ideas are derived from first hand observation, tying children to a view of science which cannot acknowledge ideas which are counter-intuitive or inaccessible to observation. This approach suggests a model for process development in science which involves children learning to observe before they are able to extend their understanding in any other way, and it is consistent with Gott and Duggan's (1995) findings that KS1 teachers consider the aims of practical work in science to be developing observation, and that investigative activities involve principally observation and recording. The level descriptions for levels 1 and 2 of Sc1 in the National Curriculum (DfE, 1995) show how this thinking might come about (fig. 6.1). Where teaching to the end of key stage level descriptions is allowed to take precedence over following the programme of study then observation can be developed without the context of more broad-ranging practical activity.

fig. 6.1 *Level descriptions for Sc1*

Level 1	Pupils describe simple features of objects, living things and events they observe, communicating their findings in simple ways, such as by talking about their work or through drawings or simple charts.
Level 2	Pupils respond to suggestions of how to find things out and, with help, make their own suggestions. They use simple equipment provided and make observations related to their

> task. They compare objects, living things and events they observe. They describe their observations and record them using simple tables where it is appropriate to do so. They say whether what happened was what they expected.

However, as discussed in chapter 3, this view of primary science preceded the NC and was contributory to determining its form.

3.2 Sequencing of questions

Brown and Edmondson (1984) show that asking questions in a sequence - any sequence, as long as it is coherent - is beneficial to learning. Table 6.2 (criterion 11) shows that there is only one recognisable sequence of any sort in either the KS1 or KS2 Teachers' Guides for 'sound'. Fig. 6.2 shows a series of questions about sound production, as they are presented in the KS1 Teachers' Guide (p.8).

fig. 6.2

1. What is this made of?
2. *What do you notice about the instruments?*
3. How do you think the sound is made?
4. How do you know that it is making a noise?
5. *Can you sort the sound makers into groups?*
6. *Which makes the loudest/softest sound?*
7. Can you make the sound louder/softer?

These questions can be divided into two groups, those inviting hypotheses and those asking for observations (though there is some ambiguity as some of the hypothesis-seeking questions, e.g., "What is this made of?" are based on observations). The two sets of questions then become 1,3,4,7 and 2,5,6. Those questions asking for hypotheses can be considered to be sequenced after a fashion, as can those inviting observations. However, the juxtaposition of the two sequences leads to a worrying lack of coherence. I am sure it is not intended for the questions to be lifted from the page and put on a worksheet as an introductory activity for children, but I have seen that happen, and also experienced the bewilderment of children who are not sure how to respond to obscure or closed questions accompanied by a space to "draw their idea". As the non-hypothesis-generating question types are routinely used by teachers, those who are encountering "the SPACE approach" for the first time will tend to interpret all the questions within the framework with which they are already familiar. These questions therefore serve to reinforce similarities between their established way of teaching and "the SPACE approach" at a time when emphasising the differences between a teacher-centred approach and a child-centred approach would be more useful. For teachers trying to develop their questioning skills, such lack of coherence is not in the interests of their long-term development as science teachers.

3.3 Wording questions so the intention behind them is clear

Not only is the children's bewilderment due to the sequencing of questions, but to unclear wording. Approximately 1 in 10 questions in the KS1 Teachers' Guide and 1 in 20 questions in the KS2 Teachers' Guide is unclearly worded. I am not sure myself what is intended by, "Does it matter where you hit the drum?" (KS2 Teachers' Guide, p.30). I would hazard a guess that the intention behind the question is to elicit children's understanding of the notion that "sounds also differ in their timbre" (KS2 Teachers' Guide, p.29), but a question asking for a yes / no answer will not illuminate that, particularly when the question which follows is, "What do you think happens to the drum?", a question which is looking for understanding related to sound production.

The intentions of the question need to be clear to the children and also to the teacher in terms of the underlying science being addressed. Laudable attempts in the KS1 Teachers' Guide to acknowledge that many schools use a cross-curricular approach to planning in KS1 classes have led to the inclusion of activities which contain no discernible science. For example, the 'Nursery Rhymes' activity (p.16, fig. 6.3) which states that children's "ideas about sounds can be explored through nursery rhymes or songs" provides no opportunity for exploration of science ideas.

fig. 6.3 Nursery rhymes

Ideas about sounds can be explored through nursery rhymes or songs.

What noise would you hear as Mary waters her garden?
What noise would Humpty Dumpty make when he falls?
What sounds would the Grand Old Duke of York's men make?
What noise would Jack's falling bucket make?

Children could make pictures of the nursery rhymes and write the words they use to describe the sounds next to the pictures.

A *first look at sound and music* contains examples of words that rhyme. This could provide the basis for further discussions about rhymes.

As a model for teachers, the inclusion of this activity is unhelpful because teachers are likely to be far more secure with language development activities than science, and blurring the distinctions between the two is potentially confusing.

3.4 Inferences regarding the role of the teacher in the Teachers' Guide

An analysis of the questions in the KS1 Teachers' Guide provides an incoherent picture of the teacher's role in teaching science. The wording is unclear in a substantial proportion of questions; many questions invite yes/no answers; children are rarely given ownership of their ideas; observations are paramount and activities do not reflect a workable model of the nature of science. The role of the teacher is therefore to direct children to make observations and to check these have been made. The absence of a background science section reinforces the focus on observation. The KS2 Teachers' Guide presents a more coherent model of skill development and learning through investigation, but question sequencing is still a problem and may well affect the quality of the learning if the written questions are used with children. The role of the teacher is therefore to encourage children to answer investigable questions, which are not necessarily derived from their ideas, by conducting fair tests. Neither of these roles is what I would have expected to uncover through the questions in the Teachers' Guides. Questions in neither guide - particularly not KS1 - bear consistent relation to a personal constructivist approach. I will now test these inferences more systematically by categorising the text of the Teachers' Guides according to the teacher roles defined in the SCH.

4. A Comparison of the Espoused and the Exemplified Teacher Roles in *NPS*

The categories of teaching behaviour shown in table 6.1 form the framework to determine how each aspect of the teacher's role is portrayed within the Teachers' Guides. Table 6.3 provides a summary of the emphasis accorded to particular knowledge and understanding, skills and attitudes within the Science Co-ordinators' Handbook, the KS1 Teachers' Guide and the KS2 Teachers' Guide. I have converted the total number of references under each category into a percentage of the total number of references in that particular text to compensate for the fact that each of the three texts was a substantially different length from the other two. These percentage figures allow direct comparisons to be made between the three texts in terms of the messages they convey to the reader through the language they use. Major differences in emphasis between the KS1 Teachers' Guide, the KS2 Teachers' Guide and the SCH are shown in bold.

Table 6.3 Comparison of Teacher Roles as Described in *NPS* Publications

NPS role	Categories derived from scienceco-ordinators' handbook	total references in text				total references in text (%)*		
		KS1	KS2	SCH		KS1	KS2	SCH
1	Elicitation strategies	4	14	19		8	7	11
	Classroom context	4	9	7		8	4	4
	Teacher attitude	1	3	25		2	1	**14**
2	Managing conceptual development	0	11	10		**0**	5	6
	Understanding conceptual development	6	38	20		12	19	11
	Teacher attitude	0	1	6		0	0	**3**
3	Guiding children in testing ideas	7	34	15		14	17	9
	Classroom context	2	6	4		4	3	2
	Teacher attitude	0	5	3		0	2	2
4	Intervention strategies	3	15	11		6	7	6
	Intervention activities	14	46	22		28	23	**13**
	Teacher attitude	7	17	19		14	8	11
5	Summative assessment	2	3	14		4	1	**8**
	Totals	50	202	175		100	97	100

* percentages rounded up/down to nearer whole number

There are clearly marked similarities between the three publications. However, there are also several differences in emphasis between the SCH and the two Teachers' Guides (emphasised in bold, as indicated above) which I will highlight and explore:

4.1 Role 1: finding out the children's ideas

Role 1 is portrayed in a similar fashion across the texts until it comes to a consideration of a non-directive attitude. This received prominent attention in the SCH, as shown in fig. 6.4.

fig. 6.4

> "The key to your role at this stage is to respond, accept and explore the child's ideas - and, above all, to be non-directive. The idea of standing back to avoid suppressing certain ideas and imposing others may be unfamiliar to some teachers. The temptation to intervene and correct wrong or confused ideas may be very strong if one is used to instructing pupils." (SCH, p.34)

However, it is far less evident in the text of the Teachers' Guides, where it received no explicit mentions beyond, "Explore the meanings...." or, "Encourage the children to record their ideas...." (fig. 6.5).

fig. 6.5

> "By carefully exploring children's ideas, taking them seriously and choosing appropriate ways of helping the children to test them..." (KS2 Teachers' Guide, p.5)

If the questions in the text of the Teachers' Guides are also taken into consideration then the difference is even more pronounced as only a small proportion of the questions is worded to give children ownership of the answer, e.g. "What do you think.....?"

As a non-directive attitude will be one of the most important yet unfamiliar aspects of a constructivist teaching approach I would have expected more reinforcement of it in the Teachers' Guides. Its absence, in conjunction with the wording of the questions, does nothing to encourage teachers to see this approach as different from any they have used before.

4.2 Role 2: reflecting on how children may have arrived at their existing ideas and how far they have progressed towards developing more scientific ideas

Role 2 is portrayed in a similarly dichotomous way, with the teachers' attitude of respect and provisional acceptance of the children's ideas again being far less evident in the Teachers' Guides than in the SCH (fig. 6.6).

fig. 6.6

> "While it is non-directive, the role is not passive. Careful listening has to go along with careful questioning designed to encourage children to explain their ideas and to give the teacher as full a picture as possible of their thinking. Reflection on the answers is essential if follow-up questions, and associated activities, are to be framed to open up the children's communication." (SCH, p.34)

In fact, the "children's ideas" section in the Teachers' Guides contains no reflection or speculation about the sources of ideas, or about how closely the ideas relate to the scientific views as the key ideas are earlier in the text, the background science is at the end (of the KS2 guide only) and there is no explicit reference to the SPACE super-ordinate categories. This section would be the sensible place to model the process for teachers, as they will almost certainly be unfamiliar with it. Instead, the ideas are linked to the science view in the summative assessment chapter, and in a way which focuses more on matching ideas to end of key stage level descriptions than on making coherent sense of the science. While this approach will help teachers with their statutory role as science teachers, it will not help them develop into constructivist teachers.

The extract in fig. 6.7 below could so easily have been extended in several ways by suggesting that:

- the children's experiences had probably led them to link those particular locations with echoes;
- that the size of the writing reflects the perceived volume of the echo;
- echoes provide evidence of sound travelling.

Such elaboration would have enriched the commentary and taken it beyond description to the level at which the teachers need to be operating. Without such a supportive explanatory framework, it will be difficult for teachers to avoid the pitfalls described by Johnson and Gott (1996) of addressing superficial characteristics of children's ideas rather than focusing on the important features.

fig. 6.7

> "Children might be able to describe where echoes can occur and how they experience echoes, but they are rarely able to explain how an echo is produced. Many children suggest that echoes can be heard in caves, tunnels, and empty rooms. They draw echoes in large, empty, enclosed spaces. Their explanations often focus on how they experienced the echo, describing it as a noise which is repeated. Children's drawings might show the sound gradually decreasing." (KS1 Teachers' Guide, p.12)

As alluded to above, the KS1 Teachers' Guide contains no background science section. Consistent with this omission is a lack of reference to managing conceptual development, encouraging teachers to see their role as simply developers of process skills. Only the final assessment section gives any guidance about the quality of children's ideas, but again in terms to match the NC level descriptions.

4.3 Role 4: providing opportunities to test or challenge ideas, perhaps leading to changes

As might be expected, in role 4 the nature of intervention activities (as opposed to intervention strategies) is far less prominent in the SCH than the Teachers' Guides. The *tentative* reference to conceptual change made in the SCH (i.e. the attitude that children's ideas may be resistant to development) is less evident in the Teachers' Guides, where the activities are presented in the conditional tense only to convey that the activities are suggested rather than definitive. There is no indication that the children may not gain the required understanding from the activities. In the absence of an analytical framework for the children's ideas, teachers need to integrate the children's ideas, the key ideas and the background science in order to "provide experiences which help children to build more effective [ideas]" (Harlen and Osborne 1985, p.37). For example in the

Teachers' Guide, the section, "Helping children to develop their ideas" contains a double-page spread of charts suggesting suitable activities for developing ideas from different starting points (see Appendix 11). The children's ideas on the charts can easily be linked to the super-ordinate categories and should therefore provide a real source of support for teachers. However, while there are some useful questions to challenge ideas (fig. 6.8), there are also some which lack focus (fig. 6.9).

fig. 6.8

Q:	"How can sounds be heard?"
Idea	"'Cos it's in front of me"
Q:	"Which directions can sound be heard from?"
Activity	Investigate the effect direction has on ability to hear sounds

fig. 6.9

Q:	"How can sounds be heard?"
Idea	"Because I'm listening"
Q:	"Which sounds can be heard?"
Activities	Test different sounds - high/low; loud/soft Listen to a variety of sounds blindfold

While not all the suggested activities involve practical investigation, the vast majority do, and this focus on practical activity - the "good primary practice" - at the expense of discussion or other approaches is an explanation for the inconsistent quality of the examples. As I discussed in chapter 3, section 4, the emphasis on "doing" can relieve the pressure on teachers' subject knowledge whereas discussion would need greater understanding. However, the children's understanding should be the focus of teaching and it is hard to see how inappropriate activities will improve either their understanding or that of teachers. These intervention planning charts are mentioned in the text but not cross-referenced to the pages of selected exemplar activities. Should the teacher ignore these charts, which are contained within a single double-page spread and so easily missed, the teaching could have a very different character due to the nature of the extensive collection of exemplar activities.

These exemplar activities themselves do not refer back to the children's ideas at all, and certainly do not provide teachers with any help in *using* and *challenging* those ideas. In fact, no reference is made to individual conceptual change in the Teachers' Guides, so teachers are likely to use the key ideas and the additional concept statements in the margins of the text as their intended learning outcomes for the children. The children's ideas need have no place in this approach as the objective is to develop the science view. Similarly, the notion of challenging ideas is included in some suggestions in the intervention planning chart but these do not appear to be paralleled in the activity pages and the emphasis on challenging ideas can therefore be missed.

4.4 Role 5: assessing the extent of any change in ideas and in process skills which may have resulted

Role 5 is not mentioned explicitly in the Teachers' Guides, and there is no attempt to show ideas for the same child from before and after the intervention activities. Maybe this is due to pressure of space, although the end of key stage assessment of skills and understanding is well exemplified. Perhaps it is assumed that identifying *change* in ideas will be straightforward, though as attending to the children's underlying framework rather than the surface features is important (Johnson and Gott, 1996) some exemplification of this would be useful, even if only by using the same contexts for the "Children's ideas" and "Assessment" sections.

5. The View of Science Teaching and Learning Implied by "the SPACE approach"

There is a dichotomy between "the SPACE approach" in the SCH and "the SPACE approach" in the Teachers' Guides, in common with many other schemes, as discussed in chapter 4. Users of the Teachers' Guides, particularly if they have not read the SCH, will be receiving messages that teaching should be directed towards the key ideas, rather than developing the children's existing understanding, whether by facilitation or challenge. While this could be due to the need to reflect the demands of the National Curriculum, its programmes of study and end of key stage level descriptions in the texts, it means that the essence of SPACE is changed quite dramatically by the time it reaches the classroom. In fact, with the emphases as they are in the Teachers' Guides, it would be possible to use them without being aware of the existence of a personal constructivist approach, and without eliciting children's ideas at all. The Teachers' Guides appear to emphasise *key ideas* in relation to concept development, and *activities* which develop process skills. *Children's* ideas are used in such a fragmentary way that it would be hard for teachers to develop this side, and easy for them to use the activities to teach the science.

So, for the user of the *NPS* materials, what is the role of the teacher? It is clearly one in which children's ideas can be found out, and practical activities can be carried out in order to develop children's understanding of science. However, the degree to which the children's ideas are accepted and valued, and the extent to which the intervention activities are controlled by the teacher, depends on which of the *NPS* publications is consulted. For this reason, referring to "the SPACE approach" as a unitary phenomenon is misleading. I will therefore subdivide it for the rest of the thesis, borrowing terminology from Argyris and Schon (1974). "The SPACE approach as espoused" refers to the practice advocated in the SCH and "the SPACE approach in action" refers to the practice modelled in the Teachers' Guides.

5.1 Implied view of science learning

fig. 6.10

> "We can see the importance of these process skills in learning by considering what happens if we try to teach concepts without using them. If we try to tell children that, for example, sound can travel through different materials without enabling them to observe or test out this idea, their only recourse is to rote learning." (*NPS* SCH, p.68)

The major flaw in the statement in fig. 6.10 is the assumption, made in chapter 2 by Bell and Gilbert (1996), that there are only two roles which can be taken by the teacher, either facilitator or teller. The possibility that the teacher could *explain* the idea that sound passes through a range of materials, and then provide opportunities for children to understand the ideas is not considered a possibility. Explanation is neither mentioned nor described as part of the teaching process in "the SPACE approach", either "as espoused" or "in action". The inductive view of science learning assumes that children can only learn through manipulation of materials without giving weight to the manipulation of ideas. It suggests that children are to learn the accepted science view through practical investigation by starting from their own intuitive understanding, and that observation will enable them to acquire all the evidence they need to support or refute their idea. While this might work for some concepts, others are counter-intuitive and the evidence is not readily accessible.

Not only does "the SPACE approach in action" focus on the inviolability of observational data, it reduces the credence given to children's ideas, effectively reducing them to the status of pre-teaching assessment. This assessment in itself is valuable but it suggests that, while SPACE operated in accord with personal constructivist principles, "the SPACE approach" is more of a *dishonest constructivism*, in which children are encouraged to explore and investigate while all of the time the teacher is in possession of the answer they are seeking. As already discussed in chapter 2, personal constructivism has always contained within it an element of deception. The transition from SPACE to *NPS* moves the deception from being implicit to explicit.

5.2 Implied view of science teaching

fig. 6.11

> "By carefully exploring children's ideas, taking them seriously and choosing appropriate ways of helping the children to test them, the teacher can move children towards ideas which apply more widely and fit the evidence better - those which are, in short, more scientific." (*NPS* KS2 Teachers' Guide, p.5)

The teacher is given the role of ensuring children discover the right answers through investigation, a very demanding position, and in order to do this they would have to adopt a role which:

a. introduces sessions within a given conceptual framework so the children know what they are looking for;
b. structures practical activities so the children have complementary findings within the given framework;
c. uses the findings from all of the children's investigations to structure a concluding discussion which enables the children to consolidate the required ideas within their thinking.

If these three steps are compared with the three approaches to conceptual change described in section 5 of chapter 2, it is clear that there are no points of similarity.

5.3 Conclusion: a paradigm shift

What outwardly appears to be child-centred learning actually requires the teacher to control the activities very closely indeed. Children will be making their own sense of science, but they will be doing it by trying to double guess what the teacher wants them to find out. Parallels with a guided discovery approach are inescapable. From "the SPACE approach as espoused" to "the SPACE approach in action" there is a paradigm shift away from personal constructivism to the guided discovery approach which characterised curriculum innovation in the 1970s.

6. Summary

The role of the teacher in "the SPACE approach" in the *NPS* Science Co-ordinator's Handbook is described in ways which fit well with the position of personal constructivism: the teacher is establishing children's ideas and helping them develop their own ideas, except for a greater emphasis being placed on the accepted science view and on challenging children's thinking. The *NPS* Teachers' Guides could easily be used by teachers to develop the scientists' view without working from children's ideas at all.

With all these differences taken into account, the resultant "SPACE approach in action" embodies a paradigm shift from personal constructivism to guided discovery.

Having analysed the documentation accompanying SPACE and *NPS* in this and the previous chapter, it is important to look at how these ideas are translated into classroom practice, and the implications for teacher development. The following three chapters address these issues, beginning in chapter 7 with SPACE, moving on to *NPS* in chapter 8 and deepening the analysis with a comparison of SPACE and *NPS* in chapter 9.

CHAPTER 7

THE SPACE TEACHER IN THE CLASSROOM

In this chapter I focus on the teachers and their role in SPACE. Much of the commentary is on excerpts from the SPACE Project research reports for the topics of 'Growth' and 'Sound' which are in Appendices 12 - 18. We researched these two topics in the classrooms of the same group of teachers, enabling us to explore informally changes and developments in the teachers' involvement in the Project alongside the anticipated research focus of the children's ideas. In order to look at the teacher's role in this way, I describe and comment on all aspects of the Project which involve the teachers - the elicitations, the interventions and the teacher development sessions - in an analysis which has lessons for understanding the process of teacher change. The analysis draws on the notions of effective teaching and teacher change which have been discussed in chapter 4. In order to appreciate the analysis fully, the appropriate appendices containing sections from the research reports should be read at the points indicated in the text.

1. The Informal 'Contract' with the Teachers

At the outset of the Project we gave the teachers a brief outline of the ethos underlying the research, that children learn through developing their intuitive ideas through investigation, and asked them to undertake at least a set minimum amount of work related to the Project. We also assured them that, while they would be given an outline of what was required of them, they would be free to interpret this outline in a manner compatible with their existing classroom organisation. There was, though, an assumption that the teachers had an understanding of the processes involved in science, were familiar with teaching science through practical investigative activities, and ascribed to a child-centred view of learning.

Over time, it became clear that the teachers were both less confident in teaching investigative science and less familiar with child-centred approaches than originally anticipated. This made the assumption that a teacher could use the materials within their existing organisational structure without affecting the efficacy of their teaching questionable, as discussed in chapter 5.

2. Teacher Development Sessions

For the Project to operate in this manner, handing responsibility for much of the data collection to the teachers, we needed to include regular teacher development sessions in the Project programme. These sessions ran for the duration of the Project at approximately two-monthly intervals and were held at a teachers' centre near the teachers' schools. The local education authority (LEA) provided supply cover so the meetings could be held during the school day. All the sessions followed a broadly similar format, reviewing progress made and then looking forward to the next stage of Project work. I deliberately designed this Project-related reflection and development to increase teacher understanding of, and participation in, the Project. For this reason, the sessions were arranged so the teachers engaged in focused discussions in small groups. This strategy ensured that examples of successful practice were shared, facilitating informal tutoring between peers. The teachers thus engaged in "social development 2: valuing collaborative ways of working and reconstructing what it means to be a teacher of science", as described by Bell and Gilbert (1996), and were effectively scaffolding each other. For the remainder of each session we focused on one particular aspect of the teachers' science practice to improve qualitatively their involvement with the classroom-based work. For example, a number of sessions were devoted to developing the teachers' questioning skills. The inter-relationship of the Project timetable and teacher development sessions is shown in table 7.1, overleaf.

Table 7.1: Timetable for Research and Teacher Development Activities

Date	SPACE Project	Teacher Development / Briefing Sessions	Data Collection
Jan 1987	Elicitation activities devised by research team		
Feb		Teachers introduced to SPACE aims & philosophy. Given experience in exploring each other's ideas	
Mar	Teachers use elicitation activities with children & collect their ideas. Individual interviews of sample by research team		
Apr-May	Preliminary analysis of ideas		
June		Teachers presented with preliminary findings. Teachers share experiences of collecting ideas. Brainstorm ways of developing ideas.	
July-Aug	Analysis & writing. Intervention activities refined by research team		
Sept		Progress meetings to exchange experiences	
Oct	Teachers use elicitation activities with children & collect their ideas. Individual interviews of sample by research team		
Nov	Intervention - children helped to develop their ideas	Briefing meeting on classroom intervention	Teachers record elicitation discussion with class
Jan 1988	Individual interviews by research team	Feedback from teachers on intervention. Exploring teachers' own understanding in new topic area. Familiarisation with fair testing	
Feb	Teachers use new topic elicitation activities with children.		
Mar	Children's ideas collected Individual interviews by research team		Teachers interviewed to evaluate their practice
April	Analysis Intervention activities refined by research team	Briefing on intervention activities. Training in questioning techniques.	
May	Teachers work with children to help develop their ideas.	Further training in questioning techniques.	Teachers record discussion with class.
June	Children's ideas collected & sample re-interviewed by research team	Teachers share experiences of working with children's ideas	Teachers re-interviewed to evaluate their performance
Sept-Dec	Analysis & writing		

3. Phase 1 of Data Collection: the Topic of 'Growth'

A description of the pilot elicitation and the second elicitation phase is in Appendix 12.

3.1 Commentary on the pilot elicitation (March 1987)

The pilot elicitation proved very useful in several ways. Firstly, it enabled us to trial elicitation activities set in everyday contexts, thus ensuring we eliminated those which did not reveal the children's ideas either because the growth was unreliable (e.g. carrot tops), or because the children failed to relate the example to the target concept of 'growth' (e.g. potato tubers), suggesting it was too strongly identified with the life-world domain to enable children to access their science-world knowledge. Secondly, it meant we could negotiate with teachers about what they could feasibly undertake in the classroom. This negotiation was very important as a two year project which requires access to children is dependent for its success on the good will of teachers.

3.2 Commentary on the elicitation (October 1987)

In the second elicitation phase, the teachers were beginning to become more involved, as shown by the paragraphs in Appendix 12, bemoaning the fact they did not have time for one-to-one discussions with children. As we were not requiring them to undertake this dialogue, there is a clear suggestion that the teachers were finding the work interesting. This interest could have been generated by our consultative approach to their involvement. However, it is more likely that it was the access to their children's ideas which had intrigued them, giving them a source of unexpected insights which enhanced their pedagogical content knowledge. The realisation that these ideas exist might also have led to the improvements in their open questioning, a further extension of their pedagogical content knowledge, as the teachers became more aware of the need to encourage the children to volunteer then explain their statements.

This greater involvement on the part of the teachers enabled us to design the intervention in a way not otherwise possible. By identifying a range of strategies (Appendices 3 and 5) rather than prescribing a particular set of activities we were able to see what activities the teachers themselves could generate from the strategies, and what learning the children could engage in. This did not link closely with the aims of the SPACE Project, which prioritised developing children's ideas. However, it had the advantage of placing conceptual development in the hands of the teachers, which is where responsibility for the delivery of the curriculum is located, and thus of ensuring both learning outcomes which were achievable in the classroom, and, as discussed in chapter 5, credibility for the Project. In terms of the long-term future of the Project, the potential for branching into curriculum development was much enhanced by this 'feasibility study'.

3.3 Commentary on the intervention (November, 1987)

A description of the intervention is in Appendices 13 and 14.

> "The amount of information the children had acquired without being taught per se amazed me, and I was convinced that involvement, observation and experience were invaluable methods of learning."
> (Teacher's comment: 'Growth' Research Report p.92)

The range of teachers' existing theories of teaching and learning was bound to make the intervention process different in each classroom, since the starting points of the teachers were so different from each other. The comment above is interesting because it reveals that particular teacher's developing views about teaching and learning. The shift in the teacher seems to be from a didactic to a more involving approach, but with the notions of personal constructivism still uncomprehended. Her understanding of the processes by which learning occurs is quite poorly developed, with 'learning by doing' being simply that, rather than providing opportunities for children to develop their use of science processes beyond observation. On the other hand, there were teachers who displayed a sophisticated understanding of the place of 'challenge' in the children's activities, showing a greater understanding of the principles of personal constructivism: the teacher of the Y3 class exemplified in Appendix 13 is demonstrating both appropriate content knowledge and pedagogical content knowledge in the vocabulary activity.

By providing the operational classroom framework (in Appendix 5) we were increasing the chances of teachers facilitating learning in the children according to personal constructivist principles. However, the strategies did not assist the teachers with either their content or syntactic knowledge. What was clearly highlighted by this phase of the Project work was that the teachers' understanding of the nature of science education did not accord with that of SPACE, in which the interaction of concepts and processes was considered to facilitate concept development through investigative activity. Content and syntactic knowledge were identified as major thrusts for forthcoming Project teacher development sessions.

4. Phase 2 of Data Collection: the Topic of 'Sound'

A description of the elicitation is in Appendix 15.

4.1 Commentary on the elicitation (February 1988)

This elicitation phase built on the previous one in that we provided teachers with support for their content knowledge. We did this in several ways. Firstly, we provided an organising framework for the key ideas of the topic of 'sound', i.e. we made explicit the natural division of sound into the three phases of production, transmission and reception. This framework was intended to aid teachers in their interpretation of the children's ideas by helping them look beneath the surface features to understanding related to the key ideas, the position argued by Johnson and Gott (1996) in chapter 3. Secondly, we provided opportunities for teachers to explore their own understanding both of the concept area and of the methodology, and to discuss their ideas with each other. We intended these opportunities both to increase the teachers' involvement in the Project, and to increase the efficacy of the data collection process. However, the inadvertent inclusion of an intervention activity in the elicitation (the drum with rice on the skin) and the imprecise instructions on another (the ear trumpet) shows the tenuous grasp of content knowledge demonstrated by researchers and teachers alike.

During a teacher development session, teachers were asked to generate criteria for successful elicitation activities. The combined list is in Appendix 16. While many of the criteria are practical and would probably have been generated if the teachers had no involvement in the Project, several, for example access, comprehensibility and extendibility show that the teachers were able to express the SPACE understanding of the purpose of elicitation and its relationship to later teaching.

The issue of the teachers' understanding of science processes was less straightforward to address. There were two reasons for this: firstly, providing opportunities for the teachers to develop their own process skills did not necessarily transfer to their classroom practice, probably because we did not provide comparable support with the pedagogical content knowledge, making the context too far removed from the classroom (Joyce and Showers, 1984); secondly, an ability to construct fair tests does not signify that teachers understand the particular view of the nature of science necessary to use investigations to develop scientific concepts.

4.2 Commentary on the intervention (May 1988)

A description of the intervention is in Appendices 17 and 18. This intervention phase was characterised by the teachers taking even greater ownership of the classroom work. The support we offered for content and pedagogical content knowledge was extended and teachers discussed and agreed amongst themselves the questions for starting the classroom intervention. By setting up the conditions for this discussion to occur, we were promoting a scaffolding process in which peer tutoring (or researcher input if necessary) led to teachers developing the necessary pedagogical content knowledge to use the ideas in the classroom.

Children's and teachers' understanding of fair testing which had earlier been problematic improved so that teachers were able, depending on the children's experience of process science, either to help the children construct a fair test, or to monitor its implementation. That was a substantial step forwards - being able to construct a coherent classroom package for the children to learn within, and ensuring the testing which was included was fair. The classroom intervention scenarios in Appendix 17 show the teachers were now up against another problem, marking either the next stage in their developing understanding of science investigations, or alternatively showing a lack of content knowledge. For the most part, teachers were accepting the identification of a data pattern as the end point in the investigative process, rather than getting the children to explain what had happened. I discussed in chapter 3 the views of Qualter et al (1990) and Gott and Duggan (1995), that teachers should not use investigations as a vehicle for the development of both processes and concepts at the same time. The children in the SPACE classes were learning to investigate, and this lack of emphasis on concept development through investigation should not be surprising. This has profound consequences for a personal constructivist approach to teaching and learning because it means that, while the children are learning the principles of fair testing, the children's existing ideas will be reinforced rather than developed, meaning that teachers concerned about the end of key stage assessments will be more likely to tell children the answer in order to get the required results.

4.3 Conclusion: development in SPACE teachers' practice

My commentaries in sections 3 and 4 have shown remarkable changes in teachers' attitudes to science education and engagement with the SPACE Project. As Bell and Gilbert (1996) recognised, this level of teacher development would not have been possible without the teacher collaboration facilitated by the peer tutoring situations which fostered ideal conditions for the feedback and coaching necessary for transfer of learning to the classroom (Joyce and Showers, 1984).

5. Development in Teachers' Practice

So far, the reports of teacher performance have been based on the impressions I gained as I visited each classroom, and by the teachers' self-reports at Project sessions. In order to collect more systematic data, seven of the Project teachers agreed to participate in the evaluation of the teacher development sessions which focused on questioning to encourage conceptual development, a full account of which can be found in Watt (1992). I asked the teachers to collect data both before and after the questioning sessions in the form of audio tape-recorded discussions between themselves and their class, and I conducted focused interviews with the teachers. The teachers also wrote a reflective assignment after the sessions. These three data sources allowed me to triangulate teacher performance and their perceptions of what they were doing. In order to analyse the data I developed a framework from Barnes and Todd (1977) which enabled changes in both social and cognitive aspects of questioning to be identified (Watt, 1996; Appendix 19). 'Social' changes involved the types and quality of interaction between the teacher and children, while 'cognitive' changes involved the actual content and organisation of the discussion.

5.1 Evidence of teacher development

This analysis, although based on a small number of teachers, produced interesting findings. They were interesting inasmuch as they were contrary to those which I expected, and because of this, they are relevant to the entire SPACE teacher development programme. The INSET sessions addressed aspects which I expected to influence the cognitive dimension of their questioning: recognising when children's statements contained hypotheses or observations and planning appropriate questions for each situation; wording open questions to elicit particular aspects of scientific understanding; observing dialogues between colleagues and analysing opportunities for conceptual development. It is thus in this area that I expected effects of the sessions to be seen. However, there were few trends in this direction. Instead, development took place within the social domain, changes which were compatible with teachers making efforts to consider the fundamental basis of their teaching philosophy. I will now describe the principal changes (previously reported in Watt, 1992) and make some suggestions about why they occurred (not previously reported).

1. A very obvious 'social' change, particularly through the teacher interviews and reflexive accounts, was the trend towards less interventionist management of discussions by 4 of the 7 teachers, and towards greater participation by the children. These developments were likely to be as a result of the Project's continuing emphasis on valuing children's ideas rather than an input connected with questioning. The fact that the changes were more evident in the practitioner accounts than in their practice suggests that the teachers were processing a fundamental change of teaching approach and beginning to test it out in practice. Alternatively, teachers' continued focus on this child-centred approach may have kept it in their minds while they encountered resistance from the children to the introduction of an approach which changed the accepted power relationships in the classroom (Rudduck, 1980; White, 1988a).

2. Teachers were still reluctant to provide appropriate verbal feedback to children's questions, leading to the absence of a 'cognitive' feature in the questioning. As this reluctance was coupled with the regular use of non-verbal strategies to convey their actual opinion, it seems unlikely that a lack of content knowledge was responsible for this feature. The inefficacy of the sessions in amending this behaviour could have been due to the teachers' interpretation of earlier Project inputs as advocating non-judgmental acceptance of *all* responses to *every* question even when the question was appropriately closed and the child's answer incorrect. For teachers endeavouring to interpret the implications of a child-centred approach for their practice, working with children's ideas is a big departure from previous ways of working. Expecting teachers to accept and implement a power shift in their

classrooms and at the same time to apply it differentially might be asking too much. I would expect such an over-generalisation in non-judgmental acceptance to diminish as the teachers become more comfortable with a child-centred approach, enabling them to focus on appropriate use of feedback to encourage learning.

3. One 'cognitive' change is that 5 of the 7 teachers attributed greater importance to the pre-planning of a small number of open questions around which to base the children's discussion. This change, from either having a tightly structured script of closed questions or having no focus for the discussion, is very helpful for a teacher working to incorporate a more child-centred style into their teaching because it facilitates the elicitation of children's ideas by providing a framework for discussion. This framework supports and guides both teachers and children in knowing which areas are important for discussion without providing a rigid straight-jacket. The usefulness of this structure might account for its incorporation since it would help the teachers retain control over the discussion, something they might fear losing in the transition to a personal constructivist approach.

4. A second 'cognitive' change, though not in an area addressed in the questioning sessions, was that teachers were asking more questions relating to the control of variables to ensure that testing was fair. An earlier Project input directed towards the science processes emphasised fair testing through the control of variables, a procedure unfamiliar to many of the teachers. This change suggests that the earlier input was understood by the teachers, seen as relevant and incorporated into their practice. The mental effort required to structure the questions to ensure all testing was fair may have meant that further new foci for questioning would have overloaded their processing. The earlier input could therefore have prevented teachers from encouraging conceptual development through seeking hypotheses and thus helping the children to develop their understanding. This would be an example

of poor timing of teacher development, providing different foci too close together to enable teachers to utilise all the inputs they received.

5. A 'social' change made at the apparent expense of a 'cognitive' one was that 4 of the 7 teachers reported using class discussions during the intervention as a forum for sharing rather than developing the children's ideas. Linked to this, there was a decrease in the number of hypotheses being sought post-training. There are several possible explanations for this pattern of teacher behaviour. One is that the clearly distinct phases for elicitation and intervention in the research programme involved the teachers and children in articulating a wider range of ideas than was pursued. Another is a lack of security in the teachers' own subject knowledge since it is not possible to challenge thinking unless there is an understanding of what is wrong with the idea, which requires a more sophisticated understanding than simply knowing whether an answer is right or wrong (as in 2. above). Teachers were given an opportunity to explore their own understanding during a Project session, but on the same occasion as developing their understanding of fair testing, an aspect which seemed to take priority in the teachers' actions (see 3. above) or was simply easier to confront.

5.2 Explaining patterns of development

Points 1. and 2. above are consistent with the idea that the context of SPACE encouraged (or required) the teachers to reflect on the philosophy underlying their practice. They were therefore experimenting with changes in line with the new philosophy, and these were evident either in their practice or in their perceptions of it. Points 4. and 5. above compound this position by providing inputs related to new strategies at a time when the teachers were still focused on their reflections. Point 3. suggests that inputs related to new strategies were incorporated if teachers perceived them to be congruent with changes they were trying to make. Therefore, both the timing and the context of the teacher development are influential in this example of teacher change.

Within the confines of SPACE, a project whose remit was to collect and interpret systematic classroom data according to a personal constructivist perspective, the fundamental changes implicitly being asked of the teachers required the majority of their energies to be directed towards reconsidering their practice in line with that aim. Attempting to develop a particular skill like questioning needed to be done once a teacher was operating within a secure theoretical framework. The teachers were still incorporating changes from earlier Project briefing sessions on which they were reflecting. The later sessions, including those on questioning were not acted on for two reasons. Firstly, they came too thick and fast for the teachers to be able to keep up. Secondly, they were pitched at a lower conceptual level at a time when teachers were striving to make much more fundamental adjustments to their way of operating.

Variations *between* teachers can therefore be explained in terms of the teachers' personal theories of learning at the outset of SPACE (Biddulph and Carr, 1992). If a teacher is initially operating in a child-centred manner then the questioning sessions will be more immediately accessible to them for several reasons: there will be less need for a negotiated change in the relationship between class and teacher (Rudduck, 1980); the prevailing classroom organisation will need less adjustment and the teachers will thus be operating within a more secure, established context. On the other hand, a teacher who is initially operating within a more didactic framework will need to adopt a different teaching style, and to familiarise both themselves and the children with the changed rules of the classroom.

5.3 Ideas about teacher change

Referring back to chapter 4, in which levels of teacher reflection (Handal, 1990) and teacher change (Fullan, 1991) are described, the three major components of the SPACE teacher development programme involve new teaching strategies (the investigative science), modified teaching strategies (the productive questioning) and new beliefs about education (the personal constructivist perspective). These aspects of practice are very closely linked to each other since investigative science and productive, effective questioning are founded on a child-centred view of learning. In order to take on board the new ideas, the teacher is required to reflect at levels 2 and 3.

Using Bell and Gilbert's model (page 83, chapter 4), the teachers need to decide that their practice should change before any professional development can occur. However, because this teacher development was linked to a research project to which teachers were recruited for various reasons unknown to me, the teachers were first confronted with the notion of new science teaching practice through the aspects of professional development (trying out new activities) and social development (reconstructing what it means to be a teacher of science). The teachers therefore had to backtrack in order to confront what they were led to consider were limitations in their own practice before they could move on.

While Bell and Gilbert's model is useful in highlighting both the time taken for development to happen, and different aspects of the change process, it compounds two features within the social development pathway: the role of social interaction between teachers as a catalyst for learning, and reconstructing what it means to be a teacher of science. This latter aspect appears to belong elsewhere, possibly at a deeper level of professional development than activities and ideas. I therefore suggest adding a third dimension to Bell and Gilbert's model which relates to depth of reflection or thought and, if extended throughout the model, makes it more compatible with Handal's three levels of reflection.

The changes discussed here are fundamental, addressing the underlying belief structures of a teacher's practice. Bell and Gilbert's model relates well to the adoption of personal constructivist approaches by SPACE teachers, but it does not attempt to account for how the lower level, strategic changes (i.e. developing teaching strategies) are handled by teachers. This suggests that Bell and Gilbert consider it was inappropriate to be asking for those changes simultaneously. However, I have devised a model which can explain the interaction between the two "levels" of change.

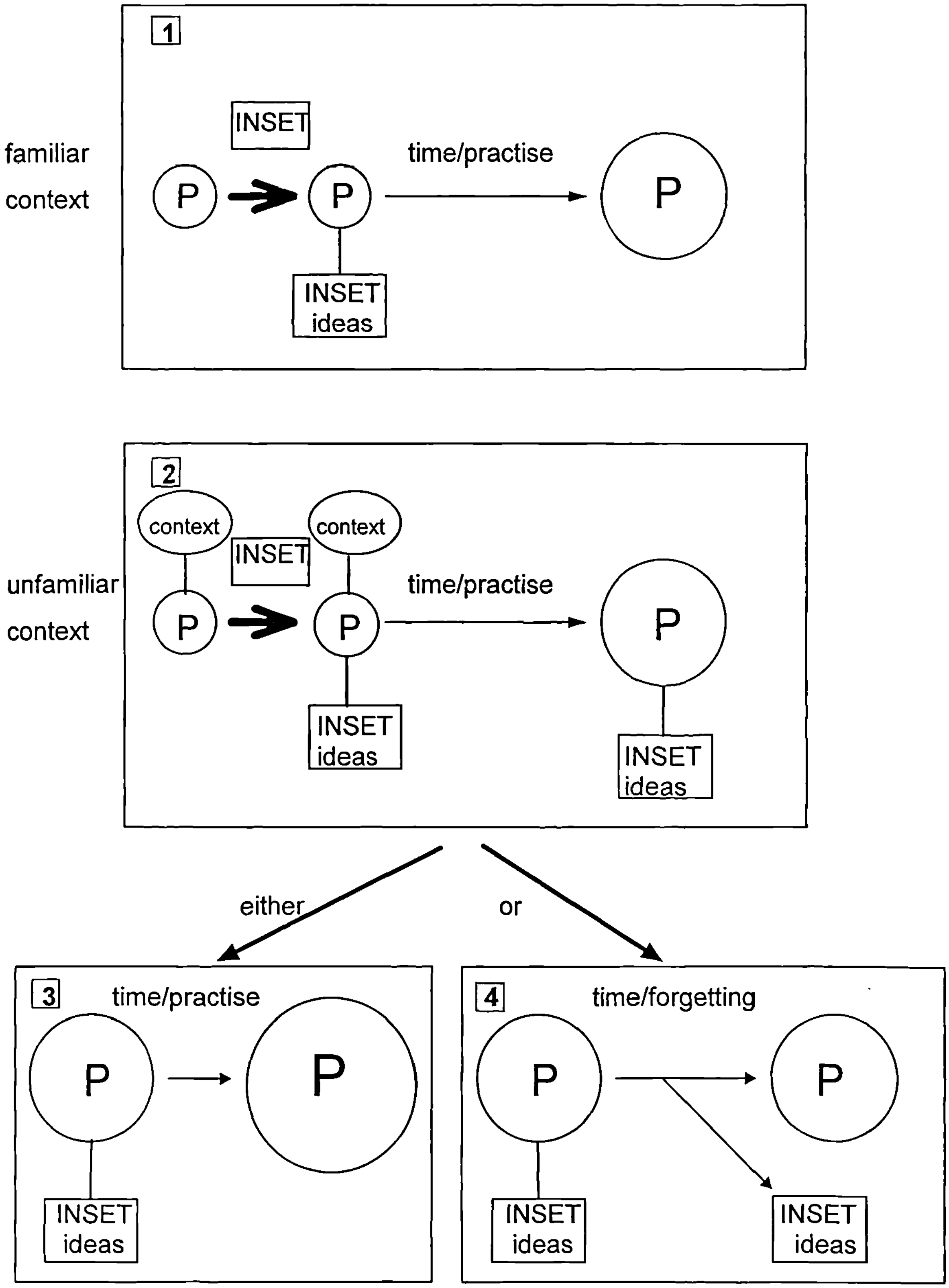
5.4 A model to relate context and timing to the effect of teacher development

The SPACE situation is complicated by having both belief-influencing and strategic INSET alongside each other. Table 7.2 shows my attempts to portray how the context and timing of strategic INSET can affect a teacher's practice, relating to the notions of Handal and Fullan.

Within a familiar context (box 1), i.e. a school or classroom known to the teacher, the teacher's practice (P) will be well-established. A short, intensive period of strategic INSET within this context is likely to have an immediate effect on the teacher's classroom behaviour, through relevant ideas being tested alongside existing strategies. This trialling of new ideas will lead to reflection at level 2. Time and practise in using these ideas is likely to lead to the teacher's practice being changed with useful ideas being incorporated and practice thus developed.

Within an unfamiliar context (box 2), a situation in which the teacher has been provoked to a fundamental examination of their practice, the teacher's established practice will be affected by the new context which will be the subject of reflection at level 3. Some strategies linked to the new context may be tested out as part of the reflective process, helping the teacher refine and personalise the unfamiliar ideas. The introduction of strategic INSET in this unfamiliar context is thus unlikely to have the same impact on practice since teachers will be involved in higher order processing of the context ideas and implementing those changes. Thus the strategic ideas will simply be registered until the teacher has incorporated sufficient ideas related to the context, at which point strategic changes will either be called upon (if compatible with the teacher's newly developed practice), and used (box 3) or forgotten or rejected (box 4).

Table 7.2 The Effects of Time, Context and INSET on Changes in Teacher Practice



Applying this model to the SPACE Project, had the context been familiar (that is, had the teachers already been operating within a personal constructivist framework), some changes in questioning behaviours would have been likely as a result of the strategic INSET. However, these changes would still be of a trial and error nature as teachers test out strategies against their established practice (Olson and Eaton, 1987).

Working in an unfamiliar context, the absence of cognitive changes can be explained firstly in terms of deficiencies in the content and pedagogical content knowledge of the teachers who have thus been unable to utilise the questioning strategies. Secondly, there could have been a problem of teachers being unfamiliar with the less influential, facilitative role in concept development and therefore interpreting it as a zero influence role (Fraser, 1978). However, the unexpected presence of social changes cannot be explained in that way. The teachers were working in a strange context and trying to find ways of reconciling new ideas with their practice. The changes observed in their practice and those they themselves perceived related to *earlier* inputs which were more fundamentally far-reaching in their effects. The strategic questioning INSET was not, on the whole, of sufficient relevance to their current development for them even to try any of its ideas. The one exception to this was an increase in the pre-planning of key questions and it is likely that this change was incorporated because it facilitated the development of the child-centred practice for which they were striving (Olson and Eaton, 1987). The teachers therefore appear to have been reflecting and changing at their own rate. In light of this, should there be a scenario in which specific skills need to be developed while major change is being considered, an advantageous approach would be to encourage reflection focused on the particular skill and set clearly within the framework of the teachers' individual changing practices, thus using the "dynamic inter-relationship" (Fullan, 1991) between new teaching strategies and new beliefs to facilitate development.

6. Summary

We negotiated that the teachers' involvement in the Project would involve them undertaking at least a certain minimum amount of work according to the guidelines they were given. This involved an assumption, tested and found wanting through INSET sessions, that the teachers possessed the necessary skills, understanding and attitudes to science teaching to enable them to undertake the work.

The teacher development sessions associated with the Project enabled teachers to develop their understanding of the Project and its view of science teaching and learning through collaborative activities involving discussion and informal peer tutoring. Informal observations of teachers in their classroom and during the teacher development sessions suggested that their practice was changing in ways which enabled them to take more responsibility within the Project. More systematic analysis supported this view, though some of the changes were not what was anticipated from the INSET given. Rather than developing the specific skills, it appears that the teachers were reflecting on their philosophy of science teaching and endeavouring to make more fundamental changes.

Chapter 8 explores the practice of one teacher in detail as she embarks on using *NPS* in her classroom.

CHAPTER 8

OBSERVING NUFFIELD PRIMARY SCIENCE IN THE CLASSROOM

Having analysed the texts of *NPS* and found a paradigm shift from personal constructivism to guided discovery between the SCH and the Teachers' Guides, I was interested in seeing how the approaches espoused and modelled therein were interpreted as part of teaching and learning in the classroom. By observing classroom action I was able to identify similarities and differences between the texts and practice, in relation to the effects any differences would have on the personal constructivist model of teaching and learning which was the hallmark of the scheme. This chapter begins with a consideration of the decisions which led me to collect the data I did, followed by a description and analysis of the data, leading to a discussion about issues of teaching and learning in the context of *NPS* in the classroom.

1. Rationale for Data Collection

In order to gather information about how *NPS* was being used in the classroom, I had to decide on the level of detail I required from the data. Most importantly, I wanted to answer questions about pupil - teacher interactions as they occurred during science lessons, and about the teacher's philosophy of science teaching. The former requirement ruled out the use of a large-scale questionnaire survey which would have relied on teacher self-report as a measure: since the *NPS* materials allude quite heavily to what they consider to be appropriate teacher-pupil interactions for "the SPACE approach", I did not feel that self-report uncorroborated by observation would provide me with sufficiently reliable data, even were there follow-up interviews with a sample of respondents. The alternative was to use observation as the principal data collection technique, which therefore required me either to be present myself, or to make extensive use of other observers who could either be animate and trained, or inanimate in the form of audio or video recorders. I decided that it was preferable to collect a relatively small amount of detailed information myself rather than attempt to identify appropriately knowledgeable observers or negotiate the use of audio or video recorders, both of which would have led to less complete data being available for analysis.

These decisions meant my research took the form of a case study of one teacher in the process of starting to use *NPS* in the classroom. By choosing this methodology I was able to adopt an ethnographic stance as a participant observer, or an "extra pair of hands" in the classroom.

In order to see what effect the *NPS* materials had on a teacher's practice, I decided it would be most useful to observe a teacher's initial attempts at using the material. I felt that, on a first run-through, a teacher would be more likely to use the materials as intended whereas subsequently they might adapt them to make them easier to use (Olson and Eaton, 1987) within their existing patterns of practice. I therefore planned to coincide my observations with the issue of the second edition of *NPS* which brought the scheme in line with the newly revised NC for science (DfE, 1995). My reasoning was that more schools than normal would be purchasing a new scheme at that time, having waited for the publication of the revisions. My pool of suitable teachers to observe was therefore likely to be larger. I anticipated that data collection would stretch over the first half of the Spring term 1996. Half a term is the duration of most school science topics, and half a term's worth of observations thus allowed a topic to be seen in all its phases - beginning, middle and end - ensuring that both elicitation and intervention were seen. I planned to observe only one topic for two main reasons: firstly, I wanted to see a teacher's initial attempts at using *NPS* and secondly, their evaluative comments would give me sufficient insights into their perceived development needs (and therefore their understanding of the philosophy underlying *NPS*) that more extended observations would be unlikely to yield much greater insights in relation to my enquiry. Were I concerned with the manner in which teachers make adaptations to schemes in order to maintain the successful elements of their existing practice then more extended data collection would have been essential.

2. Selecting an Appropriate Teacher

I planned to use the inside knowledge of a local advisory teacher for primary science to identify a practitioner who met my criteria for the subject of my case study. A teacher who met that brief was likely to be the science co-ordinator of their school. My criteria were as follows:

- A competent primary science practitioner (so that any new ideas would be building on an established foundation of primary science practice);
- Someone who had a personal philosophy for science teaching;
- Someone who was aware of the science teaching practice of the rest of the staff;
- Someone who was aware of different approaches to teaching primary science, and so had made conscious choices about their own practice.

Before I was able to identify a suitable teacher I wrote out my requirements for access to classroom data so that both myself and the teacher understood the nature of my classroom involvement. I decided that I would need commitment from the teacher to allow me:

1. To observe a science session each week for half a term, and to make field notes to record my observations;
2. To interview them both before and after the observations about the following topics:
    - Biographical details
    - The co-ordinator's role, particularly the implementation of change.
    - Personal views on teaching and learning in science
    - Personal views on *NPS*

- Identification of their own and staff's development needs

3. To have an informal evaluative chat after each session;
4. To have access to written lesson plans and half termly plans;
5. To have access to the children's work to photocopy if required.

In return, I was able to offer free enrolment for any of the staff in the school on a tailor-made module for primary science which I would run at the school in the Summer term, or whenever convenient. This module was validated at Certificate level within the modular INSET scheme of the University at which I was employed.

I sent a copy of my brief to the primary science advisory teacher who I hoped would be able to suggest some teachers who would be suitable to approach. I was given four suggestions, of which three were second choices and one was considered to be as near a perfect match as I was likely to find. My initial approaches to the Headteacher of the latter science co-ordinator were met favourably, and I was invited to approach the teacher herself in order to ascertain whether she would be willing to participate. The science co-ordinator was happy to get access to any extra assistance with science teaching, and I arranged to visit the school prior to the observation period commencing.

At my initial meeting with "Veronica" I ascertained the necessary biographical details about herself and her class, and I was able to gain an impression of her views about science education, both in general and within her school.

3. Case Study of "Veronica", a Science Co-ordinator

Veronica was science and IT co-ordinator at "All Saints CE" in a semi-rural community on the edge of a large urban conurbation. Her school currently had copies of the *Ginn* science scheme (Ginn Science, 1989), but few if any of the teachers used it. Veronica had initiated a change of scheme to *NPS* because it did what she thought was important at KS 1 and 2 and provided for development in Sc1. She particularly liked the way *NPS* told her which questions to ask, and then gave suggestions of investigations to follow them up. The rest of the staff also particularly liked that feature since they did not feel confident in teaching science and did not have a good knowledge base from which to draw. This lack of knowledge was a concern to Veronica, since she knew of some instances in which children had been misled in their ideas. She did not consider herself to be a particular expert in science - her specialism when she trained was English - but she knew more than the others and had an interest in teaching it.

Her class was Y5 and they responded very well to science activities. Several of them were very able and thrived on investigative-type activities. One boy in particular had a very well developed scientific vocabulary as a result of work he did with his parents and books he had read.

The class was to be pursuing the topic of 'sound'. *NPS* had only just arrived in school so Veronica would be rewriting the school schemes as well as beginning to teach using the materials. They had bought 2 complete sets of the Teachers' Guides, and the SCH (which had not arrived). They had not bought the pupils' books because they did not have the money for them, and Veronica was dubious about their worth. They had all the pupil readers from the *Ginn* scheme.

Science was to be on a Tuesday afternoon, from 1.00 - 2.45 p.m. The vast majority of this time was used for practical activities since the children were given the recording to do for homework.

The local science advisory teacher was scheduled to give the school INSET related to the introduction of the *NPS* materials for ten half days during the second half of the term.

4. Data Collection

Veronica introduced me to the class as "Another teacher who is going to be working with us for science this term" and had previously informed the children that I was a scientist and an "expert". She gave me a list of the children's names, grouped by 'ability' and had arranged for the children to wear name labels for my first visit. The effect of my presence on the class is impossible to judge, but the children seemed to accept me readily and talk to me in a similar manner to that in which they conversed with Veronica. Data collection followed the same pattern for each of my five visits to the classroom.

4.1 Field notes

On each occasion in the classroom I carried a small, spiral-bound notebook and pen in a pocket to record as much of the lesson as I could while it was underway. My original intention was to sit in an inconspicuous corner of the classroom for at least part of each lesson in order to observe Veronica in action with the children. However, in common with Broadhead (1989), I found that Veronica wanted to establish my classroom credibility through ascertaining my ability to interact with the children. My less participative stance was therefore attainable during class discussions, but while the children were actively involved in their practical investigations Veronica invited the children to regard me as an additional teacher in the room, so I found myself questioning the children and helping them to plan their investigations. Initially I was quite reluctant to do this, as my teaching style was not the same as Veronica's and the children were already having to adapt to some differences in her style as a result of the introduction of *NPS*. However, by listening to Veronica, I was able to style my interventions to be more in line with hers, challenging children more and directing them explicitly to change their plans. As well as providing consistency for the children, this stance gave me greater insights into Veronica's way of teaching than had I simply observed her in action. In order to take on her role I had to understand far more fully what she was doing than observing would have necessitated (Burgess, 1984).

My hastily scribbled notes in the form of words, phrases and sometimes sentences were used as the basis of as full an account of the session as possible as soon as I finished in school. Using the notes and my memory I constructed a transcript which reported, verbatim where possible, everything I observed during each afternoon of science. As many events happen concurrently in a classroom, particularly when children are seated in groups, my observations could never give a complete picture of the action but, like a video recording, focused on one aspect at a time before moving on.

Writing a literal description rather than an interpretive analysis of what I saw and heard was an aspect of data collection at which I had to become more proficient. An example of a literal description would be this observation during a class discussion:

fig. 8.1

T: "What's happening to the tuning fork on the paper?"
ch: "It's vibrating"
T: "Vibrating?" *All arms are raised straight.*
ch: "Wobbling very quickly"

(Field notes from 28.1.96, lines 221 - 227)

As a teacher I found it easy to interpret children having their arms raised straight as opposed to crooked and half-raised during a class discussion as a sign of a desire to respond. However, I could appreciate the importance of not immediately placing these familiar interpretations upon actions because there was always the possibility of there being an alternative explanation, or of the observed actions being part of a wider pattern (Spradley, 1980). To accompany my field notes, I asked for a copy of all the worksheets which Veronica used with the children. Where the children were engaged in a formal elicitation activity I also had a copy of the children's work.

4.2 Session evaluations by the teacher

At the end of each session I invited Veronica to evaluate it, and I used a micro-cassette recorder to tape record the discussion. On one occasion this evaluation was not possible as Veronica had a prior engagement. I re-played the evaluation tape after I had transcribed the field notes, and noted down the main issues which it raised. During the transcription of the field notes and the evaluations I made a list of issues which came to mind, so that I could ask Veronica about them during the final interview which was to be the culmination of my observations.

4.3 Fieldwork journal

For the duration of the school visits, I kept a personal log of the research, recording my feelings and perceptions about conducting participant observation. This journal was very useful as it enabled me to make greater sense of the classroom environment in which I was operating, while ensuring that my field notes remained as objective as possible. For example, I was able to pose questions about Veronica's actions which would then focus my observations for the next session.

4.4 Interview

The final interview with Veronica contained open questions in a semi-structured format. I used both my notes and the SCH as the basis for the questions. Having brainstormed all the issues I wanted to raise, I arranged the questions into three main sections to give some structure to the interview. The areas were: the classroom practicalities of teaching 'sound'; the children; and the *NPS* philosophy. The questions were a mixture of points for clarification and an attempt to understand Veronica's thinking about her practice. I kept the number of questions as small as possible by phrasing them in an open manner, accompanied by a series of prompts to ensure that she addressed all the areas in which I was interested. A copy of the interview schedule is in Appendix 20. This interview was conducted after school four weeks after the observations had finished. The time interval of four weeks between the end of the observations and the interview enabled me to analyse the field notes and therefore to clarify in my mind the issues I wished to cover. It did, though, mean that Veronica had become a lot more familiar with *NPS* in the interim period, thus dimming her recall of some events. The interview was recorded on audio tape and transcribed in full for later analysis.

At the end of the observations I gave Veronica a copy of all my notes (except my journal) to give her the opportunity to comment and to request alterations. She was concerned about the issue of confidentiality, about which I was able to reassure her, and her only other comment was one of amazement that so much happened in each session.

5. Analysis of Veronica's Practice in Relation to the Teacher Roles Outlined in *NPS*

In order to make sense of the role Veronica was playing in the classroom, I decided to use the framework provided by the definition of teacher roles in *NPS* which I constructed in table 6.1 of chapter 6. This framework had the advantage of enabling me to make a comparison between "the SPACE approach as espoused", "the SPACE approach in action" and the SPACE approach in the classroom. To provide as full a picture of Veronica's practice as possible, I amalgamated the data from all three sources; the observations, the post-session evaluations and the final interview.

5.1 Role 1: Finding out what children's ideas are

Veronica was very encouraging to the children and clearly valued their ideas. She had established a culture in the classroom whereby every child knew they were entitled to their own view, and they should not mind if their ideas were different from other children's. She explicitly gave children ownership of their ideas and encouraged them to express their views with confidence:

fig. 8.2

> *"We don't care if your ideas are wrong. Lots of scientists have ideas which they test out to find if they're right, so don't be afraid to have an idea"* (Session 1 lines 160-1)

In a similar vein, Veronica tried to encourage the children to draw their ideas as a rough sketch, but despite explicit instruction that the drawings were to be on the first piece of paper which came to hand, and were not to be beautiful, the children produced neat work, rubbing out many times in order to produce something, which often contained more writing than drawing. My inference here is that the classroom culture determined that written work was to be presented to the highest standard, and that writing as opposed to drawing was the medium through which ideas were communicated. At the beginning of the topic Veronica made little effort to set a context for the elicitation activities which related to the children's experiences either in or out of school, or to prepare the children to focus on their ideas. In fact, she introduced the first session by telling the children they would be "looking at" sound, wording more reminiscent of a chalk and talk session than one which was planned to be child-centred. However, between sessions 2 and 3, she introduced the concept of an "ideas board" as part of the classroom display to which all children were invited to contribute, and which Veronica used during the week as a focus for discussions and to help maintain the children's interest in the topic.

Veronica's tone throughout was non-judgmental. She moved between the groups of children as they were drawing their ideas and asked them for clarification of their views. She used the questions in the *NPS* Teachers' Guide as a starting point because she was unsure about which questions to ask. This was a successful strategy where the wording of the questions was clear, but it led to some confusion where it was not. Veronica really listened to the children's ideas and accepted them, but she immediately challenged any which did not conform to the scientists' view, sometimes by the introduction of another context (as in fig. 8.3) in the hope of encouraging the child to think again, or to expand their answer. She was thus employing strategies espoused in the SCH but not exemplified in the Teachers' Guide. As the SCH had not been delivered at that point, she must have been using her own ideas about the nature of science teaching.

fig. 8.3

> One child thought the drum made a sound by the vibrations going down to the bottom head of the drum before going back up to the top and out. Another said he had used a drum without a bottom head and it had made a sound.
> T: *"Oh, that's confusing for you then isn't it?"*
> Another then suggested that when she had used a one-headed drum the table had acted as the bottom and 'it' had bounced off the sides.
> T: *"So you think it's the table?"* T picks up a tambour and gets the last-mentioned child to hit it while she held it in mid air, well away from a table. The drum made a very clear sound.
> T: *"So that's given you something to think about"*
> (Session 1 lines 119-33)

There were occasions during class discussions when her wording suggested that the child's answer was wrong. On these occasions she employed an interesting retrieval mechanism in which she first asked for other ideas (as in fig. 8.4). This was not something she did when she agreed with a child's answer, when she repeated or reworded their idea. By inference, then, the children would know that she had disagreed with that particular answer. Veronica realised how the children would interpret her words, so she tried to convey that she was not disagreeing, in order to camouflage the manner in which she was directing the discussion according to the accepted science view. Here White's (1988) ideas about lesson 'scripts' being based upon a generalised understanding of the nature of lessons seem particularly relevant, as Veronica's script was well known to the children, despite her desire to change it.

fig. 8.4

> *"Right. Anyone think anything different? I'm not saying Clare's wrong, but has anyone got any other ideas?"* Session 1 lines 105-6
>
> *"A drum with no base. Does anyone agree with that?" No hands are raised. "Are there any other ideas? I'm not saying it wasn't a good idea, it was a good idea, and it's ideas that we want."* (Session 4 lines 37-9)

Another suggestion of the slight unease with which Veronica held those ideas which were not scientifically correct was that, when the class's "ideas board" was moved from the classroom to be displayed in the school's entrance hall, some of "those rather odd" ideas were removed so they would not be seen by other children.

Veronica's implicit messages to the children were clearly understood by them, as evidenced by the lack of support for the drum with no base, by the children expressing a desire to have "got it right this time" and by being reluctant to commit their ideas to paper. However, she was genuinely interested in the children's ideas and her approach enabled the children to become involved in thinking about the topic in a manner which suggested a high degree of motivation on their part (fig. 8.5), as they continued discussing their ideas with each other after the session had finished.

fig. 8.5

> *"We've got lots of ideas here. Has it got you guessing? Has it made you think about things you haven't thought about before?"* T asks genuinely, but not in a way to whip them up into a frenzy. The children mutter, "Yes" and nod. When T stops speaking, the children continue talking animatedly to each other. (Session 1 lines 182-7)

To summarise, Veronica's behaviours in relation to finding out children's ideas were that children's ideas should be known in order that they could be replaced by the science view, an approach which is very similar to that modelled in the *NPS* Teachers' Guides.

5.2 Role 2: Reflecting on how children may have arrived at their existing ideas and how far they have progressed towards developing more scientific ideas

Veronica used the "key ideas" and supplementary concepts from NPS to formulate her learning objectives for the children and, from the way in which she questioned them, she had a very clear idea of the direction in which she intended the children's ideas to develop. She was thinking about the sequence in which to present the topic to the children. She was also aware of how her own understanding was being stretched, and was concerned about how difficult it could be to change a child's thinking by presenting them with contrary evidence. The fact that the children were having to think, though, was central to her understanding of the *NPS* approach (fig. 8.6).

fig. 8.6

> *This way of working is asking a lot more of the children. It's really making them think rather than just absorbing the information. It should give them a much better chance of understanding the science."* (Evaluation session 1 lines 67-9)

The children's ideas were still treated seriously, and Veronica tried to make sense of the ideas in order to help move the children on, as shown in fig. 8.7 in which she was able to establish the underlying reasons for a child's prediction.

fig. 8.7

> T: *"...Let's look at the jars of water. You found that the more water...?"*
> "It makes a lower sound"
> T: *"Someone didn't expect it, did you Vicky? What did you expect?"*
> "That more water would be higher"
> T: *"So is the lower note to do with more water or to do with the air?"*
> "Water" (Session 3 lines 272-83)

Veronica actively used her knowledge of individual children as part of her monitoring of scientific development. She altered the grouping of the children in order to make them conducive for the majority of the children. These groupings took into account "ability", personality and ideas. The notion of "ability" was clearly one which influenced the way Veronica deployed her time in the classroom, and also the nature of activities she planned, with the use of a far more inductive approach being evident for children Veronica considered to be of "low ability" (fig. 8.8), supporting findings of Hodson (1993).

fig. 8.8

> DW: Those children who were doing the extra vibration activities, you know the sort on the cymbals and things...What was it that wasn't there in their ideas that you identified that made you think they need that while the others are going to be investigating?
> *T: Well I just don't feel they had any concept of how a sound is created at all. They had no idea. They knew it was this noise, but they didn't know where it came from or what made it. It was questions like oh if you plucked a rubber band and you couldn't hear it, how would you know that it was making a sound? They were saying no, if you couldn't hear it it*

wasn't making a sound. So they had to know about this vibration thing because they didn't, and I mean even at the end it was that you couldn't hear it if you were deaf. So it is that sort of thinking that made me know. I mean, all the others had this idea of vibration, although they didn't really seem to know what it was, but these just hadn't a clue about anything, that group, and they needed that extra help so they could move on any further.
DW: Sort of guided observation in a way, wasn't it, to help them see that they had missed something..that was there.
T: *Yes. Well, the observations were missing, a lot of them, I don't even think they'd developed that skill. There was a lot missing from what they said. They had to do a lot, a lot of work on just that one thing to see it all sorts of different ways. I think what helped was when they did the work with the tuning fork and the paper and...and seeing the grains of salt on the cymbal. At last they were beginning to understand it, but they hadn't up till then. Whether it will stay in their heads is something else..*
(interview lines 264-93)

The presentation of the intervention activities was tailored for the groups of children for whom the activities were intended, Veronica making a conscious decision to leave them more open for those children she considered to be "more able". She was firmly of the view that "poor" children could not manage situations in which there was ambiguity (fig. 8.9).

fig. 8.9

"[ ] I think I would try at some point during that half term to give them something really open to work on. Except the very poor children, I wouldn't give them it because they wouldn't be able to do it, they just wouldn't. You know they'd be at just such a terrible loss, but with the average to more able, yes. But I think sometimes with these very poor children I don't know whether you can ever really give them something open: I don't think their thinking will ever allow for that, not really."
(Interview lines 256-63)

However, regardless of the degree of structure Veronica provided, she had a very clear idea about what the learning outcomes of each activity were to be, and how those of each group related to the others (fig. 8.10), thus reinforcing the notion of a guided discovery approach.

fig. 8.10

DW: To what extent do you think that your pre-planning affected the way that they answered the questions?
T: *Quite a lot, I think, because they were fairly, most of them were fairly closed questions. So I think quite a lot. I tried to keep things more open for the more able children, I think pretty well they were fairly closed*

> *questions. You know I could have said you know see what you can find out about sound. Full stop. So they were fairly well directed questions. But I certainly tried to gear them towards what the children had done before, how they had answered those original sheets, what their understanding appeared to be. It was quite, but I think it was a fairly closed thing and I did, I <u>knew</u> what I wanted them to get out of it at the end. I <u>knew</u> what I wanted them to discover at the end of the lesson. It wasn't that open, generally speaking you know fairly well what they'll do.* (Interview lines 221-233)

Veronica used her understanding of the intended learning outcomes of the sessions in order to guide the content of the class discussions. She endeavoured to ask only questions to which she knew the children's responses, from her interaction with them while they were investigating. She could therefore ensure that the discussion would, "help their understanding of what they have found out and .. cement their ideas" (interview lines 427-8). She felt that the pace through the topic was much slower than she would usually have, but that the *NPS* approach ensured the constant repetition of the main ideas, which meant Veronica could be pretty sure that the children had learnt those. Her views about the pace through the topic were shared by the children, some of whom appeared confused at being asked the same question twice, in different contexts, to check the generalisability of their understanding; others were boasting that they had completed all the worksheets, suggesting that their rate of working was not usually a determining factor in Veronica's teaching.

In summary, Veronica's reflection on the nature of the children's ideas was for the purpose of enabling her to differentiate the intervention activities to enable the children to learn the required concepts. Her session objectives were more explicit than anything suggested in the *NPS* Teachers' Guides, ensuring the sessions had a clear direction.

5.3 Role 3: Helping children develop process skills so that they test and apply their ideas scientifically

Veronica remarked after the initial session that *NPS* "certainly makes them do AT1!". This in turn made her realise how little the children understood of science processes. By asking questions to determine their understanding of fair testing and manipulation of variables, Veronica was able to guide children both in the interpretation of their findings and in how their investigations could be improved.

fig. 8.11

> A group is selected to describe their investigation. They described how one person had stood still while another had moved away while playing an instrument. This was repeated for the other three directions. They measured the distances with a trundle wheel.
> T: *"And you found big differences in how far away the sound could be heard."* The group nodded. *"Did you use the same person in the middle each time?"*
> The group said, "No".
> T: *"Is it a fair test that you've carried out then? Why?"*
> The group realised that they had changed the direction and changed the person at the same time.
> T: *"You were changing two variables. What would you do next time?"*
> "Use the same person in the middle for all of them"
> T: *"And if you use different people, you need to do the testing for each direction for each person. Any more?"* (Session 4 lines 173-190)

The questioning strategy shown in fig. 8.11 carried with it the attendant danger that the children may lose confidence in their science work as a result of being challenged. Veronica was always careful to make sure that children understood the constructive nature of her interaction with them (fig. 8.12).

fig. 8.12

> T went up to Charlotte, whose results T had challenged. *"All right now, Charlotte?"*
> "Yes. The thinner one could stretch more so it wasn't as tight. We found they both made the same noise on the smaller tin."
> T: *"Yes. You need to make sure the bands are the same size. You've had to do a lot of thinking this afternoon."*
> One girl from Charlotte's group became upset because she did not know what she had found out. T went to the cupboard and got out a tin and bands and helped her think about why what they found was different from other groups.
> T: *"You might not have had it so tight round the tin. What happens when you pull it tighter? (* Session 2 lines 250-7, 261-7)

During the initial elicitation, Veronica encouraged the children to think of ways in which they could test their ideas. However, she never asked them what their investigations would be. A similar pattern could be seen at the start of each session. Veronica gave groups of children the appropriate question which they were to investigate, and provided time and encouragement for the children to discuss and plan how they would test out their ideas. The children collected the resources they needed and began their testing, but my observations showed that, when Veronica talked with the group about their activity, even viable plans were modified to a greater or lesser extent so that the group ended up with a test which was in line with what she had pre-planned (fig. 8.13).

fig. 8.13

> I go to one group (Sarah, Jane and one other) and read through their sheet. They are to find out what affects the loudness of a sound. They say they do not understand what they are meant to be doing. I ask them whether they have decided to work with a drum or an elastic band. They decide to use an elastic band and a box. I ask them what they would do if I asked them to make a loud noise. They used their hands to mime pulling the band high up from the box and releasing it. When I asked about a quiet noise they mimed a very small plucking movement. I asked them to think about what would happen to the band in each case; why would one be loud and the other soft. I suggested they drew this in picture form before getting the band and testing it out...
>
> I looked across to Sarah's group. T was working with them and they were using a tambour and dropping things onto it.
>
> I looked across to the 3 groups who had been addressing the 4 questions about how the tension of the elastic band affected the sound. They all had elastic bands stretched over large plastic boxes with a ruler or stick under the band, perpendicular to it. By moving the stick up and down the children were able to change the pitch of the band, thus making a primitive stringed instrument. (Session 3, lines 22-29, 131-139)

These strategies suggest that Veronica has an affinity with personal constructivism, but that her teaching preference is for a guided discovery approach - or, more accurately, a directed discovery (fig. 8.14), and her actions mirror the similar neglect of children's ideas in the intervention section of the *NPS* Teachers' Guide. This behaviour has similarities with that described by Olson (1981) of teachers substituting high influence roles for the low influence roles intended in curriculum innovations, either because they do not know how to adopt those roles, or cannot justify them in terms of unchanged external expectations, e.g. end of key stage assessments and Standard Assessment Tasks.

fig. 8.14

> DW: Did you know what equipment, what precise investigation they were going to do in terms of what equipment they were going to use and how they were going to answer the question.
> T: *Pretty well, pretty well. I'd have to look back again really, but yes I think pretty well, you know I mean the stuff was there for them to take and really I suppose I knew which groups were going to use rubber bands, which groups were going to hit things. You know within a range, yes; I did know what they were going to use. I can't, I mean even to the extent of those who put water in the jars and everything I think really it was fairly closed what they were doing because I knew. Whether again, this isn't as closed now, but I think yes it was it was fairly closed and I knew.*
> DW: Would you envisage that being the approach that you would continue with or might that change?
> T: *Half and half. I think I would still, if I knew what I wanted them to learn, yes I would still use that approach some of the time.* (Interview lines 234-48)

Veronica attributed the way her planning had influenced what the children did (fig. 8.14) to the nature of the questions she gave them being closed rather than open. In fact the questions were open, but her interpretation of them was not. This degree of teacher control explains why certain groups of children appeared at times to be directionless, waiting to be told what they were to do, and why children acquiesced readily to any suggested alterations to their investigation, as in fig. 8.15.

fig. 8.15

> A group of three girls who I had not talked to at all before had made themselves a beater by wrapping paper around the end of a pencil and sticking it together with sellotape. They were using the beater to hit a 'drum' made of a plastic basin covered with paper in order to find out whether the material that the drum head is made of affects the volume of sound the drum makes. They were trying to pull the paper tight so that they would get a decent drum sound. I asked if they could think of anything which might make it easier to get a sound from the drum, thinking back to investigations children had done the week before. The girls exchanged looks but said nothing, so I suggested using a plastic bag instead of the paper, and stretching it really tight like T had done the week before using the waste paper basket. The girls exchanged exclamations of recall and two of them ran off to get a plastic bag. They stretched a bag over the basin and were able to make a reverberating sound. I suggested that, as they had had such difficulty with making a drum sound using paper, they changed their investigation a bit and looked at whether it made a difference what a drum beater is made of rather than what the drum head is made of. They acquiesced straight away. I asked them to predict what they thought would be the results. They said that they thought a proper felt drum stick would make the loudest noise because it had been made specially to hit drums. I told

> them that a proper drum player would have a wide collection of sticks each of which made different sounds. One of the girls then said that the harder the drum stick the louder the sound it would make. They set out to try and test that prediction. (Session 3, lines 107-129)

Veronica did provide the children with information sheets to help them with their planning, but it appeared that the children did not use them, except to help them structure their written report. In the final interview, Veronica felt that her Sc1 objectives were not specific enough, and that she needed to focus more on the development of particular skills in sessions, evidence that she was aware that a tighter skills structure was necessary. It would be interesting to see whether that structure provided more independence for the children's planning, or whether Veronica's level of content knowledge was the deciding factor, as found by Harlen (1996) and Osborne and Simon (1996).

Veronica was very keen for the children to interact with the other members of their groups when they were discussing ideas or planning and carrying out investigations. She commented to the class several times about there "not [being] much discussing going on". However, the children in a group were often sitting in a straight line, making discussion between them difficult. The physical arrangement of the children was an aspect which Veronica appeared not to consider.

To summarise, Veronica replaced children's plans with blueprint investigations which she had already tried out, a position which gives similar regard to the children's ideas as does the *NPS* Teachers' Guide. Once the children were performing the required investigation, she was rigorous in demanding control of variables in order to ensure fair testing.

5.4. Role 4: Providing opportunities to test or challenge ideas, perhaps leading to changes

Veronica considered her role to be very different from what it was before (fig. 8.16) though her perceptions here were at odds with my observations:

fig. 8.16

> *"My role is much more active. Much more, no, not active it is less didactic. It is much more of an intervention role with the children, trying to modify individual ideas, trying to, rather than impose something on them as a class"* (Interview lines 655-7)

Veronica's interventions had two main strands. Firstly, as described and exemplified in the previous two sections, she presented groups of children with activities which were based on the ideas they had expressed and which she considered to be appropriate to the children's "abilities". Secondly, these group activities were followed by a class discussion which lasted about half an hour.

Veronica initiated the intervention activities for the groups of children by producing either worksheets or workcards which conveyed the nature of their activity through one or more questions which came from the NPS Teachers' Guide. The structure and presentation of the sheets varied from week to week as Veronica tried out different formats for the children. These sheets were differentiated in the degree of structure related to Sc1, but the underlying concepts were the same so that the class were working on a coherent set of activities. The least structured activities involved application of principles to a new context, to help the children generalise their understanding. "Investigations" invited children to answer an open question which related to the previous week's ideas. A series of investigations was developed so that children who needed more support were given structured tasks to feed into an investigation. More structured tasks were presented as "experiments" and consisted of a list of instructions for children to carry out before hypothesising about what they had observed. Veronica commented that it was important to match the level of the question to the ability of the child, and evidence of her so doing is found in fig. 8.17 overleaf in which the questions asking for anything other than recall were directed elsewhere. This strategy was consistent with her notion of inductivist approaches being more suitable for children of lower levels of achievement.

Most of these activities were set in the context of exploring either elastic bands around margarine tubs or a drum, the contexts which were suggested by *NPS* for the elicitation activities. There were explicit references to the previous week's activities, to cue the children to the ideas which they were exploring. Interestingly, though, despite Veronica's intentions that the children test their ideas, the children did not refer to their ideas as they worked but focused on carrying out a test. They did not appear to have any ownership of the development of their own understanding. Further evidence to support this inference was that the children recorded their science activities very formally under the heading, "An experiment to find out...", suggesting there was one right answer to which they were aspiring. Other activities were designed to present children with evidence they had so far not noticed, to enable them to be challenged into rethinking their ideas. Generalisations and links to everyday contexts were made by Veronica in her class discussions rather than by encouraging children to explore wider perspectives themselves.

Class discussion was an extremely important part of Veronica's intervention strategy. She was very pleased with the way in which the discussions went, and saw them as having several functions. Firstly, they enabled the different groups to hear what each other had done and found out; secondly, they helped individual children to consolidate what they had found out and "cement their ideas"; and thirdly, "they can't mess about during the lesson because it will be picked up and everybody else is going to know that they haven't had anything to offer. Again, it keeps them on target to an extent during the lesson" (Interview lines 420-2), suggesting that the lesson script had not, in fact, changed with the introduction of *NPS*. Veronica allowed plenty of time for her discussions, preferring to fill in any remaining time with a related writing / drawing task than to be unable to cover the material she intended to. The discussions usually had a very clear sequence to them, and the intended learning outcomes were evident to me as an observer. Veronica maintained she did no detailed planning for these discussions, doing them "off the top of my head".

However, because of the degree of planning evident in the sessions as a whole, she must have had a very clear idea of the material she wanted to cover. Her questioning was well focused, with a mixture of open and closed questions. Questions which might have been expected to be open were asked as recall questions when the subject matter had been addressed in earlier sessions, implying that the children should already have learnt that. The questions highlighted in bold in fig. 8.17 are of this type and the children's reactions in terms of all raising their hands show that the children understood the rules behind the exchange.

fig. 8.17

> T: *"Let's see what each group has found out this afternoon. We'll start with the first group. What was the first thing you did?"*
> "We put salt on the cymbal"
> T: *"You put salt on the cymbal. Then what?"* Right from the start, T speaks rapidly and responds very fast to the children's replies.
> "We hit it."
> T: *"Did it make a noise?"*
> "Yes."
> T: *"What did the salt do?"*
> "It jumped up"
> T: *"When did it stop?"*
> "When the noise stopped."
> T: *"Can anyone tell us why?"* T addresses the whole class, then refocuses the request to the group who have done the demonstration, *"You tell us."*
> "It's vibration"
> T: ***"What's vibration?"*** T looks to the whole class and hands are raised straight in the air. One person is selected to answer.
> "Wobble"
> T: ***"Is it slow or fast?"*** Again, hands are raised and one is chosen.
> "Fast"
> T: ***"Can you make a sound without vibration?"***
> "No"
> T: *"Then what did you do?"*
> "We used a tuning fork."
> T: *"Show us what you did."* A tuning fork is hit against the table then held against a piece of paper, which makes a buzzing sound. This is repeated with 2 different sizes of tuning fork, the smaller of which makes a higher sound. *"What's happening to the tuning fork on the paper?"*
> "It's vibrating"
> T: ***"Vibrating?"*** All arms are raised straight.
> "Wobbling very quickly" (Session 3 lines 178-230)

Occasionally, when Veronica had not worked with a particular group and so did not know the content of their investigation, the discussions were used to challenge children's findings, in a manner reminiscent of the challenging of ideas mentioned earlier. Again, Veronica realised she had led the children to disagree by her wording, and she tried to retrieve the situation by asking for reasons (fig. 8.18).

fig. 8.18

> *"Who agrees with what they've just said?"* About six hands are raised. *"Who disagrees?"* Everyone else raises their hands. *"You need to do more if you're going to disagree, you need to say why."* No hands are raised to suggest a reason. *"We're not saying you're wrong, we don't know."* (Session 3 lines 305-8)

She then tried to work out from first principles whether the group was right (fig. 8.19), and she concluded they were - though she did not acknowledge this to the children. Here was evidence of Veronica's precarious content knowledge, and the dangers for both herself and the children of pursuing an investigation other than the one she had planned.

fig. 8.19

> T strikes a tuning fork on the desk and holds it to her ear. No-one else can hear the sound it makes. T makes a point about the sound going through the air. T then strikes the tuning fork again and this time places the base of it on the desk. Immediately the fork is in contact with the desk a clear note can be heard. T asks for explanations about why this happens.
> James asserts that, when the fork is on the desk the vibrations come off the desk and into the air. This makes a noise better because there is more surface for the sound to come off.
> "*Are there any instruments which are similar to this?*"
> "A drum?"
> "*We've looked at all different instruments: guitar, violin, mandolin, viola. What did they all have the same?*"
> "A hollow"
> "*What is the hollow doing?......When I put the tuning fork on the desk, what is happening? Feel the desk*" The child who was sitting at the desk could feel the vibrations. "*The whole instrument vibrates.*" T goes and picks up a fluorescent pink, plastic 'slinky' from her desk. "*Do you remember this?...*" (Session 3, lines 306-327)

Veronica also made inaccurate and inappropriate use of analogy in the same discussion (fig. 8.20). She demonstrated 'sound waves' with a slinky by "shaking it gently from side to side", producing a swaying motion rather than a compression and rarefaction. This misinterpretation of the background science in the Teachers' Guide was compounded by the fact that this demonstration came immediately prior to Veronica eliciting the children's ideas about sound travelling, thereby telling them that sound does travel, and giving them an indication of a possible way of representing it.

fig. 8.20

> The slinky is stretched out between the two children, a distance of about 3 metres. *"Go on, Robert, make a vibration".* Robert stands holding the slinky without moving. T whispers to him, *"Shake it gently from side to side".* T guides his hands backwards and forwards in a swaying motion. *"What's happening?......What's it like?"*
> "A wave"
> *"Like a wave. Do you think that's how sound might be passed? What I'd like you to do now, is to get some paper and a pen. Ben, twang the rubber band!"* Ben has an elastic band round a box from his investigation. He twangs it and it is just audible at the far side of the room. *"Do it again. Put your hand up if you can hear the band. Now I want you to draw a picture of how you can hear the band if it's over there, and you're over here."* (Session 3 lines 335-48)

Children's everyday experiences of sound were used to help Veronica explain the principles she wanted the children to develop (fig. 8.21).

fig. 8.21

> T: *"Who plays a violin or a guitar?"* Children raise their hands. *"What happens when you tighten a string, does it go higher or lower?"*
> Someone said higher.
> T: *"Are they all the same thickness?"*
> "There are 4 strings, and one of them is thicker. The thinner ones are higher".
> "They make a quieter noise when they are loose".
> (Session 2 lines 151-61)

During the teaching sessions, it was clear that Veronica's attitude was that there were right and wrong answers, and that the right answers were to be striven for at all costs. However, in conversation, Veronica talked about the centrality of letting children try out their own ideas, and the implications of this for planning, suggesting another tension between her established teaching style and her views of the way *NPS* was to be used (fig. 8.22).

fig. 8.22

> *"Using Nuffield you have to let the children have their head more - well, I don't know if you should, but I certainly do. And that means coming to terms with the fact that you can't plan everything down to the last letter."*
> (Evaluation session 4, lines 14-6)

To summarise, both the intervention activities and the discussion involved Veronica in questioning the children, the purpose of which Veronica saw as to "make <u>sure</u> they understand it", rather than to find out what it was they <u>did</u> understand, and to help them to develop their understanding from that point. The activities which the children conducted were similarly teacher-controlled to ensure the required learning, and were in line with the activities modelled in the Teachers' Guides.

<u>5.5 Role 5: Assessing the extent of any change in ideas and in process skills which may have resulted</u>

Veronica used a variety of techniques to collect information about children's understanding at the end of sessions and the end of the topic. In fact, the continual emphasis on assessment was the most prominent feature of *NPS* in her perceptions of impact on her practice (fig. 8.23).

fig. 8.23

> *"I think it's wonderful; so much better than what we had before. And it helps me with knowing where to go on, and it helps me <u>tremendously</u> with assessment. .... I haven't got to think, 'Oh, I must assess. Because of the approach you're assessing them all the time"*
> (Evaluation session 1 lines 71-4)

Veronica questioned the children all the time for the purpose of finding out whether they had learnt the concepts in which she was interested. An examination of the terminology used by Veronica in relation to the teaching and learning supports this interpretation: she was "delighted with what the children had <u>grasped</u>"; there was "one thing I hadn't <u>taught</u> well" (my underlining).

There was an interesting transposition of summative and formative assessment evident since Veronica used the end of lesson discussions, which might have been expected to be formative in their nature, in a very structured, closed way to check that the children had learnt the required material from that session. However, she decided it was important to allow the children to select the words for the final concept map "to make them feel it was their own, not some sort of test or something I had imposed on them", despite the necessity for objectivity in the final, summative assessment of the topic. This decision allowed her to check the children's understanding of appropriate scientific vocabulary, but it meant that the children were not working with the most coherent set of words, which will have contributed to Veronica and the children finding the concept map difficult to manage. Because of her limited success with that technique, Veronica eventually resorted to a more structured format, similar to the sheet she used for the initial elicitation, requiring the children to write and draw. This format did not enable the children to have any ownership of the test, the original reason given for the strategies she employed when introducing the concept map. However, ownership no longer appeared to be an issue, suggesting that the testing of vocabulary was the implicit reason behind the student-led selection of words. Her tone of voice in response to words she either did or did not expect to hear corroborates this interpretation.

In summary, Veronica used assessment, even the initial elicitation of children's ideas, to check the extent to which the children had learnt the necessary concepts, the approach to assessment which is evident in the *NPS* Teachers' Guides.

6. An Analysis of Veronica's Questioning during the Topic of 'Sound'

An analysis of the questions which Veronica asked during the concluding discussions, using the framework described in chapter 7 (Watt, 1996), revealed an interesting pattern over the course of the science sessions. At the beginning of the topic just over one third of her questions could be categorised within the 'social' dimension with the other two thirds being 'cognitive'. These relative proportions changed weekly until, by the final session, more than nine tenths of the questions were 'cognitive' in nature. This pattern suggests that, initially, Veronica was asking the children for their ideas, and basing the discussion upon their answers. As each session progressed she referred less to the children's ideas and more to the key scientific ideas, using questions to ensure children had made appropriate observations and were making the required sense of the investigations to develop their understanding.

Table 8.1 Analysis of Veronica's questioning by type of questioning behaviour

Type of questioning behaviour	Session 1		Session 2		Session 3		Session 4		Session 6	
Social 1	8	20%	1	3%	2	6%	1	4%	0	0%
Social 2	7	18%	11	28%	3	9%	1	4%	1	4%
Cognitive 1	16	40%	16	41%	23	70%	15	63%	25	93%
Cognitive 2	9	23%	11	28%	5	15%	7	29%	1	4%

Looking at table 8.1, it is interesting to note that level 1 social aspects of questioning, aspects such as showing interest in any answer both verbally and non-verbally, decreased very rapidly after the initial elicitation, showing that children's ideas were only valued initially. Level 2 social aspects of questioning decreased less rapidly. Aspects such as encouraging maximum participation in discussion and encouraging children to respond to each others' views remained a useful strategy in helping children to assess the accuracy of their observations and results, or in helping the teacher to emphasise a particular viewpoint. Cognitive level 1 questions are extremely useful in ensuring that the children can support what they are saying with evidence, whether it is based on their own ideas or the scientific view. Twice as many questions were linked with checking that observations had been made rather than seeking hypotheses. The falling off in the higher level of cognitive questioning is interesting and suggests that, in line with the checking of relevant observations, Veronica was not trying to probe more deeply to extend children's own understanding. Rather, she was concerned to reinforce the scientific view and check that children could substantiate it, which would not require higher order thinking.

7. Inferences about Teaching and Learning Drawn from Observations in Veronica's Classroom

From observing Veronica and the children in her class there are features of her practice from which it is possible to infer various personal theories of science teaching, and features of the children's behaviour which shed light on their implicit theories of what it is to be a science learner. A comparison of these should make it possible to identify similarities and differences between what is going on in Veronica's classroom and what one might expect to see in a classroom in which personal constructivism is being practised.

7.1 Veronica's personal theories of science teaching, actual and espoused

Observations of Veronica suggest that she considered the teacher to control the children's learning, by structuring their learning experiences and consolidating their understanding at the end of the session. The terminology cited in section 5 supports this view, as does her focus on the scientific viewpoint as the aim of teaching. There is some evidence, particularly in relation to the lower achieving children, that scientific phenomena must be amenable to observation, leading to an inductivist view of science. Currently held ideas should be elicited but are provisional, and should be challenged and changed as soon as possible. Veronica prioritised children's understanding and was of the opinion that, if children had to think, they were more likely to understand the science, and that they would learn better when they were motivated. This motivation appeared to be linked with children being "active and busy", although she stated clearly how science processes were linked to learning. This view of science teaching requires teachers to have an understanding of science in order to know which questions to ask, and to be able to give explanations and structure discussions.

In contrast to her observed practice, Veronica espoused a much greater involvement of the children's ideas in the teaching process, both at the elicitation stage and during the intervention, particularly in relation to children's planning of investigations to test their ideas. She said her topic planning would now have to be more flexible, dependent on the children's ideas. This increased flexibility would only be necessary were her old-style planning by activity rather than by learning objective. At the beginning of the topic Veronica would have been able to - and in fact did - plan learning objectives in terms of the key ideas to be covered. Only the allocation of ideas to activities would need to come later, after the elicitation had revealed any particular learning needs.

Veronica considered her new practice in science to be different from her approach to teaching in other curriculum areas, though they had recently begun to precede mathematics topics with an assessment, and she set group problem solving tasks in other areas. Her opinion was that the difference in approaches between subjects would not affect the children because they would learn that school science learning had a particular form for each subject (fig. 8.24), a view supported by Shulman (1986).

fig. 8.24

> T:*..I feel science is so different to anything else in that there's this understanding of concepts which isn't quite the same in other areas of the curriculum.*
> ...
> DW: Do you think they [the children] notice that there is a difference?
> T: *Well they just think of it as a subject that you do in a different way. I don't honestly know that they notice that there is a different approach. It is just the way you do science..."* (Interview lines 699-701; 713-716)

In terms of constructivist views of teaching and learning, Veronica's espoused practice bore some relationship to the personal constructivism of "the SPACE approach as espoused". However, her actual practice appeared to involve using elicitation of ideas as a baseline assessment for the topic, so that she knew where to target her teaching for the children to learn the required concepts. Her practical activities, which I have described earlier as 'directed discovery' on account of her tenuous grasp of scientific knowledge, could more accurately be described as the unacknowledged use of illustrative activities, since there was one right answer which the children were to achieve. Thus, the practice I observed bore little relationship to any form of constructivism. It could be considered to be closer to a sociocultural standpoint, but the teaching would all need to be as explicit as the concluding discussions for that to be the case. A socio-cultural explanation would account for the changing pattern of types of questioning behaviours during the topic, with later sessions containing far fewer questions associated with valuing the children's ideas and far more associated with checking observations and the ability to explain statements.

Referring back to Wolfe's typologies of teacher attitudes to science, as described in chapter 2, Veronica's practice is consistent with the "formalist" style, though her espoused practice, which she incorporated in parts, had some "rationalist" elements to it, specifically "challenging pupils to predict, explain and justify their use of evidence". Her tightly controlled introduction of rationalist approaches with relative ease is consonant with Smith and Neale's (1991) finding that it is formalist teachers who are more likely to make a successful transition to rationalist approaches because of their familiarity with setting objectives.

7.2 Children's implicit understanding of science teaching - inferred from observations

From my observations, the children had clearly understood Veronica's approach to teaching science to be formalist prior to her purchasing NPS. Consequently, the children conformed to all the behaviour patterns which Rudduck (1980), Edwards and Mercer (1985) and White (1988) suggest are found in classrooms where the power balance is clearly in favour of the teacher. They knew that the teacher was usually the source of knowledge, and that the teacher had the one right answer. Therefore, the children sought approval for their ideas; those who were asked to expand on their answers hoped they had "got it right this time"; some children asked to be told the answer "so they are right" and all straight away acquiesced to quite major changes in their investigations at Veronica's 'suggestion'.

Since purchasing *NPS*, only the last of these behaviours was still consistent with Veronica's practice, though the children were either unaware of this, or unable or unwilling to adjust to the initial acceptance of their own ideas. Similarly, the children did not heed Veronica's instruction to produce quick drawings which were not necessarily neat, which suggested that all school work, even on scraps of paper, was a final product to be judged. Their lack of metacognitive awareness, i.e. understanding of how they learn, resulted in children not referring to their ideas when they were asked to test them, suggesting that science was considered to be about doing an experiment rather than developing their understanding, and their approach to setting out science work very formally as: "an experiment to find out..." further confirmed their expectation that science has one right answer. A similar confusion was introduced by being asked the same question in two contexts, suggesting that the development of understanding was not a familiar idea to them, and that Veronica's established delivery 'script' did not allow enough time to do what the children perceived as the same work twice - nor for all children to complete the worksheets.

7.3 Unspoken issues in relation to the introduction of *NPS*

These observations suggest that Veronica instituted *NPS* without considering the effect it might have on the children who already had a clear understanding of the rules of learning in science. It is already possible to see, as Rudduck (1980) found, that the children were able to reduce Veronica's effective use of *NPS* by continuing to work according to former expectations of presentation which consistently increased the amount of time spent on elicitation at the expense of intervention. The resultant "SPACE approach" was therefore unlikely to be what Veronica had anticipated, and this was reflected in some of her evaluative comments. However, other comments (e.g. fig. 8.24) suggest that her awareness of the issues surrounding the negotiation of changes with the class is not well developed. It is worth noting that the SCH mentions that children may have an initial reluctance to volunteer their ideas, but does not develop that theme any further. A presentation of the sociological perspective would help give teachers important insights into their practice and its efficacy.

Following my final interview with Veronica, at which I raised questions about the children's understanding of learning in science, she appeared to have thought about the issues I raised because a few days later I received a package containing the children's thoughts about the new way of doing science. Each child had written their views on an A5 piece of paper. As they concorded very closely with what Veronica had told me the children would say, I am rather suspicious of the status of the ideas and suspect they were written following a class discussion as every child was positive in their opinion. Nevertheless, the children's views were interesting and a range (though limited) of opinions was expressed, as shown in table 8.2, below.

Table 8.2 Children's opinions about *NPS* (n=27)

I can understand science better	16
I like doing my own experiments	13
It's more fun, less boring	13
I like my ideas being important	7
I like discussing with my group/class	5
Doing experiments is better than watching	4

Interestingly, nearly two thirds of the class considered they could understand science better using this approach, which is consistent with Veronica's own impressions.

Veronica considered her summative assessment to reveal not only a much greater degree of learning in the children, but also a narrower range of attainment than she expected at the end of a science topic, with most children learning more than she predicted. She was reluctant to attribute these improvements to *NPS* because she had not conducted a fair test. However, she felt the children were more involved and motivated because they were instigating their own learning and that that was a more efficient approach to teaching science. She is so pleased with the outcomes that she is not intending to experiment with any other different approaches but to develop her use of this one.

As I have just shown, there are quite large discrepancies between Veronica's teaching and the role espoused in the SCH which might be expected, given that the SCH did not arrive with the rest of the scheme and was therefore not available for her perusal. These differences were particularly marked in terms of the degree to which children's ideas were accepted, valued and used as the basis for child-directed intervention activities, though she espoused similar ideas about children's ownership of learning to those contained in the SCH. Interestingly, though, her classroom performance matched closely the practice advocated on the activity pages of the Teachers' Guide. Neither she nor the Guide emphasised developing children's existing ideas - the children's ideas were things to be challenged and replaced with the scientists' views. Her questioning was obviously based upon that in the Teachers' Guide, and even when the wording was different there was a preponderance of questions encouraging children to make relevant observations rather than to explore their own ideas, a pattern also found in the Teachers' Guide. However, she used the key ideas and background science in a prominent way so that each session had very clear learning objectives. Therefore her practice was more structured than a guided discovery approach would have been.

From the perspective of observer, the children in Veronica's class were certainly being taught science in a way which enabled them to give the required answers. Whether this learning was due to "the SPACE approach in action" or simply to Veronica having very clear learning objectives and placing great emphasis on: *"constantly reinforcing, assessing, questioning and I just haven't been aware of that before this term"* will need to be the subject of further research. As approaches allied to guided discovery have been discussed as being over-reliant on observation, leading to little learning and providing an unrealistic model of science (Hodson, 1993), then the latter seems more likely.

8. Summary

I decided to collect detailed case study data from one teacher through semi-structured interview and participant observation in order to explore how *NPS* was used in the classroom. The data revealed that the teacher was using an approach which was very similar to that modelled in the *NPS* Teachers' Guide for 'sound', including the questions she asked. It was possible to infer from observations that the established unspoken rules regarding classroom learning of science were symptomatic of there being one right answer of which the teacher was in control. Veronica was changing many of these rules to suit the *NPS* approach, but without involving the children in negotiation or discussion about how the classroom processes would be different, and consequently the children did not alter their patterns of behaviour. Despite the children neutralising some of Veronica's actions, both parties expressed similar perceptions of the beneficial effects of the *NPS* approach. It is not possible to determine whether the improvements in understanding which occurred were due to the particular teaching approach, which owed little to personal constructivism, or to a focus on the reinforcement of key concepts and clear learning objectives.

This detailed exploration of the changing practice of one teacher provides insights into primary science teaching which can be broadened by comparing aspects of her practice with that of one SPACE teacher. This comparison is undertaken in chapter 9, resulting in more detailed analysis of the social dimension of teaching and learning.

CHAPTER 9

COMPARING SPACE AND NUFFIELD PRIMARY SCIENCE

In chapter 7 I focused on the development of teacher practice over the course of SPACE, using illustrations from what we considered to be "good constructivist practice". That chapter was written very much from the perspective of the SPACE researcher where constructivism was the view of learning we were seeking to promote. The issue of successful classroom practice, i.e. practice that leads to children learning science, has not been clearly addressed in relation to SPACE. That is my intention in this chapter, in which I compare Veronica with one of the SPACE teachers. Given that I am looking at only two teachers, my conclusions must be of limited generalisability, but the analysis helps to illuminate two issues: firstly, I suggest reasons for the differences between the NPS Science Co-ordinators' Handbook and the Teachers' Guides , described in chapter 7; secondly, I address the question, raised at the end of chapter 8, about whether Veronica's success was due to "the SPACE approach" or to other factors. I relate both of these issues to distinctions between the social and cognitive dimensions of teacher behaviour.

1. Teaching according to SPACE and *NPS*

I have compared the practice of Veronica with one of the SPACE teachers, "Susan". The similarities and differences which I identified shed light on what seem to be features of effective practice in the learning and teaching of primary science.

1.1. Teacher profiles

At the time of the research, Veronica and Susan had similar profiles. They each taught in a small primary school which had a largely suburban intake of children and was affiliated to a church. They were each science co-ordinator for their school, had been teaching for over twenty years and were considered to be effective primary science practitioners. At the time of data collection, Veronica was teaching a class of 32 9-10 year old children and Susan was teaching 31 7-9 year olds. Coincidentally, both teachers were working on the topic of 'sound'.

As well as these similarities there were important differences between the teachers. Susan was a collaborating teacher in the Primary SPACE Project, while Veronica was just beginning to implement the *NPS* materials. Because of these different contexts the times of data collection were different, with Susan being involved from November 1987 to May 1988 (pre-National Curriculum), and Veronica from January to March 1996 (revised National Curriculum). These two contexts meant that the teachers had very different experiences of personal constructivism: Susan was new to the philosophy and developed her understanding through the teacher development which was part of SPACE. Veronica attended science co-ordinators' INSET sessions with her LEA advisory teacher and was introduced to various constructivist classroom techniques before she decided to purchase the *NPS* materials.

1.2 Comparisons of teacher practice

I have compared the two teachers using the framework described in chapter 7 (Watt, 1996; Appendix 19) which enables both the cognitive and social aspects of their practice to be analysed at two levels of competence. I am using this framework because it makes differences between teaching approaches very clear. If I used the five aspects of the *NPS* teacher's role, I would still need a way of describing the differences between the teachers, which are likely to be in terms of a greater emphasis on either the cognitive or social dimension of teaching. I support my analysis with examples of interaction between children and teachers. Rather than replicate examples from the previous chapter, I refer back to them.

Social aspects of teacher language

Level 1: general management of discussion

Veronica encouraged children to contribute ideas by having a positive intonation and stating generally that she wanted to hear their ideas whether they were right or wrong. As described in chapter 8, table 8.1, her questions became progressively more closed after the initial elicitation and her verbal responses unintentionally made it clear which answers were acceptable. Each time she realised what she had said she attempted to retrieve the situation, but the children understood her code (figs. 8.4; 8.18).

Susan, on the other hand, encouraged children with particular wording, and by allowing children time to consider their answer. She signalled children's ownership of ideas in her questions ("What do you think...?") and responses ("That's an interesting idea") throughout the topic, not just during the elicitation (fig. 9.1). Her intonation subtly signalled her opinion of the children's ideas, but she repeated each question until she had heard everyone's views and responded similarly to every answer.

fig. 9.1

> *S: "That's an interesting thought. What does Belinda think?"*
> ch: "You need to be silent if you're going to listen to things, like if you're very loud then you need to be real quiet"
> *S: "That's an interesting thought, isn't it? That's a very good idea. What about Emma? Have you got any thoughts on how this can alter the sound?"* (tape AA, lines 117-121)

Level 2: enabling greater participation in discussion

During Veronica's class discussions the children responded individually to her questions. This strategy enabled Veronica to match question difficulty to the child she intended to answer, something she did consciously to enable "the poor ones" to participate. Children were only invited to comment on each other's ideas when Veronica wanted to reinforce the science view.

Susan, though, deliberately sought the views of the whole class, and her acceptance of each idea enabled the children to build on what each other said. Fig. 9.2 is an example of a child applying other children's ideas in a new context. She made a conscious decision to organise class or group discussions as opposed to one-to-one dialogues during the intervention so that children could "bounce ideas off one another and move each other on".

fig. 9.2

> "The box with the elastic band is sort of like a guitar - hollow in the inside and, like James said, it bounces in and hits everywhere and it spreads out - like when Jason said you drop a stone and it went all out in circles like that, it spreads all out in circles like that, but not in water - in sort of air." (Tape AB lines 269-272)

In terms of the social dimension of teacher language, Susan is using higher order strategies to give children ownership of their development and learning in a way Veronica is not. Veronica is controlling the classroom learning while Susan is encouraging the children to take more responsibility themselves. Whether the children are able to accept this responsibility is discussed in section 2.2.

Cognitive aspects of teacher language

Level 1: maintaining logical continuity in discussion

Throughout the topic, Veronica had a clear idea of her objectives for each session. She posed questions to introduce the intervention activities with the intention of moving children towards the accepted science view. During discussion she asked children for hypotheses but, after the initial elicitation, her questions largely demanded deduction or recall. She took answers from a range of children until she heard the answer which agreed with the scientists' view then she moved on. Veronica focused on the children's observations, early in the topic prompting children to notice or recall relevant evidence, and later checking that observations had been made (fig. 8.17).

Though she had a good understanding of the science topic, Susan seemed to have no clear objectives for her discussions beyond finding out the children's ideas, even during the concluding discussion for the topic. She had a number of key questions planned but, unlike Veronica, she did not stop asking for contributions and move to the next question once she had received the desired 'scientific' answer (fig. 9.3). There was no focus on children's observations. By accepting virtually all of the children's responses, she achieved repetition rather than continuity within the discussion.

fig. 9.3

> S: *Now how does that sound travel from there to you so that you can hear it? Has anybody got any ideas on that. Edward?*
> ch: Sort of like air blows it everywhere
> S: You think the air blows it everywhere. Very interesting Edward. What would Mark say?
> ch: It sends sound waves all round the room so we can all hear it.
> S: You think there are sound waves travelling all round the room from my desk to you so that you can hear it. That's nice. Nigel, what would you like to say?
> ch: The wind's blowing the sound to you.
> S: The wind is blowing the sound from here to you. Can I just ask you Nigel, is there a wind in the classroom?
> ch: No. It's coming from outside.
> S: All right, I see. Now what would Jason say?
> (tape AB lines 3-16)

<u>Level 2: monitoring the development of ideas in discussion</u>

Veronica really listened to the answers children gave her throughout the topic. She always challenged ideas which were not scientific, even at the elicitation stage, although the nature of the challenge changed from provoking thought (fig. 8.3) to asking other children for contradictory evidence as the weeks progressed. She also challenged the children's use of science processes where their investigations showed inadequate understanding of fair testing (fig. 8.11).

Susan also listened to children's ideas though she did not use these as the starting point for challenge or further probing. She never extended a child's hypothesis by asking for reasons why something happened (fig.

9.4), only seeking to clarify their meaning. In an interview she expressed disappointment that the children had not taken the step of hypothesising themselves. She kept referring back to a child's idea which was 'scientific' and asking the children to apply the idea in other contexts, something they were unable to do as they were not building on any foundation from either earlier discussions or their own ideas (fig. 9.5). She too challenged the children's use of science process skills.

fig. 9.4

> S: *..Yes, another interesting thought. What about Erica?*
> ch: Loud sounds kind of camouflage all the other sounds.
> S: *I see. Loud sounds camouflage other sounds. Now that's an interesting word she's used. Camouflage. What do you really mean by that, Erica?*
> ch: Like a kind of snake in the grass disappearing.
> S: *So, a loud noise will make smaller noises disappear, is that what you're saying? That's a good, an interesting thought. Clare?* (tape AA lines 128-133)

fig. 9.5

> S: *..Now what would Jason say?*
> ch: When you throw a stone into water, little waves come out and the stone, and then the water carries the waves and it's like if you hit something with something else, it's like hitting the water and the waves, and the air acts as the water, and the waves just are carried by the air to your ears so you can hear it.
> S: *That is a superb explanation. I hope you all heard that very clear, children. Jason thinks that sound is like when you drop a stone in the water, and you all know what happens when you drop a stone in the water.*
> *....(1 exchange)....*
> ch: All waves coming out of it. Sort of circling; big circles coming.
> S: *Right, so Simon says you see waves coming away from where the stone dropped in the water, and Jason said that the sound waves are like that. Now then, somebody said about the air. How do you think the sound travels through the air? Paul?*
> ch: It echoes.
> S: *You think the sound echoes. I see. I think Jason gave us a clue, didn't he, when he gave us that very nice explanation. Steven, what do you think?*
> *....(4 exchanges)....*
> S: *I wonder if we can go back to Jason. Yes, Jason?*
> ch: If it hadn't no air, um we couldn't live without air, then you couldn't hear anything 'cos there'd be no air to carry the sound waves.

> *S: Right, Jason thinks we need air to carry the sound waves. That sounds very nice. Can anybody guess or say what sound waves look like if you could see them. What do you think they might look like? Joanne?* (tape AB lines 16-23, 26-33, 44-49)

In terms of the cognitive dimension of teaching, Veronica is ensuring that ideas are developed in a way that Susan is not. As I commented in chapter 8 in relation to table 8.1, Veronica tends not to use higher order cognitive strategies because these are incompatible with the degree of control she is exerting. Susan's discussions do not have evident logical continuity as, even at the end of the topic, she does no more than draw attention to the science view when a child mentions it. In relation to children's ownership of learning, there is the same pattern as in the social dimension, with Veronica controlling the learning and Susan handing control over to the children who do not seem to be accepting it.

2. Analysis of similarities and differences between the teachers

Veronica's and Susan's classroom performances are clearly very different. If the strategies of the two teachers are each summed up in a word, Veronica's is *challenging* while Susan's is *accepting.* Thus, Veronica uses the children's ideas as a springboard for helping children to consider a more scientific perspective, while Susan helps children to verify their existing understanding through investigation.

The National Curriculum provides all the statements of science knowledge against which Veronica carries out her summative assessment and was not in existence when the data were collected from Susan. This will have had an unquantifiable effect in providing Veronica with an impetus for ensuring that children make progress towards the science they are required to know or understand. However, Veronica's description of her former practice suggests that her knowledge-focused approach pre-dates the National Curriculum requirements, and there is no way of knowing how Susan's teaching would be affected by its implementation.

Using the four categories of social and cognitive teaching behaviours, I have clarified the different patterns for each of the two teachers. These differences revolve around whether it is the child or the teacher who controls the classroom learning. Looking more broadly than the four categories, there are also similarities in Veronica's and Susan's experiences, which again relate to the social dimension. I explore these similarities and differences in the next two sub-sections.

2.1 Differences between teachers: control and ownership of learning

Susan shows more 'social' behaviours than Veronica at both levels, but particularly at the higher level of children negotiating understanding between each other. This suggests that Susan wants the children to control the learning process, a position reminiscent of Driver et al's (1994) writing about the social context of learning. In both cases the negotiation is between children, about their own ideas, rather than between teacher and child using society's science view as the focus for discussion and learning. Therefore, not only are the children given control of the classroom learning process but they also have ownership of the science ideas they are developing. Veronica's approach, which makes the accepted science view central, does not involve shifting control from herself towards the children to enable negotiated learning to occur. The children have neither control nor ownership of learning. Her firm grip on the right answer means children are 'discovering' this through investigation and having their learning reinforced through discussion.

Veronica uses more cognitive behaviours than Susan, particularly at the lower level as she structures discussion to lead to the science view. This difference enables Veronica to take her discussion forward rather than repeating questions and waiting for a child to contribute the science perspective so that she can draw attention to it. Neither teacher makes great use of the higher level cognitive behaviours, but for very different reasons. As mentioned in chapter 8, Veronica is not concerned with developing the children's understanding but with reinforcing the science view. Susan, on the other hand, is very concerned with developing understanding, but because she has handed ownership to the children her efforts at influencing the discussion are unsuccessful because she is giving them contradictory messages about her role. Her 'social' position is therefore dictating the stance she can take in respect of the 'cognitive' dimension of teaching.

Thus, in terms of the ownership of learning, Susan is handing it to the children, a position unfamiliar to them, which leads them to reinforce their existing knowledge rather than move themselves forward. Veronica is under the impression she is enabling the children to take ownership of learning (chapter 8, section 7.2), but she is exercising strict control by working in the way familiar to the children. Here are two extremes, with neither negotiating new positions with children but both considering the children to be more involved. Each of these positions has been identified in earlier research into the implementation of child-centred curriculum innovation, described in chapter 4, section 2.1. Susan's actions are consistent with Fraser's (1978) findings because she changes an unfamiliar low influence role (facilitating) into one with zero influence (accepting). Veronica moves in the other direction, turning the same unfamiliar, low influence role into a more familiar high influence one (directing) (Olson, 1981).

2.2 Similarities between teachers: changing established lesson scripts

Despite the obvious differences between the teachers, there are similarities in the manner both Veronica and Susan change their established lesson scripts. These changes are of different degrees but have similar effects in each classroom. Susan undertakes fundamental changes, particularly evident in her responses to children's ideas and her handing the ownership of learning over to the children. She is surprised the children are not raising their own hypotheses and suggesting explanations for phenomena. As I have alluded in earlier paragraphs, the children do not respond to these changes by adopting the necessary responsibility. They use discussions and investigations as opportunities to rehearse their current understanding rather than trying to move their thinking on, taking the more familiar, passive role noted by Tasker (1981, as cited in Gunstone, 1991).

Similarly, Veronica tries to change the status of children's written work to reflect her changed view that children's understanding can best be assessed through elicitation of ideas. Thus neat writing and drawing which have previously been required are replaced by a quick sketch on any scrap of paper (chapter 8, section 5.1). The children consistently frustrate Veronica's desire for them to only spend a short time on drawing in order to produce work which conforms to their understanding of school work.

Both teachers therefore discover what Rudduck (1980) found, that unless the children are involved in the change and can understand its purpose, they will continue to behave according to the framework with which they are familiar. Innovations in classrooms can therefore be neutralised by children being unable or unwilling to change.

2.3 Conclusions: the children's perspective

The children in both classes appeared to enjoy the science teaching, though I have little other than subjective impressions on which to base that view. Enjoyment, though, is not synonymous with learning, as Fraser (1978) found. Children have expectations of teaching and learning in classrooms and, as has been mentioned in previous chapters, that does not include a sudden valuing of their ideas and use of them as a starting point for learning. SPACE and *NPS* are therefore not only strange for teachers, but for children too. Learning from their ideas requires the development of a whole range of metacognitive skills in which teachers as well as children are unlikely to be well versed (MacDonald 1990, as cited in Gunstone 1991).

3. Changing Practice Successfully

Veronica and Susan have approached curriculum change from very different perspectives. As one approach is more productive for children's learning than the other, it is important to work out which particular features of Veronica's and Susan's situations led to changes being either successful or unsuccessful. Veronica purchased the *NPS* materials to provide teachers in her school with questions to use in developing the children's understanding, and to provide for children's development in process skills. At first she was very reliant on the questions in *NPS* but, over the course of the topic, she learnt to model her own questions on those in the Teachers' Guide. She commented on several occasions how much *NPS* made the children use process skills, and how the children's lack of proficiency in this area was highlighted by the activities, as shown in fig. 8.11. As a result of the topic, she introduced a school-wide framework to assist children with the control of variables and the construction of fair tests. Veronica's practice therefore shows development in both areas of identified need, suggesting she found a structure she could use for reflection and action in the *NPS* materials.

Veronica's introduction to personal constructivism preceded her purchase of the *NPS* scheme, through INSET sessions, so it could be argued that she accepted the philosophy at an earlier stage. However, given the nature of her practice, which is very much finding out the children's ideas in order to replace them with the scientific view, it seems that she does not have the appropriate repertoire of teaching strategies to implement constructivist practice. Rather, she is attempting to engage with the philosophy by incorporating the useful strategies into her existing framework (Olson and Eaton, 1987). In support of this position, Veronica expresses the view that the major impact on her practice is the prominence of assessment in her teaching, particularly at the beginning of the teaching sequence.

> *"My teaching's far more differentiated doing it this way than ever it was before. Quite frankly I don't think it was particularly before, not in the way it is now because I think the major difference, the huge difference in teaching this way for me than anything I have done before is that I begin with an assessment...And I have never done that before, begin teaching a science topic by assessing children. I mean, you always think of an assessment coming at the end, but now it has to come at the beginning because until you know what they know how can you move them on?"* (Interview lines 658-667)

Those aspects of Susan's practice which are particularly notable are linked to the 'social' aspect of teaching, the acknowledgement and valuing of children's ideas, which is an important part of the primary personal constructivist approach to teaching, and one which requires substantial changes in thinking about teaching and learning. However, Susan's practice can almost be described as dysfunctional with regard to children's learning. She is so accepting of children's existing ideas that the intervention activities are based on testing these out, giving the children little opportunity for new learning. In fact, when she asks the child who expresses the majority of the scientific ideas where these come from he says that he has read about it in books and been told about it. Even that revelation does not prevent Susan from drawing attention to his ideas repeatedly during the final discussion of the topic. It is as if she can only introduce the accepted science view through a child's contribution. That approach to science teaching, of leaving the introduction of science concepts to chance and hoping children generate relevant ideas, is far removed from Susan's previous practice in which she was very clear about what she wanted the children to learn, but in which children's ideas did not figure. It was also far from the intentions of SPACE.

Susan was introduced to the primary personal constructivist philosophy and attendant teaching strategies as part of SPACE. This immediately required her to collect data about the children's scientific understanding, for which she perceived a need to adopt particular strategies, constraining her from using her established approach to science teaching. The changes in her practice reflect only a partial engagement with the SPACE INSET, described in chapter 7, but a complete change in terms of the social dynamics of classroom interaction. Whether Susan's motivation was to change her practice or just to do what she thought she was being told by us for the SPACE research, she makes a radical change which has great implications for the quality of children's learning.

Veronica has incorporated certain constructivist aspects, while Susan has tried to transform her practice along constructivist lines. However, neither teacher is working in a constructivist way; Veronica is too controlling and Susan is too accepting. What I can reasonably conclude from this analysis is that changing teaching approach is easy for neither teacher nor children. By selecting appropriately from the new approach, successful practice can be maintained (Olson and Eaton, 1987). However, attempting a more complete change of philosophy can be very disabling.

4. Identifying features of successful practice in Nuffield Primary Science

It is unlikely that personal constructivism will lead to substantial learning in the classroom because of the interpersonal dynamics and unspoken procedures which determine the smooth running of the classroom. The social dimension of schooling has significant implications for the use of the *NPS* materials in the way advocated in the SCH. However, "the SPACE approach in action", as modelled in the Teacher Guides, can certainly be used successfully in the classroom. The authors of the Teachers' Guides achieve this by reducing the emphasis on the problematic social dimension of learning, the valuing of children's ideas and accepting them as provisional knowledge. By so doing, the children's ideas appear to be separated from the intervention activities and the scheme therefore loses its constructivist credentials in the transition. What remains is the guided discovery approach with which primary teachers are familiar because it is the "learning by doing" of "good primary practice".

Since guided discovery is so maligned (Hodson, 1993), it is important to identify what makes Veronica's practice so successful in terms of children's learning. The answer is likely to be the reinforcement of key concepts and use of focused learning objectives which Osborne and Simon (1996) have found to characterise effective primary science teaching. *NPS* is therefore compensating for a lack of teacher content knowledge by providing a framework to assist the teacher in developing the children's understanding: key ideas and background science containing explanations of phenomena. The structured approach to teaching which this framework encourages has the potential for being used as part of socio-cultural teaching since it supports the teaching of the accepted science view without focusing on changing children's ideas.

5. Summary

A comparison of two teachers, one using *NPS* and one working with SPACE, showed neither teacher to be using a constructivist approach, though their practices were very different from each other. The differences involved Veronica, the *NPS* teacher, in controlling children's learning while Susan, the SPACE teacher, handed control to the children. Both teachers were therefore reinterpreting the unfamiliar, low influence facilitative role but in different ways, as either a high influence (control) or a zero influence (acceptance) role, both of which change the nature of classroom interactions. Similarities occurred in relation to the children neutralising attempts to change established classroom routines because they were not included in the change process. This problematic, social dimension of learning is much less evident in the *NPS* Teachers' Guides, leaving a guided discovery approach to teaching. Once in the classroom, the practical guided discovery element can be balanced by the use of teaching strategies which appear to make *NPS* successful in leading to learning: a clear framework for developing understanding utilising focused learning objectives, structured discussions and the reinforcement of key concepts. This approach can be more closely allied to a socio-cultural perspective, and has the advantage of meeting children's expectations for school learning experiences.

This chapter concludes my presentation and analysis of data. In chapter 10 I therefore draw my conclusions about the effective teaching of primary science.

CHAPTER 10

CONCLUSIONS: EFFECTIVE TEACHING IN PRIMARY SCIENCE

This chapter brings together the three main issues presented in the introduction which have been central to my thesis: constructivism, the nature of primary science and effective practice in primary science. Under each heading I summarise my conclusions from the literature and address the contributions of SPACE, *NPS* and SPACE / *NPS* teachers to the current understanding of each area. I then address the social dimension of teaching and learning before considering the way forward for primary science education from our current position of knowledge. I conclude that there is not a place in primary science for constructivism, but that SPACE and *NPS* have made valuable contributions to understanding the teacher's role in primary science and have been necessary staging posts to a more thoroughly researched view of the effective primary science teacher.

1. Constructivism

1.1 The view from the literature

The loosely defined framework of constructivism hides within it very different assumptions about the nature of science education allied to the three approaches for cognitive change: cognitive conflict, building on children's ideas and developing ideas consistent with a scientific viewpoint. The first aims to get children to accept that their view is not generally explanatory using evidence related to the currently accepted scientific view; the second aims to help children find their own idea unscientific by testing it out through investigation; the third aims to present children with the accepted scientific view and to help them understand why it is sensible. It is incredible that these three perspectives can be held within the one umbrella framework of constructivism, particularly as the third, socio-cultural view, is claimed by the constructivists but not located there by its proponents. The socio-cultural approach is so different from anything within the constructivist framework that I consider it should be separately defined because, unlike the other perspectives, it does not consider children's ideas to be theories to be developed and changed.

Constructivism as I have defined it at the end of chapter 2 is disputed both as an explanation of how children *learn* and as a *teaching* theory. However, the broader notion that children play an active role in generating their own understanding is much less contentious. Further problematic is the direct linking between the learning process and the teaching process, with the goals for teaching being subsumed within the individual's right to learn. Effective teaching and effective learning cannot come from the same theoretical base because the ideal timescales for the two operations are completely different: teaching is ideally fast, while learning as an unassisted operation takes time. In terms of my own learning, receiving minimal inputs from others while being expected to reinvent the wheel to develop my understanding is very frustrating. Teaching should therefore be about more than facilitating children's learning, and should aim to provide the building blocks to assist in structured knowledge acquisition. Thus socio-culturalism is the approach to teaching science which should supersede constructivism and which should lead to effective learning.

1.2 The contribution of SPACE to the constructivist debate

I have located SPACE within the "building on children's ideas" approach to personal constructivism which derives from Harlen and Osborne's (1985) application of the Generative Learning Model (GLM) to primary science. It shares this location with, most notably, the LISP work from New Zealand. Both of these Projects are distinguishable from other major constructivist research by being conducted with primary school children. The parallels between this particular constructivist approach and "good primary practice" are inescapable and Osborne and Wittrock (1985) clearly state that, where constructivism is applied in another age phase of education it should adopt a different, more challenging, approach. The effect of combining child-centred heurism with constructivism is to produce an approach which focuses so completely on children's intuitive understanding as the basis for teaching that, while it can be justified by some in terms of personal learning, in terms of addressing societal expectations for science learning it is sadly lacking.

Methodologically, SPACE has made significant contributions to the phenomenological approach to ideas elicitation. The range of reliable techniques which are now available for teachers to use is much enhanced, particularly through the use of children's drawings.

1.3 The contribution of *NPS* to the constructivist debate

I would hazard a guess that the SCH was written largely by researchers while the Teachers' Guides were written more by practising class teachers. These distinctions would explain why the SCH conveys messages which are much closer to SPACE than do the Teachers' Guides. These differences need not necessarily be a problem, except that "the SPACE approach in action", as described in the Teachers' Guides, has shifted away from constructivism by deprioritising those aspects which focus on the social dimension of learning, which is at odds with society's notion of schooling. In so doing, it is apparently advocating guided discovery, a discredited approach to teaching and learning. The questions contained in the Teachers' Guides, particularly for KS1, reflect the type of questions teachers routinely ask in the classroom rather than the type which would be desirable in order to implement a constructivist approach to teaching and learning.

The embodiment of this theoretical shift contributes to the constructivist debate by identifying those aspects of constructivism which are both unworkable and untenable in the classroom. It is thus clear that valuing children's ideas and endeavouring to develop these through investigation is incompatible with effective classroom science learning.

1.4 The contribution of SPACE and *NPS* teachers to the constructivist debate

The teaching of both Veronica and Susan shows that there are a wide number of constraints to teaching according to a constructivist approach, since neither of them achieved their intentions. Firstly, its requirements in terms of subject knowledge are significant; secondly, it requires a very experienced and skilled teacher to ensure that learning happens and thirdly, its sudden adoption as an approach will be at odds with familiar lesson scripts because it gives ownership of learning to children, requiring both teacher and children to change roles. By confirming earlier research findings, both teachers demonstrated that the desire to change role is insufficient to ensure success, as new roles have to be clearly understood and compatible with the children's expectations of teaching and learning.

2. The Nature of Primary Science

2.1 The view from the literature

"Good primary practice" is such a well established ethos that it is difficult to see how any subject new to the primary curriculum could establish an identity at odds with the belief that children's interests are central to their learning, which should be by first hand experience. The philosophy of science supplies a justification for a practical, observation-based approach in the form of inductivism, that general theories are built up as a result of making observations in specific instances. It is therefore not surprising that constructivist primary science as described in section 1.2 has been embraced by primary practitioners because it fits the ethos even more closely than the earlier process model. While this is still an under-researched area in the primary phase, research does not support the pre-eminence of learning through practical work. A purely inductive approach to science is being replaced by a more deductive approach which makes more selective use of practical work in favour of more extended discussion and thought. This socio-cultural approach is a more realistic model of how scientists learn in science, and it matches more closely society's aims for science education.

2.2 The contribution of SPACE to understanding the nature of primary science

It is easy to focus on learning through investigation as being synonymous with the SPACE position. However, that neglects the wider range of intervention strategies which the Project developed and advocated. Refining children's use of science vocabulary and helping them generalise from one context to another were successful discussion-based strategies both of which are compatible with the view of the nature of primary science outlined above.

2.3 The contribution of *NPS* to understanding the nature of primary science

The intervention planning charts intended to help teachers develop children's ideas suggest almost entirely practical activities as ways forward. This emphasis is on practical work at the expense of concept development because activities are suggested which are nonsequiturs when it is easy to identify appropriate discussion-based tasks. These logical inconsistencies strengthen the view that, even with young children, practical experience is not always the most productive form of learning.

2.4 The contribution of SPACE / *NPS* teachers to understanding the nature of primary science

An explicit structure to guide the children in their investigations was significant both by its absence in Veronica's classroom, and by its later adoption throughout her school as a result of her learning during the "sound" topic. If children are to develop their ideas in a scientific manner then they must be assisted to do so by the provision of a structure within which they can work because, as Nott and Wellington (1996) and Qualter et al (1990) have said, children cannot be expected to develop both their understanding of processes and of concepts at the same time. Investigations can very easily be used by children to prove what they already know, and are very difficult to use to stretch understanding. They are also intellectually dishonest as an approach as children are not in a position to be able to claim new knowledge. Veronica's practice demonstrated this dishonesty very well as she amended the children's plans to fit her intentions, and refused to accept their findings if they were not in line with her expectations.

3. Towards a Definition of Effective Practice

3.1 The view from the literature

It is very clear that good content knowledge, both syntactic and substantive is central to effective teaching. That in itself is of limited use unless it can be appropriately translated for the classroom, as pedagogical content knowledge. The small-scale studies cited in chapter 4 conclude tentatively that teachers with good subject knowledge are able to:

- use their semantic knowledge in order to identify those aspects of science topics which were important for students to learn
- use their pedagogical content knowledge to construct a powerful set of explanations using appropriate representations
- engage children in open discussion, making use of the students' questions and contributions in order to develop their understanding
- use their curriculum knowledge to select activities which provided opportunities for the students to learn the identified concepts.

Conversely, teachers with poor subject knowledge characteristically:

- close down discussions and activities in order to stay within the bounds of their knowledge of the subject
- emphasise aspects other than concept development - either process development or study skills
- choose activities which do not provide opportunities for learning important concepts.

The resulting teaching fits within Wolfe's rationalist typology but is able to use other strategies as appropriate, for example demonstrating from within the formalist approach. Were all of the strategies for effective science learning combined into one approach, as suggested by Howe (1996), then a hybrid in terms of a socio-cultural perspective and constructivism would be formed, with personal constructivism contributing an awareness of children's ideas. The children's ideas would not necessarily need to be changed, but teachers would need to be aware of their existence and know how to encourage children to access their science knowledge in preference to these ideas.

3.2 The contribution of SPACE to an understanding of effective teaching

SPACE, as the first large-scale constructivist study with primary school age children to take place in Britain, has made significant contributions to our understanding of primary science teaching. The use of teachers to select the intervention activities limits what SPACE can say about developing understanding. From the data we collected, there is evidence of little learning as a result of the interventions, but had the interventions been more systematically selected and applied the position might have been different. However, the elicitation of children's ideas has clear messages for effective teaching, as follows:

a. SPACE started a large research movement into children's ideas in science. Any teacher who reads *Primary Science Review*, or *Primary Science*, cannot fail to be aware of the existence of these everyday notions. SPACE has therefore been extremely valuable in alerting teachers to the existence of children's ideas, and therefore to more informed starting points for teaching.
b. This elicitation familiarised teachers with the use of drawing as a powerful assessment technique.
c. Sensitising teachers to the importance of listening to children has provided the possibility of matching their explanations to the child's current level of understanding, thus making meaningful learning more likely.
d. By providing a focus as intuitively attractive as children's ideas, teachers have been able to identify with science in a way which is more

approachable and less threatening to those with a poor science understanding (Russell et al, 1992). This therefore provides motivation and enthusiasm for looking afresh at the teaching of primary science.

e. Providing starting points which teachers can discuss with children in everyday language, and which children enjoy, ensures that children are motivated to learn, making teaching easier to manage. This will result in teachers' attitudes to science teaching becoming more positive.

Not only has SPACE contributed to the understanding of effective practice, it has shown that it is possible to have a tremendous impact on classroom practice through working in collaboration with teachers. Establishing this collaboration was enhanced by the credibility with which we embued the research. This credibility as researchers / curriculum developers has meant that the SPACE research is more widely known than most other initiatives. As a vehicle for changing practice, credibility has been shown to be very important, and future initiatives should incorporate that into their methodology, taking care to ensure a balance with reliability and validity.

3.3 The contribution of *NPS* to an understanding of effective teaching

Building on these insights, *NPS* was in a position to present differently formatted information to teachers about primary science teaching.

a. The emphasis in *NPS* on assessment is something with which teachers can identify, and it leads both to well targeted teaching and to wider understanding of the process of diagnostic assessment.
b. *NPS* presents key ideas for children to learn in a manner which enables teachers to devise clear learning objectives for the science activities they are undertaking. The use of these objectives, phrased as key ideas rather than detailed pieces of knowledge, sends a clear message that primary science is concerned with conceptual development.
c. The repetition of key ideas leads to learning. From my research I cannot say whether it was the focus on key ideas (as opposed to isolated, unlinked activities) or the repetition which was more important, or whether it was a combination of the two.

d. The clear content objectives in the Teachers' Guides not only provide teachers with a clear goal for their teaching but show that, by giving appropriate support with pedagogical content knowledge, teachers who do not have a scientific background are able to bring about coherent learning. Thus, it encourages concept- rather than knowledge-based teaching.
e. The layout of the Teachers' Guides provides a clear structure for teaching science, with or without elicitation, and encourages teachers to see the process as a coherent one for both their teaching and the children's learning.
f. The differences between *NPS* and SPACE tell us that successful teaching has as contributory parts the notion of instruction, in which teaching is directed towards a particular goal, and also questioning for confirmation, in which teachers can check that children have gained the required understanding.
g. *NPS* has reinforced the view that children who are motivated will find learning more enjoyable and easier.
h. In line with research findings about the importance of continued teacher support and development alongside curriculum development initiatives, the Nuffield Foundation is producing a regular newsletter to support the classroom implementation of *NPS*. One of its functions is to publicise local INSET related to *NPS* (Bell, 1996).

If "the SPACE approach in action" is compared with research on effective teaching, we see *NPS* helping teachers to:

- identify important concepts
- select appropriate activities
- respond appropriately to ideas
- use a range of practical activities
- reinforce main points

All of these aspects are related to pedagogical content knowledge. *NPS* is therefore supporting teachers' pedagogical content knowledge by providing examples of activities and questions, and highlighting key ideas to be learnt. All of these aspects can to a large extent be addressed at the planning stage, when teachers can refer to the Teachers' Guides and to other sources of science knowledge.

3.4 The contribution of SPACE / *NPS* teachers to an understanding of effective teaching

Even given Veronica's thorough planning, her level of science understanding was influential in determining the lack of autonomy the children experienced in designing and carrying out intervention activities. Unless teachers are very secure in their understanding they will tend to control the content of the children's intervention activities in the way Veronica does, in order that they know which questions to ask. By analysing the practice of teachers such as Veronica, it is possible to identify areas in which teachers are not being adequately supported:

- creating powerful representations
- engaging children in open discussion

These two aspects of effective practice are interactive, requiring decisions to be made during the lesson. They are therefore dependent on an *understanding* of pedagogical content knowledge rather than a nodding acquaintance with it. An *awareness* of pedagogical content knowledge, which can be provided by curriculum support materials such as *NPS*, will not be sufficient. Veronica's desire to control class discussions has been found in other teachers with similar levels of content knowledge by Harlen (1996) and Simon (1996). While the *NPS* Teachers' Guides provide background science they cannot help the teacher to make decisions in action.

4. The Social Dimension of the Teaching and Learning Processes

There is evidence of the children's understanding of the teaching and learning process influencing both Susan's and Veronica's practice. The children in Susan's class had a passive view of learning which they were unable to adapt when faced with changed expectations, and those in

Veronica's class dictated the pace of work to enable them to meet the expectations of presentation she had established earlier in the school year. This is in line with Rudduck's (1980) research which shows that students can neutralise any attempts a teacher makes to change their practice if they have been uninvolved in an understanding of the nature and purpose of the changes. Classroom dynamics revolve around accepted rules, routines and roles in which children are socialised during their entire school career. Attempting to introduce a new way of working part way through the school year is unlikely to be successful, given the prevalent dynamics. A lot of preparatory work needs to be done with pupils, involving them in the changes, in order for them to accept any shift in the classroom power balance. It is, though, important that any such change should be compatible with the standards against which children (and teachers) are judged at school. As society's aims for schooling involve the acquisition of an agreed knowledge base, then personal constructivism is not a compatible approach. However, a more active role for children in learning is desirable and should be attainable given a socio-cultural approach to the negotiation of understanding.

5. The Way Forward for Primary Science Education

Primary constructivism has been a useful vehicle for raising the awareness of primary teachers to assessment in science, and has provided interest and motivation to find out ideas. However, as an approach to teaching it has been found wanting because of the ownership children are given of their ideas and their learning, and the lack of emphasis on the accepted science view. It is not the way forward for primary science education because it is based on "good primary practice" rather than research, and the SPACE research does not provide evidence to support its wider implementation because children make insufficient progress towards society's goals.

Research points towards a socio-cultural approach to teaching which makes the teacher's role more active and involves the development of scientific ideas alongside the everyday, life-world notions which SPACE targeted. Teachers will need tremendous support with this approach, not least because the implications of this model for teachers' understanding of science are enormous. It is unrealistic to attempt to improve the science knowledge of every teacher within a short time span, and effective support materials will be essential. The successful features of NPS, for example the key ideas and the questions (though modified and improved), will be invaluable, and even more so if supplemented with examples of effective representations and explanations of scientific phenomena.

My research has shown how socio-culturalism can develop from constructivism, because that is the direction of the movement from SPACE to *NPS* to *NPS* in the classroom, and future development should continue in that direction.

In order to inform future developments, in chapters 11 and 12 I suggest implications of my thesis for the design of continuing professional development, curriculum materials and research.

CHAPTER 11

IMPLICATIONS FOR CONTINUING PROFESSIONAL DEVELOPMENT AND CURRICULUM MATERIALS

Throughout this thesis I have referred to factors which affect the success of primary science teaching. There are clear implications from this for the provision for continuing professional development (CPD). Given the cost of CPD and thus the impossibility of all teachers having access to it in the near future, I argue for the construction of curriculum materials in such a way to enable children to have access to a reasonable quality of science education in the classroom of all teachers, not just those who feel confident and are knowledgeable in science. In this chapter I establish areas for CPD and then show how well designed curriculum materials could alleviate the problem.

1. Teachers Need a Good Understanding of Science

Shulman's (1986) distinction between syntactic and content subject knowledge is something of which teachers need to be cognisant. Recent approaches to establishing teachers' content knowledge have mostly been within the constructivist paradigm and have involved a modelling of the constructivist learning process so that teachers can use it in the classroom. Given the lack of evidence to support that as a paradigm for teaching, a more promising approach seems to be that of Harlen (1996) in which researchers talk with teachers about "big ideas" in science and scaffold their developing understanding. This research technique would be amenable to group discussion with a facilitator / mentor who has a well-developed understanding of the science concepts under discussion.

Teachers' understanding of the nature of science has, in my experience, been developed through the use of process-led investigations without much content to give them a real purpose. Given the importance of a realistic understanding of the involvement of *processes* in learning, something which need not involve practical work at all but could be largely discussion-based activity even for young children, it will be a more fruitful approach to consider learning through the use of process skills rather than focusing on the one restricted scenario of investigation. Should investigations be the appropriate form of practical work, then teachers will need either to have addressed the concepts beforehand (so that the children would be using the investigation for confirmation and process development) or to provide a structure for the investigation (to enable the children to focus on the concept development).

2. Teachers Need Pedagogical Content Knowledge

Traditionally, INSET courses provide teachers with interesting ideas to use in the classroom, in much the same manner as science curriculum materials. However, because it is so important for teachers to understand the underlying science and be able to convey it to children, the rationale for the selection of these activities needs to change. Rather than choosing fun activities which will motivate children, teachers need to present a coherent picture which explains the underlying concepts. INSET courses can contribute to this in several ways. Firstly, by modelling the process of identifying the underpinning knowledge so that teachers will find it easier to identify appropriate activities in their classrooms. This approach to INSET was adopted very successfully by Asoko at the Association for Science Education Annual Meeting this year (de Boo, 1997). This approach will go some way to helping teachers formulate their own learning objectives for children. Secondly, by helping teachers to develop appropriate representations to explain phenomena to children. Again, this approach was modelled by Asoko (1997). Thirdly, by developing approaches to assessment so that teachers can identify the scientific starting point for their children's learning. In this regard, teachers' use of language will need close attention so they know which questions to ask to cue the children to science rather than everyday thinking.

3. Start from Teachers' Existing Practice

Teachers do what they do for a reason, namely that it works for them and is compatible with the way they operate in the classroom across the curriculum, both overt and hidden. By enabling teachers to select those aspects which they find attractive from curriculum development initiatives there should be several benefits. Firstly, teachers will be more likely to use things that they themselves have selected. Secondly, they will be able to make intelligent decisions about how best to use these new aspects within the framework of their existing practice. Thirdly, once the strategies are being used, the teachers will be in a position to reflect on the efficacy of the strategies because the context within which they are using them will be familiar, stable and successful (Olson and Eaton, 1987). Thus, while there is likely to be a short-term dilution of the initiative, in the long-term it is more likely to be incorporated successfully.

4. Start from Teachers' Existing Theories of Effective Teaching and Learning

This second point follows directly from the one above. The presentation in theoretical terms of a new approach to teaching and learning may seem an obvious way to introduce ideas which are intended to move practice forward. However, as teachers do not routinely reflect in theoretical terms, starting at a deeper level inhibits teachers from making realistic decisions about what they can feasibly and successfully adopt, as seemed to be the case with Susan. Instead, teachers should be encouraged to incorporate new strategies into their existing practice. Their reflection would then be in the familiar context of established personal theory. Working from the *known* would enable practice to be developed progressively as the reasons for doing things become better understood. For teachers to discard a working theory and replace it with one which has only been experienced in abstract, theoretical terms, however attractive it may seem, puts teachers in the position of being dysfunctional.

5. Make Attitudes Towards Science Teaching Explicit

Carré and Ovens suggest that a teacher's attitude towards science has a marked effect on the way the individual teaches it. They advocate a mix of "sensationalist" and "rationalist" attitudes, with some of the teacher directed strategies of the "formalist" for effective science teaching. However, without good content knowledge, a teacher is constrained from adopting more rationalist approaches. If a particular mix of attitudes to science teaching is associated with effective teaching, teacher education should encourage teachers to reflect on their attitudes to science teaching before they attempt to develop their practice. However, the forced adoption of a particular set of attitudes is unlikely to advantage the children, or to lead to long-term professional development for the teacher (Norton, 1994).

6. Consider the Social Dimension of the Teaching and Learning Processes

As children have a very well developed understanding of the classroom and its rules, and these can influence the efficacy of attempts at curriculum development, teacher education should explore the social dynamics of the classroom and help teachers to develop strategies for negotiating and implementing change with pupils (Rudduck, 1980).

7. Ensure the Availability of On-going Support Within and Outside the Classroom

The need for more than a one-off session for INSET to be effective is well documented. If teachers are to be helped to reflect on the strategies they are implementing, with a view to building on them for further change, they must do that within a context of support, feedback and guidance (Joyce and Showers, 1984). Only by being observed can the teacher be helped to see how their actual practice relates to what they espouse, providing a vehicle for reflection and development.

8. Implications for Curriculum Scheme Development

The CPD outlined above would require considerable resources. As these resources are unlikely to be available, a more realistic position should be established, using curriculum schemes as the medium for support.

a. Teachers need assistance in formulating learning objectives which have appropriate conceptual content (Osborne and Simon, 1996). By using materials such as *NPS* in which the learning objectives are clear, teachers should become more familiar with this process.
b. Teachers need help in identifying the concepts involved in activities so they can ensure activities are compatible with their learning objectives. Were curriculum materials developed which clearly identified the relevant concepts then teachers would not be so dependent on developing that understanding themselves.
c. Teachers need models of appropriate questions, similar to the best examples in *NPS*. Teachers will then, as Veronica did, begin to adapt the questions to suit their class as their confidence grows.
d. Teachers need help in developing appropriate representations to explain concepts to children (McDiarmid et al, 1989). The *NPS* background science contains representations, e.g. The "slinky" which Veronica used to explain sound travelling, but these need to be located in the main body of the text for them to be routinely incorporated into teaching.
e. Teachers need help with the appropriate use of practical activities, so that they can use the most appropriate form for the understanding they are trying to generate (Nott and Wellington, 1996). Sensitive scheme development would provide a model for teachers to adopt and follow.
f. Teachers need help with assessment so they can identify the science which is underlying the children's ideas and statements (Johnson and Gott, 1996). This links closely with b., except that it requires a higher level of expertise. The teacher cannot interpret the children's language at their leisure as part of planning, it will need to be done in real time in the classroom. However, an understanding of the science underlying

the activities, i.e. the learning objectives, will provide a framework within which to interpret the children's ideas.

As a short-term measure, scheme development which includes the appropriate conceptually-orientated information would provide teachers with a structure which they could use intelligently without having all of the knowledge themselves. Of course, such curriculum materials would never be a substitute for a teacher with good content and pedagogical content knowledge, but they would make it more likely that children would not be disadvantaged should their teacher not be a science specialist.

CHAPTER 12

IMPLICATIONS FOR FUTURE RESEARCH

Recent issues of *Primary Science Review* have contained a debate about the importance of research, particularly constructivist research, for primary school teachers. Gibson (1996) is of the view that present constructivist research offers little to teachers as it is repetitive and focused on eliciting children's ideas. It has served its purpose and raised the awareness of teachers who now needed help to use these ideas constructively within their practice. In a rebuttal, Boulter (1997) justifies the continued focus on children's ideas as only one of a range of types of research, but one which, "is quicker, and easier to fund and organise, as it can be pre-structured and it produces the clear and unambiguous results that impress funders". What is regrettable about Boulter's position is that she is justifying continuing research which is of little intrinsic value and which does not take the understanding of effective teaching further forward. What is unfortunate about Gibson's position is that, through *Primary Science Review*, she has been fed a rich diet of children's ideas and believes that employing constructivism in her classroom will improve her teaching. Thus, research which is easy to do is justified on those grounds, and teachers become hooked but not helped. Research needs to move forwards and embrace socio-cultural perspectives on teaching and learning because they are supported by evidence from research on effective teaching.

This thesis has raised many questions about effective teaching, and further research is sorely needed to improve our understanding.

1. Teachers need content knowledge, but how much? What are the "big ideas" which will enable them to teach science to primary school children in a manner appropriate for their stage of development?
2. Teachers need syntactic knowledge, but how can it be employed most effectively? How do process skills developed through "good telling and good puzzling" (Sutton, 1992) compare with those generated through "doing"? How can young children be helped to become more scientific in the way they operate?
3. Teachers need pedagogical content knowledge. Is there a best way of introducing concepts to young children? How can teachers learn to give explanations? What are the most effective representations for children to understand? How can teachers best be helped to interpret the science underlying children's ideas?
4. In order to become more effective teachers of primary science, which of the above-mentioned aspects is most important, or are they interdependent? If they are interdependent, how can they best be introduced to teachers in a sequential manner?
5. Teachers need to be effective at teaching children, but we know very little about the sense children make of the process of learning in science. How can we help children to be active participants in the learning process? How can children's questions be part of a much larger framework constructed around the social demands of school science learning?
6. The link between doing and understanding in science has been questioned in connection with science at secondary and tertiary levels. The area is still poorly researched at the primary level. Should there be a distinctive form of learning in science for young children?

Small and large-scale studies, in collaboration with teachers, will enable us to answer these questions about effective teaching in primary science from a more informed stand-point. Collaborative ventures must be the way forward because knowledge is constructed in the classroom, so that is where research into teaching and learning should occur. Setting up a collaboration is no guarantee of its success and, as stated in chapter 10, establishing the credibility of researchers is very important. However, future researchers must exercise creativity in balancing the competing demands of credibility, reliability and validity.

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Appendix 1

Appendix 1

My contributions to SPACE Project development

The main areas to which I made significant contributions were as follows:

Elicitation

1. The inclusion of an "exploration" period, during which slow changes (e.g. growth and evaporation) could happen and during which children had the opportunity to consider their ideas before articulating them.

2. The use of everyday, familiar examples (as oppose to 'textbook illustrations') to be the stimuli for the children to express their ideas. For example, evaporation was considered through clothes drying, and watching puddles evaporate.

3. The development of the use of annotated drawings as one of the main data collection techniques.

4. A consideration of what might have led children to hold their ideas through interpretation of their drawings. It appears from the Nuffield Primary Science teachers' handbook that this has retrospectively become an aim of SPACE, even though it was not listed as such when the research reports were being written.

Intervention

1. The inclusion of an intervention strategy which encouraged children to generalise from one context to another.

2. The use of specific (but open) questions as a starting point for intervention

3. The involvement of teachers in the construction of the intervention package.

INSET

1. I was responsible for shifting the focus of the teacher meetings from being purely project briefing sessions to being staff development sessions. The impact of this development is reflected in the development of an INSET package as part of the Nuffield Primary Science materials.

2. I developed the content of the INSET sessions and was responsible for delivering them. The sessions involved the teachers in broadening their understanding of science, and in developing their questioning and other teaching strategies to enable them to take a more active role in the development of the classroom work for the Project.

My contribution to the SPACE Project research reports

I played a major role in the design of the data collection instruments to be used with the children for six science topics, and I was one of the principal data gatherers for the interviews with individual children for the same topics. I was directly involved in the writing of three of the research reports resulting from the research, as reflected in the authorship credits.

The sound report was entirely written by me. That involved: an annotated description of the classroom work; the development of the analytical framework for handling the interview data; categorising and interpreting the children's ideas as portrayed in drawings; analysing the role of the teacher in the classroom work, particularly in the intervention. A conservative estimate of the length of the sound report is 17,000 words.

Within the evaporation and condensation and the growth reports I was responsible for describing the classroom work for each phase, analysing and interpreting the children's drawings, selecting appropriate examples from drawings and interview scripts to illustrate the analytical commentary. My contribution to each of these two reports is around 6,500 words.

Appendix 2

Primary SPACE Project Research Team

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Appendix 3

SPACE methodology: Introduction to SPACE research reports pp. ii-vi

The involvement of teachers

Schools and teachers were not selected for the Project on the basis of a particular background or expertise in primary science. In the majority of cases, two teachers per school were involved, which was advantageous in providing mutual support. Where possible, the Authority provided supply cover for the teachers so that they could attend Project sessions for preparation, training and discussion, during the school day. Sessions were also held in the teachers' own time, after school.

The Project team aimed to have as much contact as possible with the teachers throughout the work to facilitate the provision of both training and support. The diversity of experience and differences in teaching style which the teachers brought with them to the Project meant that achieving a uniform style of presentation in all classrooms would not have been possible, or even desirable. Teachers were encouraged to incorporate the Project work into their existing classroom organisation so that both they and the children were as much at ease with the work as with any other classroom experience.

The involvement of children

The Project involved a cross-section of classes of children throughout the primary age range. A large component of the Project work was classroom-based, and all of the children in the participating classes were involved as far as possible. Small groups of children and individuals were selected for additional activities or interviews to facilitate more detailed discussion of their thinking.

The structure of the Project

For each of the eight concept areas studied, a list of concepts was compiled to be used by researchers as the basis for the development of work in that area. These lists were drawn up from the standpoint of accepted scientific understanding and contained concepts which were considered to be a necessary part of a scientific understanding of each topic. The lists were not necessarily considered to be statements of the understanding which would be desirable in a child at age eleven, at the end of the Primary phase of schooling. The concept lists defined and outlined the area of interest for each of the studies; what ideas children were able to develop was a matter for empirical investigation.

Most of the Project research work can be regarded as being organised into four phases, preceded by an extensive pilot phase. These phases are described in the following paragraphs and were as follows:

Pilot work
Phase 1: Exploration
Phase 2: Pre-Intervention Elicitation
Phase 3: Intervention
Phase 4: Post-Intervention Elicitation

The phases of the research

Each phase, particularly the Pilot work, was regarded as developmental; techniques and procedures were modified in the light of experience. The modifications involved a refinement of both the exposure materials and the techniques used to elicit ideas. This flexibility allowed the Project team to respond to unexpected situations and to incorporate useful developments into the programme.

There were three main aims of the Pilot phase. Firstly, to trial the techniques used to establish children's ideas; secondly, to establish the range of ideas held by primary school children; and thirdly, to familiarise the teachers with the classroom techniques being employed by the Project. This third aim was very important since teachers were being asked to operate in a manner which, to many of them, was very different from their usual style. By allowing teachers a 'practice run', their initial apprehensions were reduced, and the Project rationale became more familiar. In other words, teachers were being given the opportunity to incorporate Project techniques into their teaching, rather than having them imposed upon them.

In the Exploration phase children engaged with activities set up in the classroom for them to use, without any direct teaching. The activities were designed to ensure that a range of fairly common experiences (with which children might well be familiar from their everyday lives) was uniformly accessible to all children to provide a focus for their thoughts. In this way, the classroom activities were to help children articulate existing ideas rather than to provide them with novel experiences which would need to be interpreted.

Each of the topics studied raised some unique issues of technique and these distinctions led to the Exploration phase receiving differential emphasis. Topics in which the central concepts involved long-term, gradual changes, e.g. 'Growth', necessitated the incorporation of a lengthy exposure period in the study. A much shorter period of exposure, directly prior to elicitation was used with 'Light' and 'Electricity', two topics involving 'instant' changes.

During the Exploration, teachers were encouraged to collect their children's ideas using informal classroom techniques. These techniques were:

i. Using log-books (free writing/drawing)

Where the concept area involved long-term changes, it was suggested that children should make regular observations of the materials, with the frequency of these depending on the rate of change. The log-books could be pictorial or written, depending on the age of the children involved, and any entries could be supplemented by teacher comment if the children's thoughts needed explaining more fully. The main purposes of these log-books were to focus attention on the activities and to provide an informal record of the children's observations and ideas.

ii. Structured writing/drawing

Writing or drawings produced in response to a particular question were extremely informative. This was particularly so when the teacher asked children to clarify their diagrams and themselves added explanatory notes and comments where necessary, after seeking clarification from children.

Teachers were encouraged to note down any comments which emerged during dialogue, rather than ask children to write them down themselves. It was felt that this technique would remove a pressure from children which might otherwise have inhibited the expression of their thoughts.

iii. Completing a picture

Children were asked to add the relevant points to a picture. This technique ensured that children answered the question posed by the Project team and reduced the possible effects of competence in drawing skills on ease of expression of ideas. The structured drawing provided valuable opportunities for teachers to talk to individual children and to build up a picture of each child's understanding.

iv. Individual discussion

It was suggested that teachers use an open-ended questioning style with their children. The value of listening to what children said, and of respecting their responses, was emphasised as was the importance of clarifying the meaning of words children used. This style of questioning caused some teachers to be concerned that, by accepting any response whether right or wrong, they might implicitly be reinforcing incorrect ideas. The notion of ideas being acceptable and yet provisional until tested was at the heart of the Project. Where this philosophy was a novelty, some conflict was understandable.

In the Elicitation phase, the Project team collected structured data through individual interviews and work with small groups. The individual interviews were held with a random, stratified sample of children to establish the frequencies of ideas held. The same sample of children was interviewed pre- and post-Intervention so that any shifts in ideas could be identified.

The Elicitation phase produced a wealth of different ideas from children, and led to some tentative insights into experiences which could have led to the genesis of some of these ideas. During the Intervention teachers used this information as a starting point for classroom activities, or interventions, which were intended to lead to children extending their ideas. In schools where a significant level of teacher involvement was possible, teachers were provided with a general framework to guide their structuring of classroom activities appropriate to their class. Where opportunities for exposing teachers to Project techniques were more limited, teachers were given a package of activities which had been developed by the Project team.

Both the framework and the intervention activities were developed as a result of preliminary analysis of the Pre-Intervention Elicitation data. The Intervention strategies were:

(a) Encouraging children to test their ideas

It was felt that, if pupils were provided with the opportunity to test their ideas in a scientific way, they might find some of their ideas to be unsatisfying. This might encourage the children to develop their thinking in a way compatible with greater scientific competence.

(b) Encouraging children to develop more specific definitions for particular key words

Teachers asked children to make collections of objects which exemplified particular words, thus enabling children to define words in a relevant context, through using them.

(c) Encouraging children to generalise from one specific context to others through discussion.

Many ideas which children held appeared to be context-specific. Teachers provided children with opportunities to share ideas and experiences so that they might be enabled to broaden the range of contexts in which their ideas applied.

(d) Finding ways to make imperceptible changes perceptible

Long-term, gradual changes in objects which could not readily be perceived were problematic for many children. Teachers endeavoured to find appropriate ways of making these changes perceptible. For example, the fact that a liquid could 'disappear' visually and yet still be sensed by the sense of smell - as in the case of perfume - might make the concept of evaporation more accessible to children.

(e) Testing the 'right' idea alongside the children's own ideas

Children were given activities which involved solving a problem. To complete the activity, a scientific idea had to be applied correctly, thus challenging the child's notion. This confrontation might help children to develop a more scientific idea.

In the Post-Intervention Elicitation phase the Project team collected a complementary set of data to that from the Pre-Intervention Elicitation by re-interviewing the same sample of children. The data were analysed to identify changes in ideas across the sample as a whole and also in individual children.

These four phases of Project work form a coherent package which provides opportunities for children to explore and develop their scientific understanding as a part of classroom activity, and enables researchers to come nearer to establishing what conceptual development it is possible to encourage within the classroom and the most effective strategies for its encouragement.

The implications of the research

The SPACE Project has developed a programme which has raised many issues in addition to those of identifying and changing children's ideas in a classroom context. The question of teacher and pupil involvement in such work has become an important part of the Project, and the acknowledgement of the complex interactions inherent in the classroom has led to findings which report changes in teacher and pupil attitudes as well as in ideas. Consequently, the central core of activity, with its pre- and post-test design, should be viewed as just one of the several kinds of change upon which the efficacy of the Project must be judged.

The following pages provide a detailed account of the development of the Growth topic, the Project findings and the implications which they raise for science education.

Appendix 4

Appendix 4

Elicitation guidelines: Sound research report appendix III

APPENDIX III

Teacher Guidelines for SPACE Exploration - Phase II (March 1988)

We intend to give the children a chance to think about the new topic area before trying to find out what their ideas are.

The exploration phase should be very low-key, simply putting a range of experiences before the children so they've got something around which to structure their thoughts. We are doing the exploring of their ideas at this stage. Every child should have the opportunity to observe, consider and record their ideas. Some children may wish to go further and they should be allowed to do so but fight your instincts to teach or extend the activities - just observe their responses and record their ideas. Systematic investigation will be encouraged during the intervention phase.

Class discussion, as has been mentioned by many of you, allows children to bounce ideas off each other and it's therefore not the most effective way of getting the children's own pre-existing ideas. Instead, we can use other methods which have worked well. Class discussion will no doubt be used during the intervention phase when we are actively encouraging children to reconsider their ideas.

Class Log-Books

These are books into which anyone can make an entry, either written or drawn, and they worked well in the first phase. They are not for investigations/experiments or results, only observations and comments/ideas. If entries can be named (and dated if possible) then the log-book is a valuable record of a child's reaction or observation.

A simple instruction like, "Have a look at these things, and there's a book here for you to write/draw anything you notice", is as explicit as necessary, though enouragement might also be required to maintain interest.

Drawings/Diagrams

These are best done when the children have had a chance to experience the activities for a period.

The main purpose of these is to give children a non-verbal way of expressing their ideas. It's not the drawing skills that are important, it's the ideas. If it's helpful, then children can add explanatory comments to their drawing. Where necessary and practicable, ask individuals to explain their drawings and add the explanation to the drawing yourself, either on the reverse of the paper, or on an attached sheet.

Exploration Experiences

These activities should be set up and left in the classroom for the children to have the opportunity to play with. The activities shouldn't be extended in any way by adding variables or changing conditions, and no measurements or 'results' need to be recorded.

STRING TELEPHONE

Equipment 2 yogurt pots, one knotted onto either end of a 4 metre length of string

An introduction could be something like: ''With a partner, hold one yogurt pot each and make sure the string is pulled tight between you. Take it in turns to whisper a message to each other (e.g. 'draw a house', 'write your name 5 times') and see how well you hear the message. Write down what you think you hear and then see if it was what your partner said.

DRUM

Equipment Drum, or tambourine
rice or silver sand
beater

Instructions, for example: beat the drum and listen to the sound it makes. Put rice/ sand on it and watch what happens when you beat it. Put your finger lightly on the drum when it is making a sound.

Draw pictures to show:

(a) how you think the drum makes a sound;

(b) how you think the sound gets from the drum to you so you can hear it;

(c) how you think you hear the sound.

PLASTIC LEMONADE BOTTLE-FUNNELS

Equipment Top of plastic lemonade bottle.

Put the funnel to one ear. Listen to the sounds around you. What difference does the funnel make?

Individual Drawing

Draw how the funnel helps you to hear differently.

RUBBER BANDS

Equipment Rubber band
fingers, pencils etc. to hook band around

Instructions, for example: "Stretch a rubber band between a thumb and a finger/ fingers and a pencil etc. Pluck it with your other hand and see what you notice. Can you play a tune?

LISTENING WALK

If possible, take the children on a walk around the school and/or grounds and get them to listen to the sounds around them.

Class Log Book

A 'Sounds' or 'Listening Book' in which children can write/draw about any of these activities, and also

(a) types of sound which they have heard recently;

(b) sound makers they have experienced recently.

Appendix 5

Appendix 5

Intervention guidelines: Growth research report appendix VI and unpublished ideas sheet; sound research report appendix V

Using children's ideas as the starting point for classroom activities

Aims

1. To work with the children's ideas, using them as a starting point for classroom activities.

2. To monitor and record your children's ideas.

3. To evaluate the different types of intervention which you try.

How you might go about it

1. Children have lots of ideas about a whole range of topic. Please don't tackle more than you feel you can manage. You might choose to

   (a) pick one area (e.g. metals, plant growth, evaporation/condensation) to explore with your class;
   (b) divide your class into groups with each group exploring a different area;
   (c) do something in between these.

Please hold a minimum of four sessions based upon this SPACE work which should incorporate at least three relevant activities from the ideas sheet. These will include one each of:

   1. Try out children's own ideas
   2. Vocabulary
   3. Generalisations

2. You have noted the ideas your class have already. It is important to see if and how these ideas develop through the intervention period. Pick at least one child for each intervention activity and look at how their ideas are influenced by the activity.

3. Your views on the success of the intervention activity are very important. Please evaluate briefly the different types of intervention which you try in terms both of their success in developing ideas and as class activities.

Support

We hope to visit every school once a week during the intervention. These visits are intended to help you, not to judge you. Please ring me up if you want to talk about anything.

	VOCABULARY	GENERALISATIONS	MAKE THE IMPERCEPTIBLE PERCEPTIBLE	TRY OUT CHILDREN'S OWN IDEAS	TEST THE RIGHT IDEA ALONGSIDE THE CHILDRENS'
	Collect examples & non-examples of the word. This may involve a literal collection of items or a range of different activities.	Use discussion as a means of finding out which events (if any) children see as related to each other or to past experiences and help children make cautious generalisations.	If the children's ideas are based on a change, which they can't observe happening, see if it's possible to make that change occur visibly.	Use children's ideas as starting points. Encourage them to test their ideas in a scientific manner.	It may be worth feeding in a suggestion based upon the scientific view if the children find their own ideas to be inadequate.
metals	rust - colour and corrosion metal dissolve	. what is a metal? . metals change in water . some metals change in water . the air changes the surface of many metals	Fine steel wool rusting with water on it.	How can you make something rust? How can you stop something rusting? What happens when something rusts? (steel wool will react most obviously)	. coat metal in vaseline/ school glue (something which can be removed to check the metal) . look for rusty things indoors/away from water.
moulding rotting	mould rot	. food moulds/rots if it is left in the air for a long time. . mould comes from something in the air.	Time lapse photography	What makes something mould? How can you stop something moulding?	Keep in a bag with most of the air sucked out.
desiccation	stale 'left out'	. something goes into the air . something goes from foods that are left in the air		What makes something go wrinkly? How can you stop something going wrinkly?	Rehydrate a dried sample (doesn't work if it is too dried up)
cooking	rises	. heat changes food irreversibly.	Use an oven with a glass door.		
burning	disappear melt	. heat changes things irreversibly			
pure water	disappear shrunk evaporate soak dry disintegrate	. water 'dries' into the air . different things can help the water evaporate, e.g. wind, heat. . what different forms can water take?		Where does the water go? What can make the water go?	What different forms can water take?
solutions	dissolve melt		water atomiser	coffee and water go.	Weigh solute before and after evaporation.
	condensation mist (a good alternative to condensation) steam smoke	comes from something in the air.		water comes from inside the can	. breath on warm and cold mirrors. . put ice into polystyrene cup . put empty can into fridge and bring it out into the room. . dye the iced water. . cover the can. . wrap the can in cloths.
	grow growth (involves a expand change of mass, enlarge volume and shape)	growth is continuous (human hair and nails) food becomes part of us			
	seed bean	all green plants need certain conditions to grow.	Measure a rapidly-growing species, e.g. maize, at the beginning and end of each day.	What do plants need to grow? How can you make seeds start growing?	Measure rapidly-growing species at beginning and end of each day. Grow same plant in different Grow different plants in same media.
		Some vegetables change into new plants if they are kept for a long time. The food in the potato is used up as the plant grows.			
	develop hatch		Monitor an egg's development through the shell - candling hen's egg or magnifying cabbage white butterfly egg.		

APPENDIX V

Teacher Guidelines for INTERVENTION (May 1988)

Timespan: April 25th - May 27th (5 weeks)

[Post-Intervention interviewing: June 6th - 24th]

The most important aspect of the Intervention will be the children carrying out investigations based upon questions which they would like to answer.

The children will obviously need help in turning their questions into investigations, and to help them, you and us in this process some starting points for investigations will be given. As before, children should be encouraged to decide on the particular investigation they want to do themselves, though it will be concerned with the activity you suggest to them, in the first instance. Please use these starting points, because it's important that all of the children have experiences of these fundamental concepts before they do more elaborate work. Obviously, some children are likely to be capable of more complex thought, while others will be stretched sufficiently by considering these basic activities. Remember, if children are at the stage of simply making observations then investigations involving imperceptible things are inappropriate.

Helping children to make generalisations

Another very important point is that the investigations are not seen as isolated activities but that children are encouraged to relate them to other experiences they have had. One possible route into this area is to pick up on the experiences which children use to interpret activities - for example, "It's like when you ride your bike down a hill".

- What makes it like riding a bike down a hill?
- Is there anything else that it's like?

Work on developing vocabulary

Children's everyday vocabulary seems to develop to include some words which scientists use to describe events. If children are using words like, for example, 'vibrate', it's important to establish what children mean by them. Try collecting examples of situations when words are used, and also alternative words that different children are using to mean the same thing. This again can't be done in isolation from activities such as investigation - words are used in a context, and **when** words are used is an integral part of the word.

There are certain observations which it would be beneficial for children to have made accurately in order to give them a firm foundation from which to investigate. If possible try to encourage children to pay careful attention to their activities.

To summarise, base your intervention work around children trying out their ideas in investigations.

(1) **Trying out the children's ideas**

Start from simple investigations and pursue them scientifically. Encourage

- predictions
- careful planning
- careful observation
- considered conclusions

(2) **Vocabulary**

This is an integral part of other activities, and should be considered in this context.

- Establish common, agreed definitions for important words which children are using, particularly if they are scientific words.
- Collect alternative words which different children are using to mean the same thing.
- Use the above two to try to encourage children not to use an unsuitable word when you can suggest an alternative, everyday word which is better.

(3) **Generalisations**

This is an integral part of other activities. Look for ways to draw links between the activities and children's experiences, possibly through the way children explain what happens in their investigations/observations.

(4) **Observation**

Use any appropriate opportunities which arise to encourage children to extend their skills of observation, to help them build up their bank of background knowledge and experience.

(5) **Recording**

Please find an appropriate form in which children can record their work. It would be very valuable for us to be able to have this work after the intervention, or at least a copy of it.

Appendix 6

Appendix 6

An informal look at children's ideas: Sound research report pp. 9-52

3. CHILDREN'S IDEAS

Part 1: An informal look at children's ideas

The children in each of the classes participating in Project work were asked by their teachers to record their ideas about sound. Their recorded ideas were responses to questions which were in some cases suggested by the Project team and in other cases posed by the teachers themselves. The teachers of infants accumulated most of their information in the form of notes made during discussions with pupils while the teachers of juniors made more use of individual diagrams. The ideas contained in these diagrams have been categorised in a manner compatible with the analysis of the interviews, and frequency counts have been performed. Where percentage figures are given the sample size is stated alongside them.

The children's drawing and writing provided a very rich source of data regarding children's ideas, and they allowed access to aspects of the topic which were difficult to probe in individual interview. For example, some insight was provided into children's representations of sound, and into their perceptions of the practical activities with which they were involved.

This section considers children's ideas about sound under the following headings:

3.1.1 What is sound?

a. the perceived association between sound vibrations.
b. the causal relationship between sound production and vibrations.
c. the recognition of attentional effects in hearing.

3.1.2 The production of sound

a. Explanations in terms of physical attributes and conventional usage of objects.
b. Explanations in terms of the application of a force.
c. Locations and mechanisms for sound production: the role of vibrations.
d. The development of a generalized concept of sound production.

3.1.3 The transmission of sound

a. Explanations in terms of attributes of the listener and the sound producer.
b. Sound 'travels'.
c. Sound travel in the absence of media.
d. Sound travel through string.
e. Sound travel through air.

3.1.4 *The reception of sound*

a. Sound reception by the ear.
b. The funnel as a sound box.
c. The effects of pressure and compression of sound.

3.1.5 *Children's representations of sound*

3.1.6 *Vocabulary used in association with sound*

3.1.7 *Summary*

3.1.1 *What is sound?*

a. The perceived association between sound and vibrations

Sound is something which cannot be seen directly but which can be experienced through vibrations in the media of hearing, seeing and touching. It is a phenomenon which is accessible to every child through at least one sensory modality. Children can have experiences both of producing sounds and of receiving them since sound is produced, transmitted and received as vibrations through particular media. There is an inextricable link between sound and vibrations which is there for children to observe and incorporate into their constructs, and children made different degrees of association between sound and vibration.

Many young children did not suggest any association between movement or vibration in the sound producer.

Fig. 3.1

(Age 6 years)

"The drum stick makes the sound."

The example given in Fig. 3.1 shows how the child considered the action of the drumstick hitting the drum to be sufficient to generate the sound. The rice which was on the skin of the drum and could have led children to observe the skin vibrating was either ignored by children of this age or was itself made the focus of attention, implicated in sound production to the exclusion of the stick or drum.

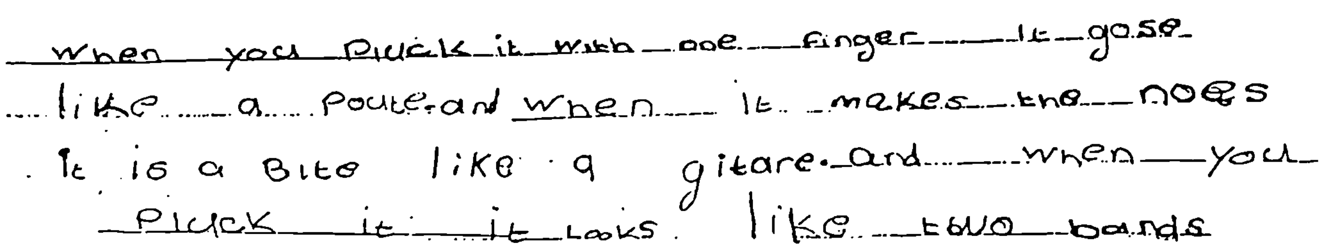
Fig. 3.2

(Age 7 years)

"The rice is going up and down to make the sound."

The plucking of a rubber band provided an interesting example of perceptible vibrations and half of the infant and lower junior children (n = 54) observed and commented on the movements of the band. These comments were not, however, related to sound production.

Fig. 3.3



(Age 6 years)

"When you pluck it with one finger it goes like a ? and when it makes the noise it is a bit like a guitar and when you pluck it it looks like two bands."

It is possible that these children had not yet had wide enough experiences of vibration in the context of sound production for them to find it helpful to associate the two events. Fig. 3.4 is an example of a child who had started to form such an association.

Fig. 3.4

(Age 7 years)

"It makes a tune because the box is long. When you pull it back (elastic band) it shivers. When it stops making a noise it doesn't move."
(Teacher's note)

b. The causal relationship between sound production and vibrations

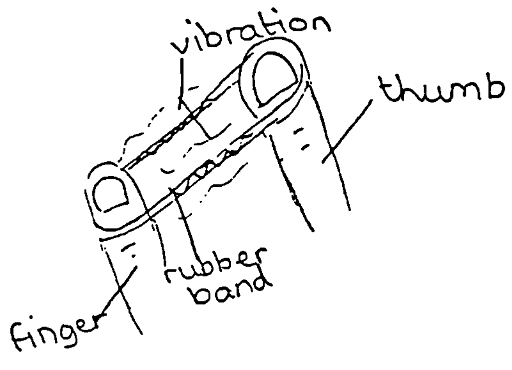
Children who had made an association between sound production and vibration did so in several ways, and it seems likely that the context of the observations might have influenced the link that was made. Links between sound and vibration were often suggested in terms of cause and effect, so that sound was either caused by vibration, or vibration was caused by sound. A small number of children thought that vibrations and sound were the same thing. Very few responses linking sound and vibration were made by children in the two younger age groups, infants and lower juniors.

i. Vibrations cause sound

Of the range of activities with which children interacted, the rubber band provided the context which generated the most mention of sound being caused by vibrations (32% of upper juniors, n = 31) and this link was made by more girls than boys (47% of girls, 14% of boys).

Fig. 3.5

When I hold the rubber-
band between my thumb
and my finger and then
pluck it, the vibration of
the rubberband makes a
noise, and I think that
that is how you can
hear them.

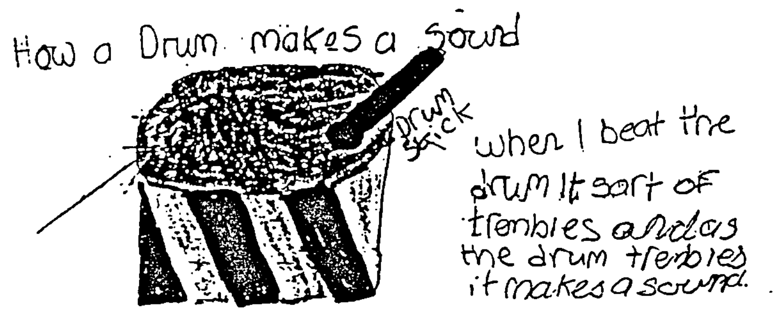


(Age 9 years)

"When I hold the rubber-band betwen my thumb and my finger and then pluck it, the vibration of the rubber band makes a noise, and I think that that is how you can hear them."

Children were directly involved in generating movement in the band by stretching and releasing it so this might have been another factor, together with the perceptibility of the vibrations, which encouraged children to mention this idea. Children's ideas concerning the drum also tended to suggest that vibrations caused sound, though some children did suggest that sound caused vibrations.

Fig. 3.6



(Age 10 years)

"When I beat the drum it sort of trembles and as the drum trembles it makes a sound."

Sound causing vibrations was the more common explanation given for the string telephone and the vibrations seemed to be associated with the sound travelling rather than the sound being produced. This could have been due to the nature of the activity, which exemplified sound transmission and children might not have focused their attention on the production of speech.

Fig. 3.7

Your voice g turns into sound vibrations and they travel along the string into the other yoghurt pot so the other person can hear it.

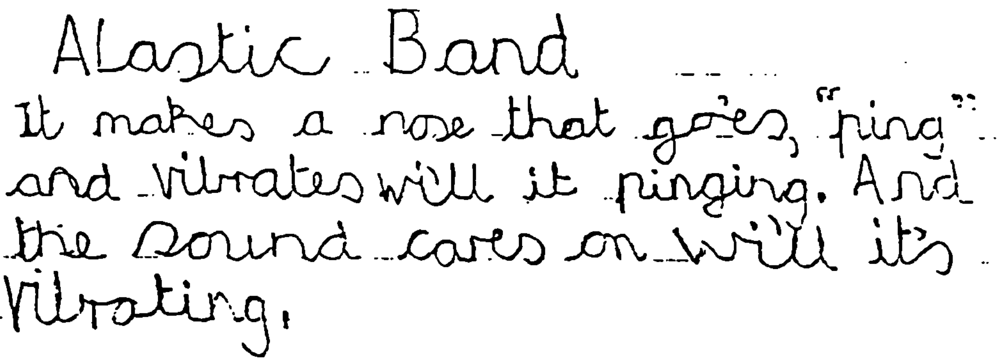
(Age 9 years)

"Your voice turns into sound vibrations and they travel along the string into the other yoghurt pot so the other person can hear it."

ii. Sound is vibrations

Some children's writing and drawing seemed clearly to suggest that sound and vibrations could not be separated.

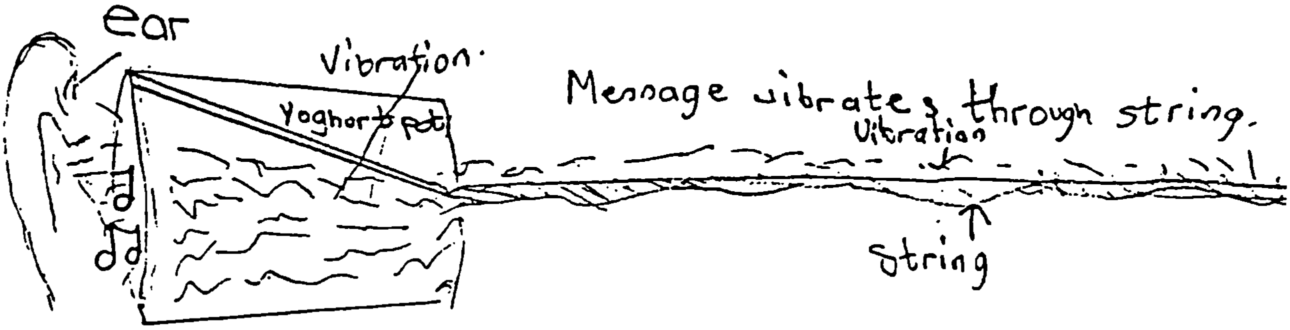
Fig. 3.8



(Age 7 years)

"Elastic band. It makes a noise that goes 'ping' and vibrates while it's pinging. And the sound carries on while it's vibrating."

Fig 3.9

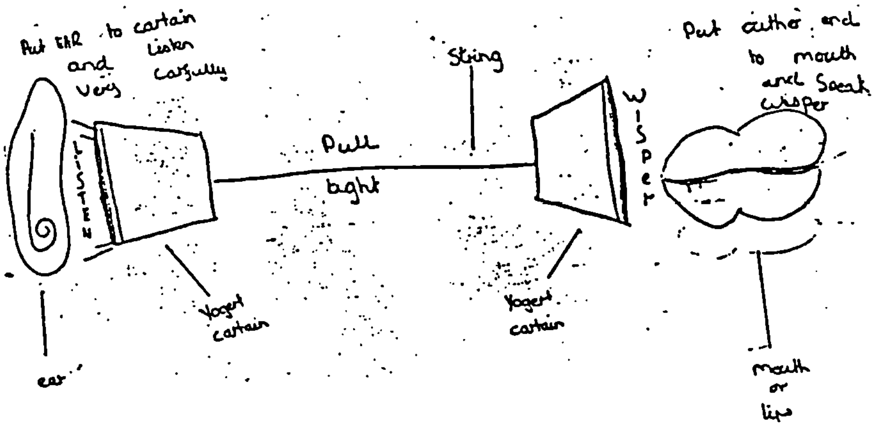


(Age 10 years)

c. *The recognition of attentional effects in hearing*

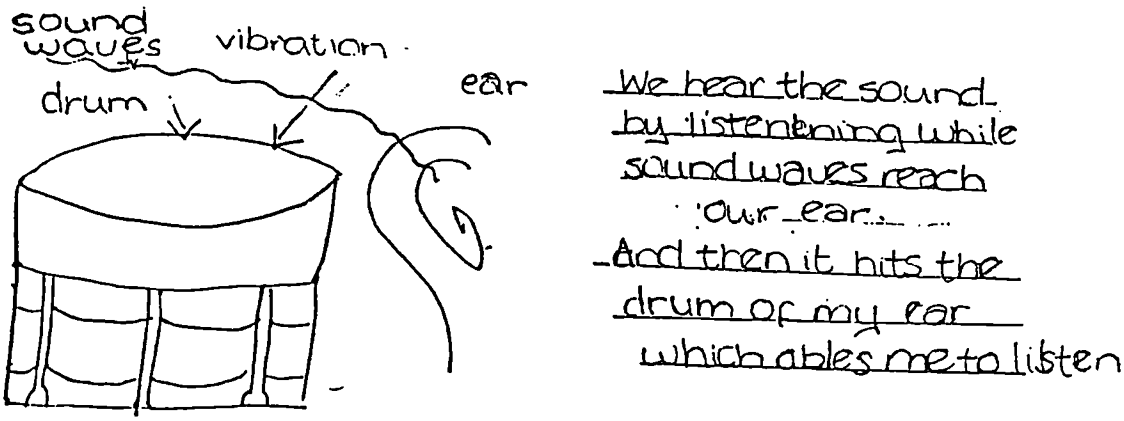
There is an etymological distinction between hearing and listening, and it is a distinction which a small number of children in each age group emphasised in their answers to questions about how they heard: they asserted that they heard because they were listening. This emphasis on the need for the hearer to be attending to the sound was sometimes given as a complete explanation for hearing (Fig 3.9). However, it was often an accurate and valid comment as a component part of a more complex response (Figs. 3.10, 3.11). The psychological model of 'active listening' shows an awareness of the effects that concentration and attention play in hearing.

Fig. 3.10



(Age 9 years)

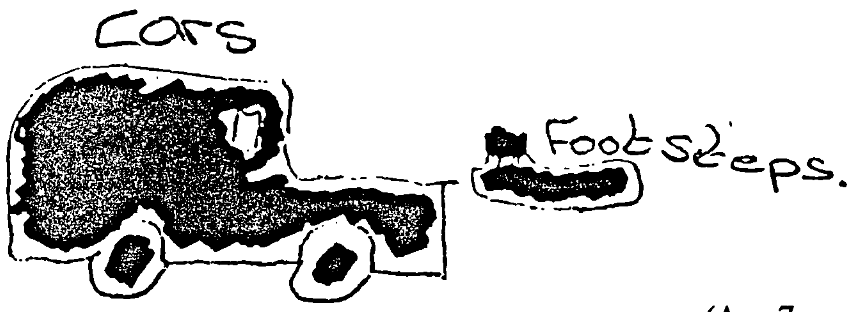
Fig. 3.11



(Age 10 years)

"We hear the sound by listening while sound waves reach our ear. And then it hits the drum of my ear which ables me to listen."

Fig. 3.12



(Age 7 years)

"The noise goes through the air to people who are listening. If they're not listening they'll only hear a bit of it and not all of the sound."
(Teacher's note)

3.1.2 The Production of Sound

In order for a sound to be produced by an object, the object must vibrate. Vibrations are caused by an input of energy, often a physical action which results in an observable impact. There are, therefore, many contingent variables related to sound production which can be observed by children. Some involve gross features of the system such as the impact, the implement, the action delivering the hit or physical attributes of the sound producer. Other observations may be of less obvious characteristics, such as vibrations. The ideas which a child has about sound production are likely to relate to the range and quality of their experiences and observations.

a. Explanations in terms of physical attributes and conventional usage of objects

Many younger children appear to consider that sounds occur because they know about the conventional usage and physical attributes of particular objects. For example, a drum makes a noise because of the stick (Fig. 3.13), or because it is made of plastic.

Fig. 3.13

The drum made the sound
and the stick the drum noise

(Age 6 years)

"The drum made the sound and the stick the drum noise."

Fig. 3.14

I think the drum makes a
sound because it is hollow and it
echo's

(Age 7 years)

"I think the drum makes a sound because it is hollow and it echo's."

Fig. 3.15

The drum makes a soud
because of the bang it
makes.

(Age 7 years)

"The drum makes a sound becuase of the bang it makes."

Children had similar ideas about the rubber band which was thought to make a sound because of the composition of the band and properties of the rubber (Fig. 3.16).

Fig. 3.16

"It's because it's thin elastic. It flicks up and down when you let it go." (Teacher's note)

(Age 7 years)

The degree of tension in the rubber band or the drum head was also related to the pitch of the note produced. The number of children expressing this idea increased with age to approximately one quarter of the upper junior sample (n = 31) for the rubber band. In the rubber band activity children were asked whether they could play a tune on the band, and this might have encouraged more children to attend to the variables of tension and pitch. Fig. 3.17 shows the only child to have mentioned the word 'pitch'.

Fig. 3.17

I noticed that when I plucked the rubber band it made a low noise. If I streched the band tighter the pitch of the noise was higher. The more I stretched the higher the noise became.

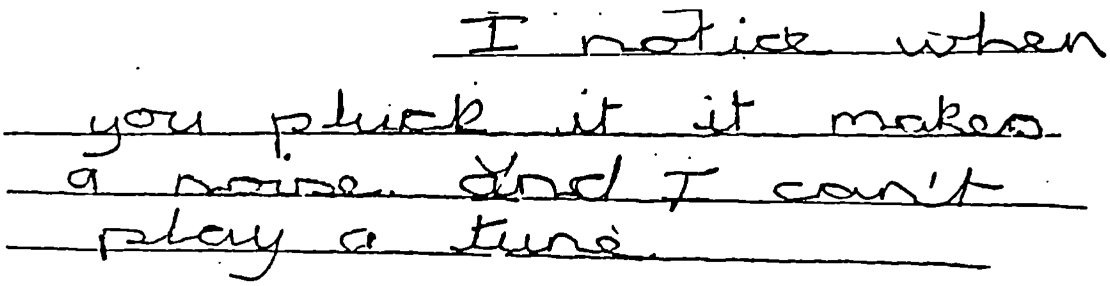
(Age 9 years)

"I noticed that when I plucked the rubber band it made a low noise. If I stretched the band tighter the pitch of the noise was higher. The more I stretched the higher the noise became."

b. *Explanations in terms of the application of a force*

As illustrated by Figs. 3.18 and 3.19, the force used to generate the sound from the instrument was often commented upon. Such explanations made an attempt to suggest a mechanism of sound production. The statements were related to observations which the children had made.

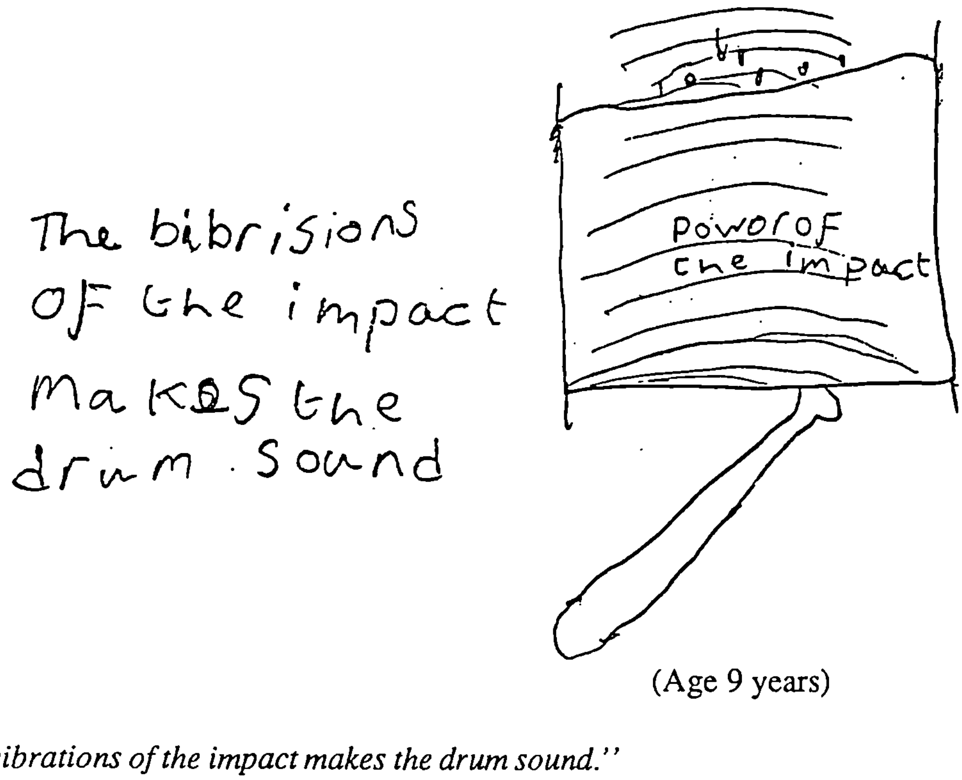
Fig. 3.18



(Age 7 years)

"I notice when you pluck it it makes a noise and I can't play a tune."

Fig. 3.19



(Age 9 years)

"The vibrations of the impact makes the drum sound."

c. Locations and mechanisms for sound production

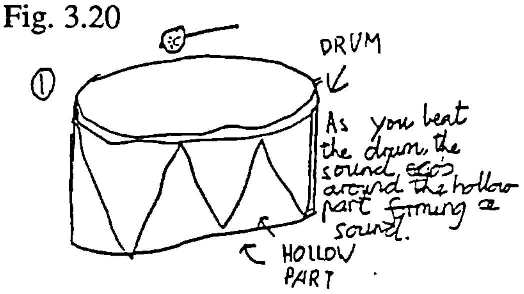
Mechanisms by which a drum produces sound were suggested by a number of children. The proportion of children suggesting a mechanism increased with age from 13% of infants (n = 24) to 98% of upper juniors (n = 84). The mechanisms involved two possible locations for sound generation: inside the drum and at the surface of the drum.

A variety of mechanisms of sound production was mentioned to explain the process of making sound at each location.

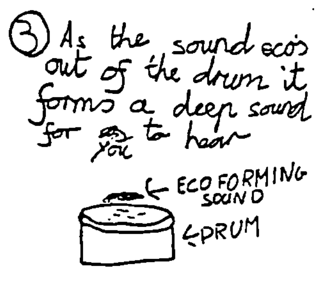
i. Sound generation inside the drum

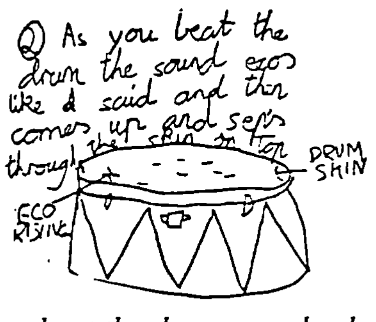
Of the children suggesting a mechanism, inside the drum was the location suggested by all of the infants and just over one third of juniors. The most common ideas were that the sound inside the drum 'echoed around' (Fig. 3.20) or that the inside of the drum vibrated. Alternatively, the inside of the drum was thought to make a sound when it was compressed by the impact lowering the drum head (Figs. 3.21 and 3.22). The existence of air inside the drum was mentioned by some upper junior children (Fig. 3.22). It is unclear whether the air was thought to fill the inside of the drum, or whether it was a convenient label for what was really thought to be an empty space.

Fig. 3.20



"As you beat the drum, the sound echoes around the hollow part forming a sound."



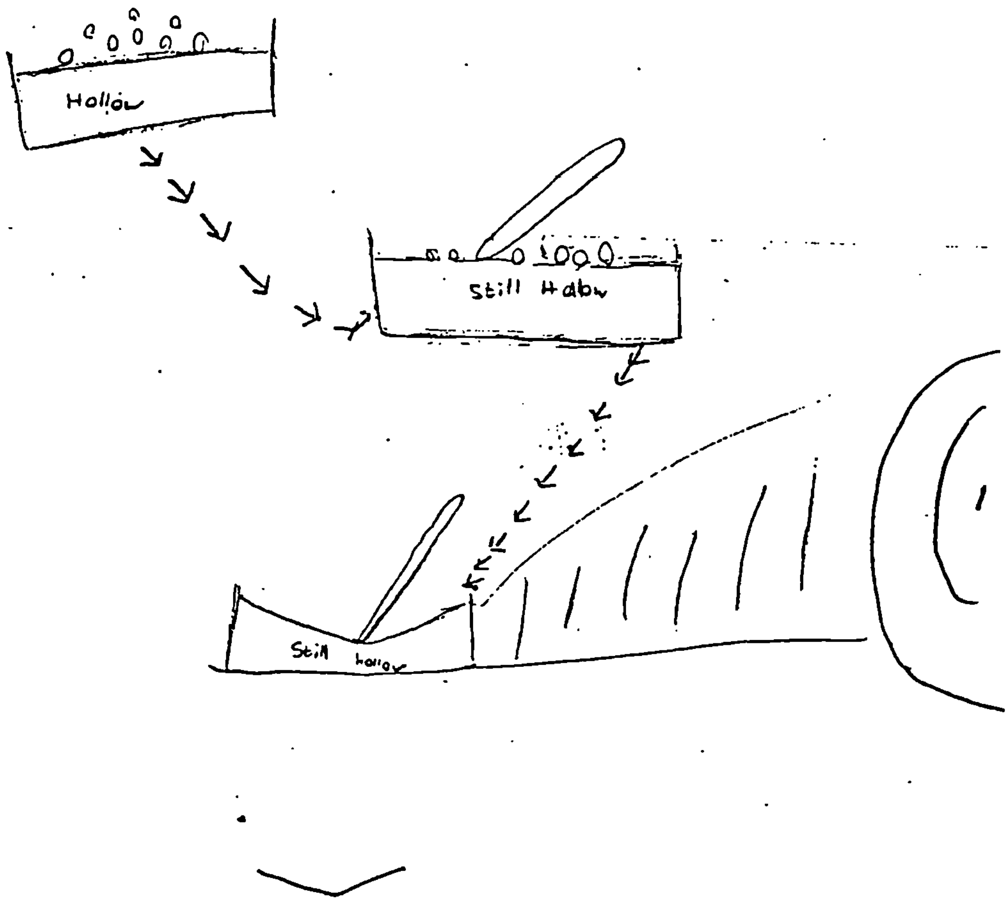


"As you beat the drum sound echoes like I said and then comes up and seeps through the skin on top."

"As the sound echoes out of the drum it forms a deep sound for you to hear".

(Age 10 years)

Fig. 3.21

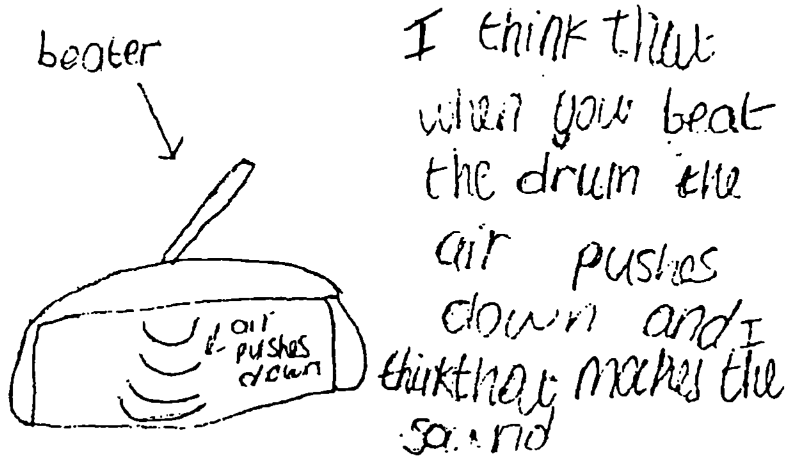


when it goes in we here
the vibration

(Age 9 years)

"When it goes in we hear the vibration."

Fig. 3.22



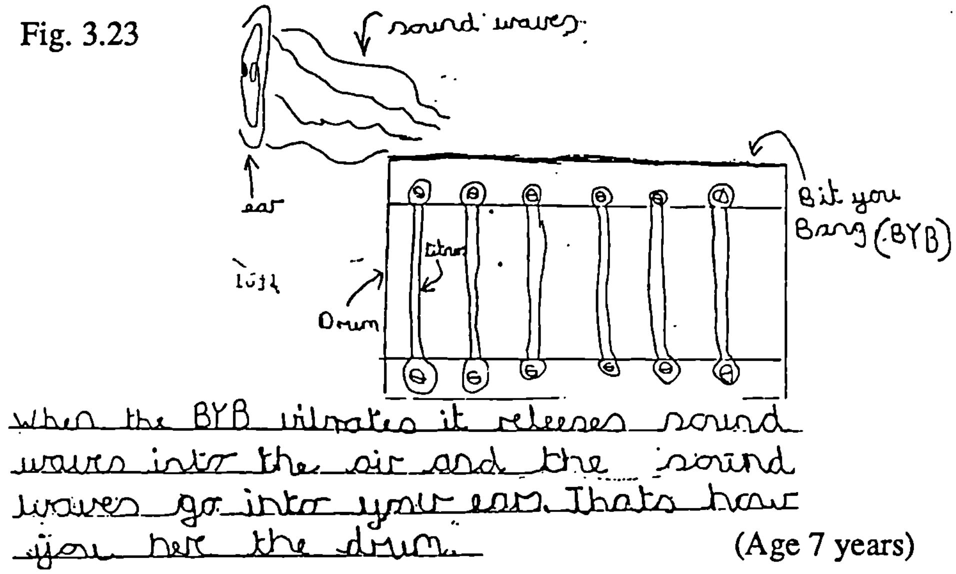
(Age 10 years)

"I think that when you beat the drum the air pushes down and I think that makes the sound."

ii. Sound generation at the surface of the drum

The surface of the drum as the location of sound production was suggested by two thirds of juniors. The most common mechanism was that the drum head vibrated (Fig. 3.23). This explanation, while accurate, was only rarely accompanied by any mention of any other vibrations, e.g. sound waves.

Fig. 3.23

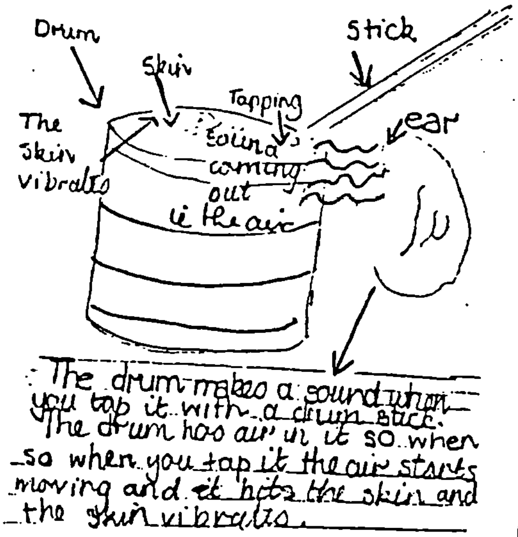


(Age 7 years)

"When the BYB vibrates it releases sound waves into the air and the sound waves go into your ears. That's how you hear the drum."

Some children suggested that the air inside the drum caused the drum head to vibrate (Fig. 3.24).

Fig. 3.24

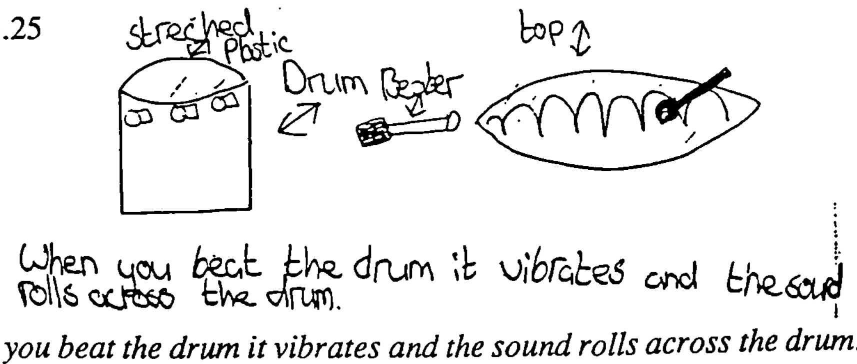


(Age 10 years)

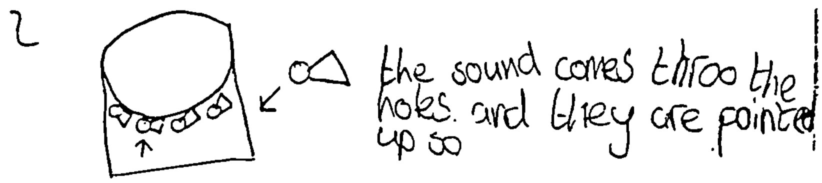
"The drum makes a sound when you tap it with a drum stick. The drum has air in it so when you tap it the air starts moving and it hits the skin and the skin vibrates."
(Some teacher annotation)

Other children suggested that the sound came straight off the drum surface. Fig. 3.25 might be an attempt to articulate the fact that the head vibrated, though Fig. 3.26 appears to contain no suggestion that the drum head did anything other than deflect the sound upward after the blow from the stick.

Fig. 3.25



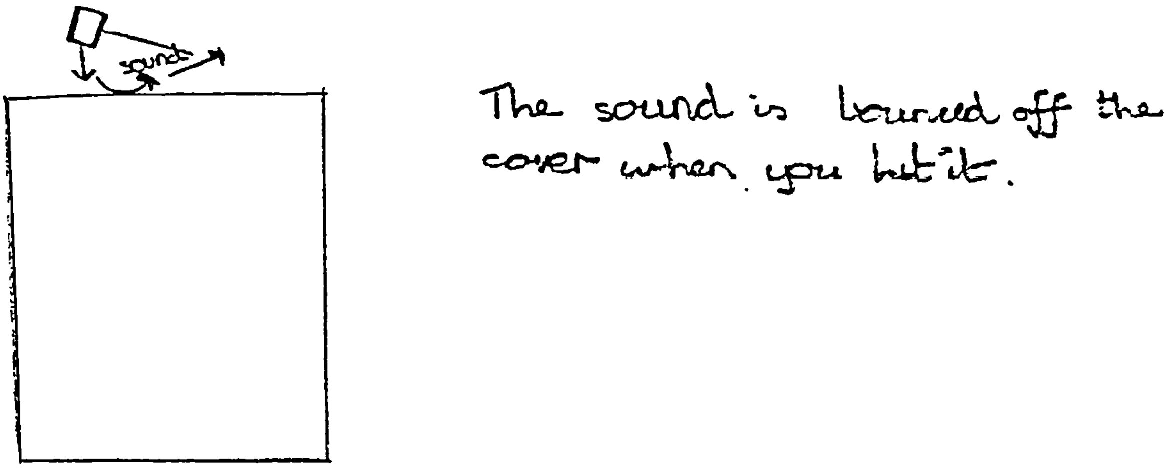
"When you beat the drum it vibrates and the sound rolls across the drum."



(Age 10 years)

"The sound comes through the holes and they are pointed up so."

Fig. 3.26



(Age 10 years)

"The sound is bounced off the cover when you hit it."

iii. Sound generation involving the surface and the inside of the drum

A mechanism was described in which the sound appeared to start at the surface of the drum and then to move downwards through the drum until it reached the bottom. It then either came out of the bottom of the drum (Fig. 3.27) or was deflected back up and out of the top (Fig. 3.28). A further, connected elaboration suggested that the drum head was made to vibrate by the sound as it passed from the inside of the drum, out through the head (Fig. 3.29).

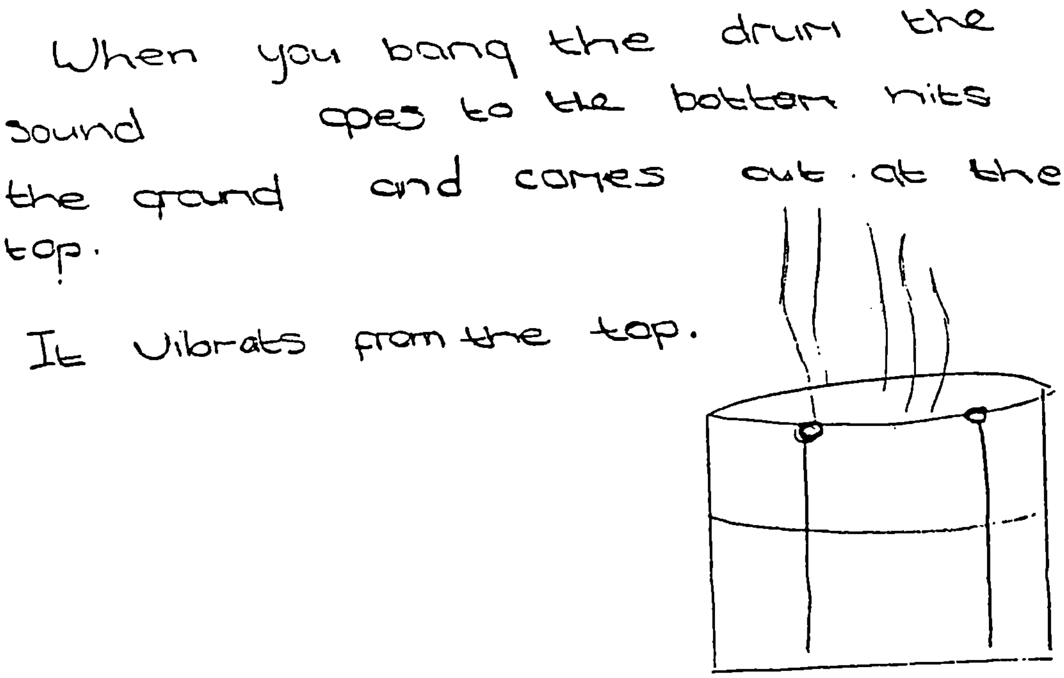
Fig. 3.27

The strings underneath make the sound. –
they vibrate
When you hit the top of the drum the noise
goes through the drum and makes strings vibrate
There is nothing in the drum

(Age 7 years)

"The strings underneath make the sound - they vibrate.
When you hit the top of the drum the noise goes through the drum and makes strings vibrate.
There is nothing in the drum."
(Teacher annotation)

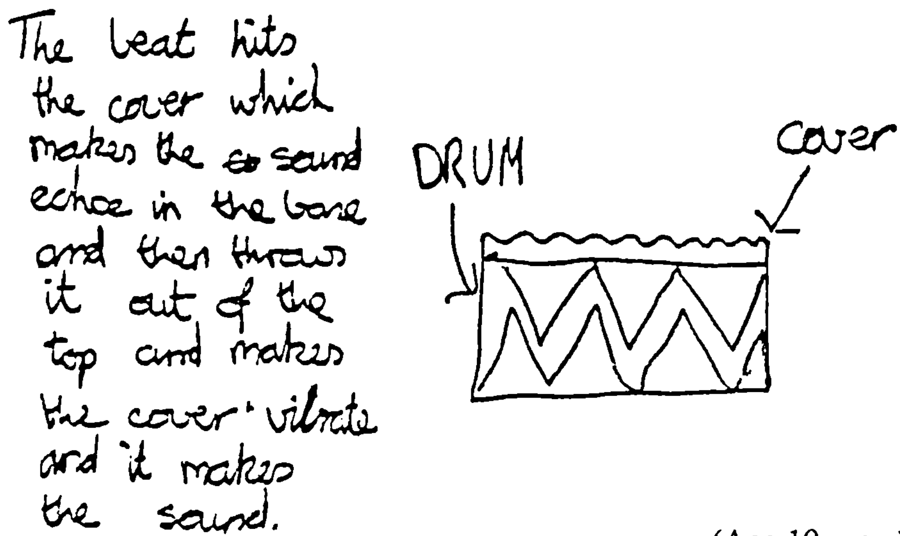
Fig. 3.28



(Age 10 years)

"When you bang the drum the sound goes to the bottom, hits the ground and comes out at the top. It vibrates from the top."

Fig. 3.29



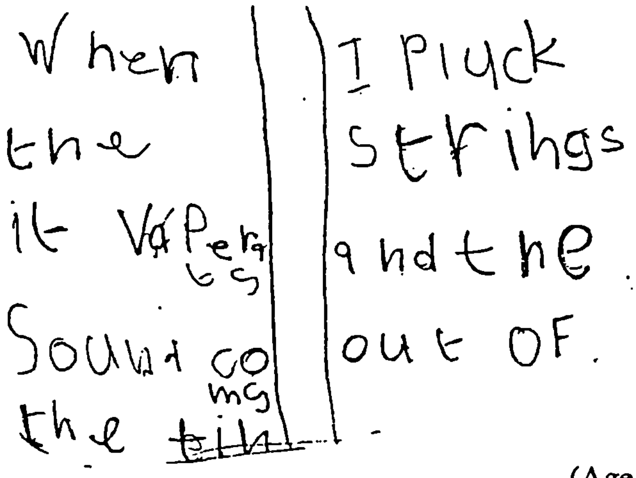
(Age 10 years)

"The beat hits the cover which makes the sound echo in the base and then throws it out of the top and makes the cover vibrate and it makes the sound."

The mechanisms suggested in Figs. 3.27 to 3.29 could be considered to have much in common with a conventional explanation for sound production. However, air was not mentioned and it is possible that the sound was regarded as a discrete entity rather than as vibrations travelling through a medium.

There are few obvious parallels between the mechanisms suggested for the production of sound from a drum and those from a rubber band, possibly because the rubber band does not have a built-in resonating chamber. The similar mechanisms which were found were given by children who stretched their elastic bands round a box before plucking it (Fig. 3.30). The rubber band which was plucked without using a box generated only a small range of ideas, all related to vibrations travelling round the band (Fig. 3.31). The vibrations were sometimes suggested to turn into sound when they came into contact with something, for example the pencil or the thumb, which was keeping the band stretched. Children seem to have used observations made in a range of sense modalities to influence their ideas.

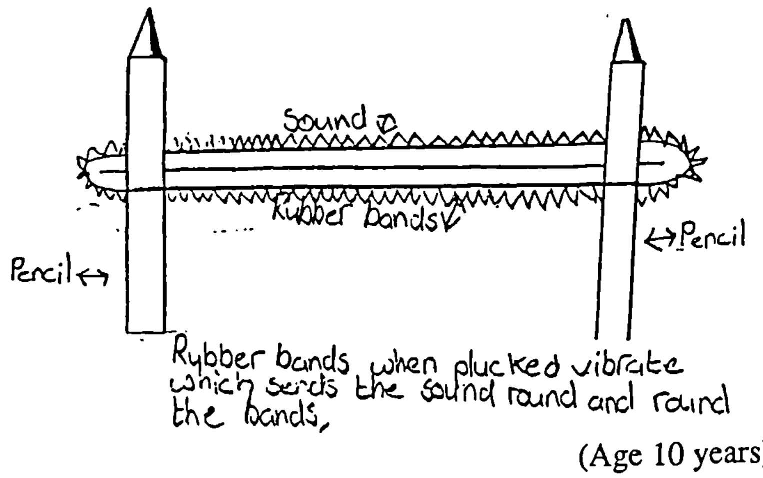
Fig. 3.30



(Age 7 years)

"When I pluck the strings it vibrates and the sound comes out of the tin."

Fig. 3.31



(Age 10 years)

"Rubber bands when plucked vibrate which sends the sound round and round the bands."

The specific mechanisms which children suggested for sound generation appeared to be context-specific, with the rubber band responses being different from the drum. In principle, though, there were common groups of response, making reference to physical attributes of the object, to the force needed to generate sound or to vibrations.

d. *The development of a generalised concept of sound production*

Fig. 3.32 shows how one child has made a generalized observation from his experiences of the production of sound.

Fig. 3.32

Nearly every thing you hit makes
a Sound

(Age 7 years)

"Nearly every thing you hit makes a sound."

This statement is interesting since it contains a generalization which suggests that objects can be made to make a sound by hitting them. This generalization between experiences was not very common and more children focused upon the physical attribute of a specific object when offering an explanation for sound production.

Fig. 3.33

When you hit the drum it makes a
noise that is because the skin is stretched
Out.

(Age 10 years)

"When you hit the drum it makes a noise that is because the skin is stretched out."

Fig. 3.32 and Fig. 3.33 show contrasting approaches to the problem of understanding why objects make sounds. In Fig. 3.32 the child has observed that there is a relationship between hitting things and their making sounds. There is no evidence of any ideas about why there might be exceptions within this relationship, for example related to the tension in the object. The child whose work is represented in Fig. 3.33, on the other hand, has observed the need, in a specific case, for tension to be present in order to make a sound. There is no evidence that this child has generalised this necessary condition to other sound makers. It would be possible to speculate about whether starting from a generalised statement and determining the exceptions to the rule, or generalising from a specific example would be more profitable than the other in terms of the conceptual development which could be promoted.

3.1.3 Transmission of Sound

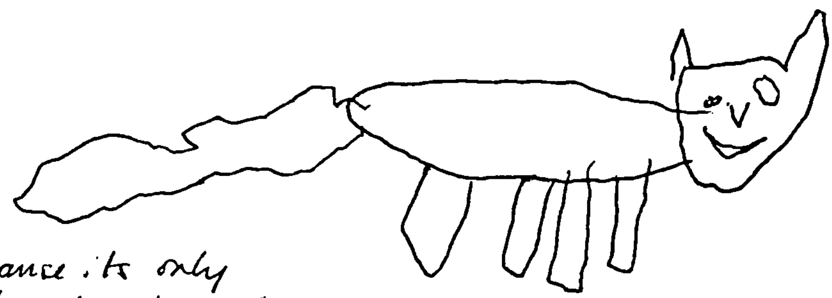
a. Attributes of the listener and the sound producer

In describing how hearing is possible, many younger children referred both to attributes of themselves as listeners and to attributes of the sound producers without mentioning sound travelling. These attributes were:

- . proximity
- . volume
- . attentional factors
- . attributes of the Exploration activity

Fig. 3.34 for example, shows dogs barking across a road. The child whose drawing this was said they could hear the dog because of its proximity and the volume of the bark.

Fig. 3.34



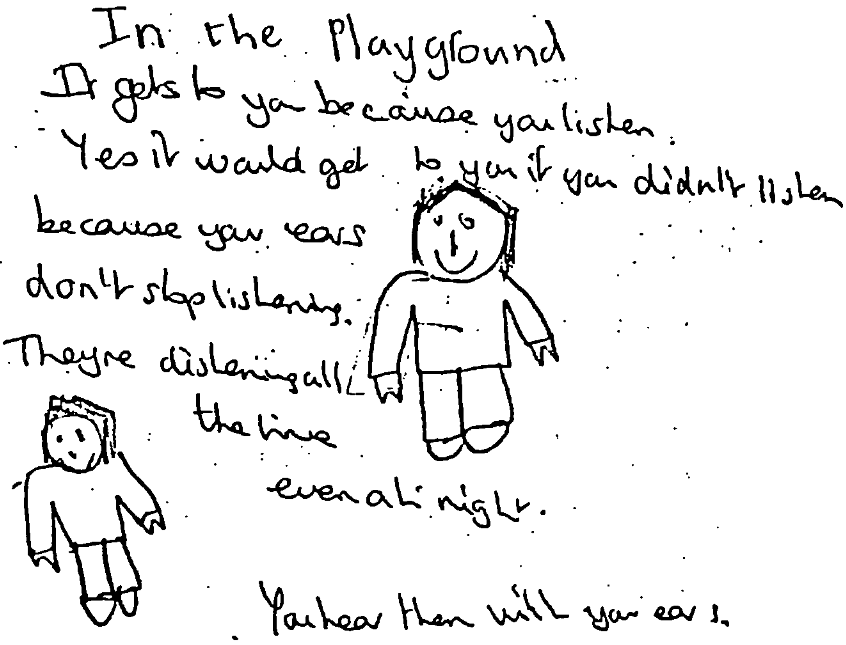
It gets home because its only across the road and it barks loud.
you hear them with your ears.

(Age 7 years)

"It gets home because it's only across the road and it barks loud. You hear them with your ears." *(Teacher annotation)*

The range of playground noises in Fig. 3.35 was thought to be heard by means of ears, because ears listen all the time. This response is another example of 'active listening', the particular psychological perspective on hearing which seems to be held by certain children.

Fig. 3.35



(Age 7 years)

"In the playground. It gets to you because you listen. Yes it would get to you if you didn't listen because your ears don't stop listening. They're listening all the time even at night." (Teacher annotation)

In order to suggest any of these explanations children needed to make observations, all of which would be relevant to the notion of sound travelling and would not be inconsistent with an explanation that incorporated transmission. However, these children have not extended their ideas to include an explicit mention of sound travelling.

b. Sound 'travels'

A large number of children did consider sound to travel, and a variety of pathways through which the sound could travel were mentioned. The explicit suggestion that sound went from one place to another was sometimes not elaborated further, as shown in Fig.3.36

Fig. 3.36

When you bang the drum the sound goes in your ear

(Age 7 years)

"When you bang the drum the sound goes in your ear."

This response was often linked with the word 'travelled' suggesting that 'sound travelling' might have been a phrase which children had encountered in a formal learning situation.

c. Sound travel in the absence of media

A substantial number of lower junior children who did specify a pathway for the sound suggested that it could only travel when there was nothing in its way to impede it. For example, rather than travelling through a medium such as the air or the string on a string telephone, the sound went through cracks around doors and windows, or through holes in the yogurt cartons of the telephone. Thus the sound had to be without a medium in order to be able to travel. The example in Fig. 3.37 shows how a child considered the message to go through the string telephone via a hole in the centre of the string. The notion that the sound needed to travel along an unimpeded path was also mentioned in Fig. 3.38 in connection with the drum. The sound was thought to leave the drum through a hole in the side of the drum.

Fig. 3.37

There might be a hole in the strng. and it goes throgh.

(Age 7 years)

"There might be a hole in the string and it goes through." (Teacher's annotation)

Fig. 3.38

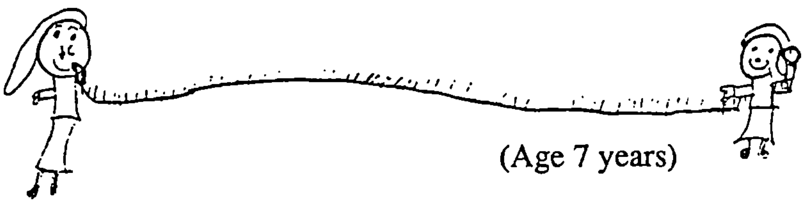
when you bang the drum
there is a hole at the side to let the
bang out

(Age 6 years)

"When you bang the drum there is a hole at the side to let the bang out."

Fig. 3.39

When the string is pulled tight the
sound Kelly makes sort of jumps along
the string.
Sound jumps along string goes into cup
and then into your ear



(Age 7 years)

"When the string it pulled tight the sound Kelly makes sort of jumps along the string. Sound jumps along string goes into cup and then into your ear."
(Teacher annotation)

The notion of the need for an unimpeded pathway for sound travel might be intuitively linked with other experiences of travelling, since movement would be impeded by anything in the path of a moving object. It is possible that sound was envisaged as an invisible object with dimensions whose passage from source to receiver needed space. Children's notions of the nature of air also have a bearing here, since it would be possible for 'air' simply to be a label for the empty space around rather than implying a colourless, odourless substance with mass, volume and density. Were this the case, mention of sound travelling through air would also be an example of sound moving through an empty space rather than through a medium.

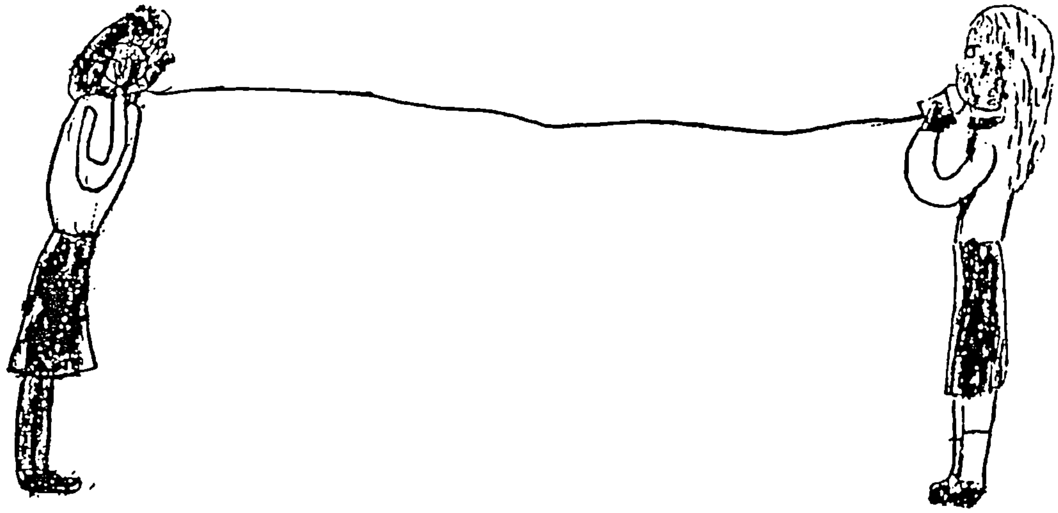
Figs. 3.37 and 3.39 illustrate two differing views about the role of the string in the string telephone. The advantages to these children of having the string are not clear but it does not appear to be perceived as a medium for transmission.

d. Sound travel through string

Many children did seem to consider the presence of a string, the explicit link in the string telephone between sound source and receiver, to explain the sound travelling. The number of children who expressed the idea of a medium through which sound travelled was greater with this activity than any other, with one third of the lower juniors (n = 34) and a half of the upper juniors (n = 40) responding in this way.

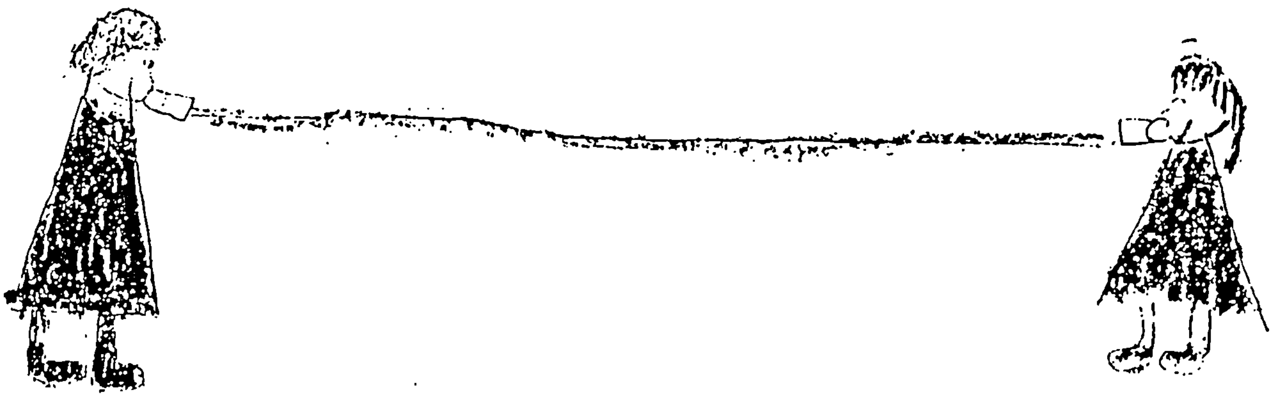
A detailed inspection of the children's drawings of themselves using the string telephone revealed large differences between upper and lower juniors. Over half of the lower juniors drew pictures in which their portrayal of the string telephone suggested an arrangement of the apparatus which would not carry a message from one person to another (Figs. 3.40, 3.41).

Fig. 3.40



(Age 7 years)

Fig. 3.41



(Age 7 years)

This age-related difference in the accuracy of representation is ambiguous and could imply that the younger children's drawing skills were less developed or that the importance of accuracy was not perceived. Alternatively, there could be a difference in the perceptions of the role of the string between upper and lower juniors. The portrayal of two children facing each other (Fig. 3.40), of communicating through a slack string and of sending and receiving messages with both cups to the mouth (Fig. 3.41) and other responses which showed inaccurate representations of the string telephone and the two communicators were common only in the lower junior age range. This could suggest that children of that age have had sufficient experiences of sound to suggest that the string is responsible for carrying the message, but that they might not have been aware of which properties of the string were necessary conditions for it to transmit sound. Upper juniors expressed ideas which clarified these necessary properties by stating when the string telephone system would not work and thus also when it would (Fig. 3.42).

Fig. 3.42

When it was stack I could not here Johnathan but when it was pulled ~~tat~~ tiet I could here him. I think it did that because the vibration can not move down.

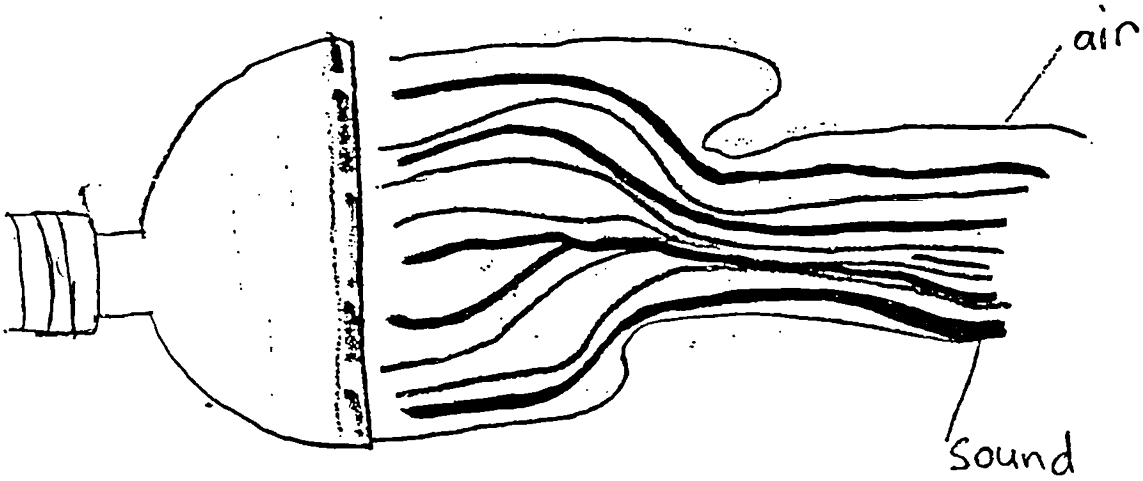
(Age 10 years)

"When it was slack I could not hear Jonathan but when it was pulled tight I could hear him. I think it did that because the vibration cannot move down."

e. *Sound travel through air*

The other Exploration activities elicited far fewer mentions of sound travelling through a medium, and the predominant view, particularly amongst lower juniors, was that sound needed to travel without a medium so that its passage was unimpeded. The air was mentioned by a small number of children but it was, in many cases, unclear whether the air was considered to be a medium or a space. Some children have attempted to portray air and sound entering the 'funnel' ear trumpet (Fig. 3.43), thus clarifying their intentions.

Fig. 3.43



(Age 7 years)

Whether the transmission of sound through the medium of air is intuitively accessible to children, or whether it is an idea which has been acquired from secondary sources is not clear. The example in Fig. 3.44 is suggestive of the 'bell jar and alarm clock' demonstration in which the bell jar is gradually evacuated, making the alarm clock inaudible.

Fig. 3.44

I think I heard that speacial sound
because the rubber band vibrates in
the air and if it was in a little
space and hardly no air it would
have a lower and duller sound.

(Age 9 years)

"I think I heard that special sound because the rubber band vibrates in the air and if it was in a little space and hardly no air it would have a lower and duller sound."

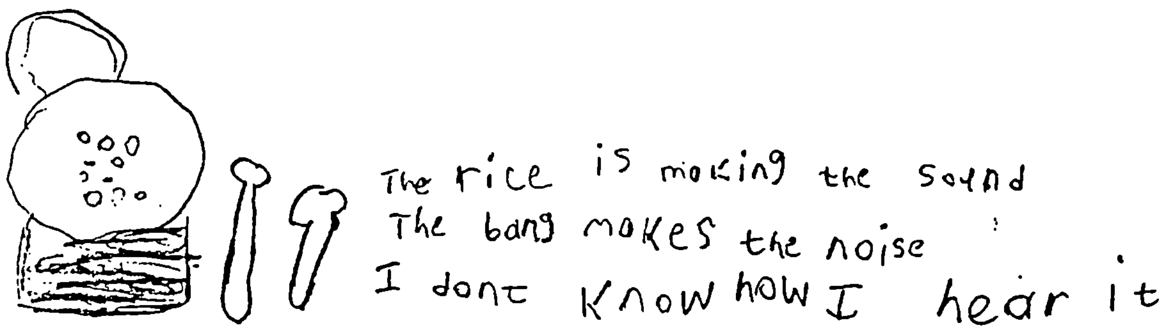
3.1.4 The Reception of Sound

Children's ideas about the reception of sound provided information about two distinct processes: the manner in which the ear received sound, and the process by which sounds were perceived once they had entered the ear. These two processes will be discussed in turn.

a. Sound reception by the ear

Children of junior age were more likely than infants to refer to their ears as the part of their body which was involved with receiving sound. Figs. 3.45 and 3.46 are examples of responses from younger children who either indicated no understanding of sound reception or who explained it without mentioning the ear.

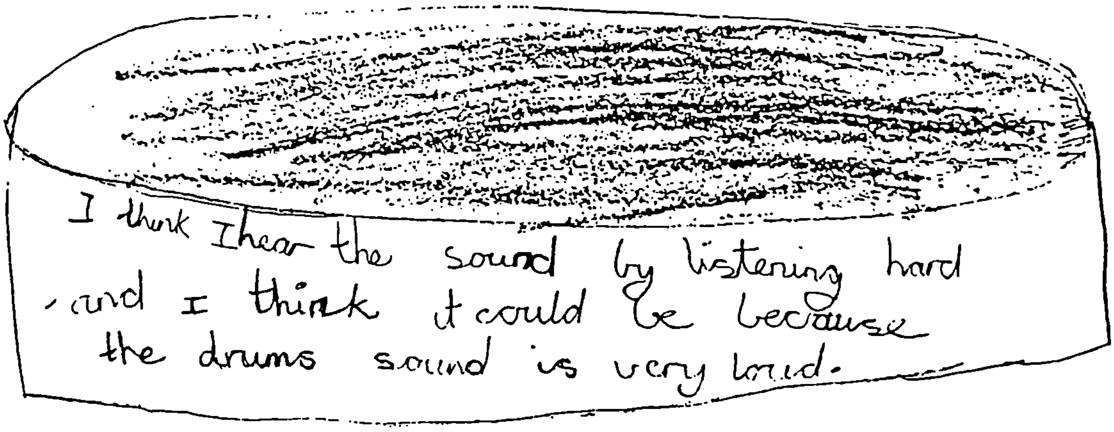
Fig. 3.45



(Age 6 years)

"The rice is making the sound. The band makes the noise. I don't know how I hear it."

Fig. 3.46



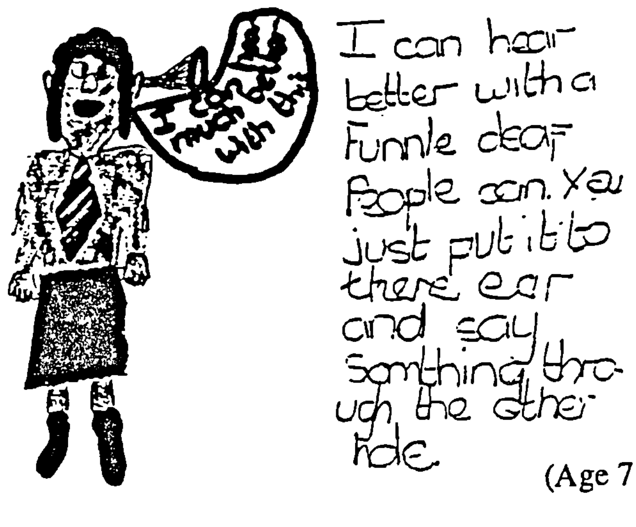
(Age 7 years)

"I think I hear the sound by listening hard and I think it could be because the drum's sound is very loud."

The Exploration activity involving the funnel ear trumpet encouraged children to express their ideas about how the ear trumpet affected hearing and it also provided some insights into the perceived nature of sound.

A prevalent response from infant and lower junior children was that the funnel helped them to hear better, but with no further explanation. Fig. 3.47 draws an interesting parallel with the ear trumpet activity from the child's own experiences.

Fig. 3.47



(Age 7 years)

"I can hear better with a funnel. Deaf people can. You just put it to their ear and say something through the other hole."

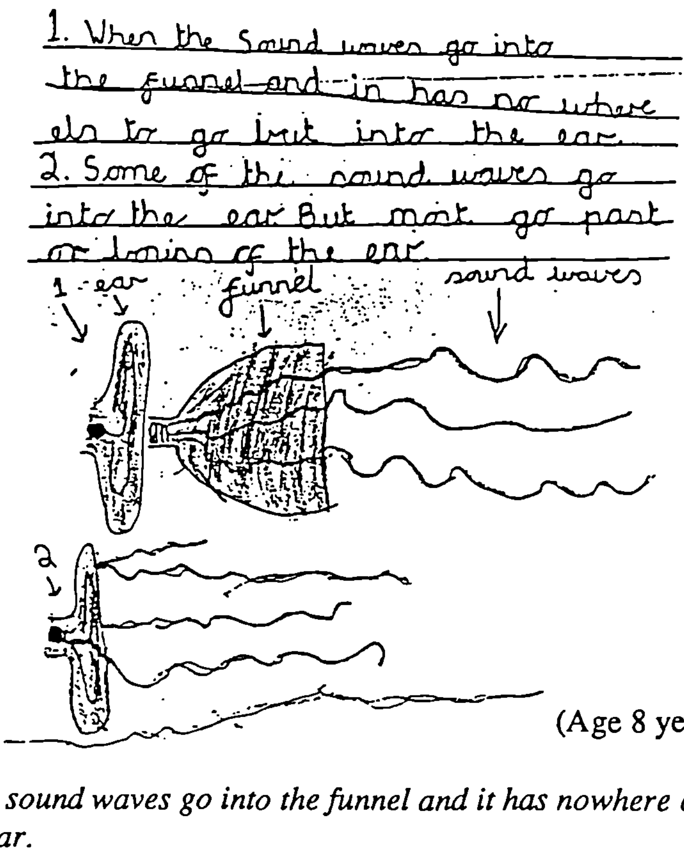
This unelaborated response of the funnel simply enhancing hearing was rarely given by upper juniors who tended to suggest more detailed mechanisms which could have created the auditory effects which they had noticed. The perception of distorted sounds appeared to lead some children to suggest mechanisms for sound collection which would explain the distortion rather than the apparent amplification which was expected. However, three detailed mechanisms were suggested, mainly by upper junior children. These were:

i. The funnel as a collector
ii. the funnel as a sound box
iii. The effects of pressure and compression of sound

i. The funnel as a collector

The simplest notion which was mentioned by some children of every age was that the ear trumpet enabled more sound to enter the ear because the opening of the funnel was wider than the ear. This type of explanation relates directly to the properties of the funnel which would be most obvious were a funnel observed in everyday use: the funnel is used to guide a large volume of material, for example, water, through a narrow opening like the neck of a bottle in the same way that sound is thought to be guided into the ear.

Fig. 3.48



(Age 8 years)

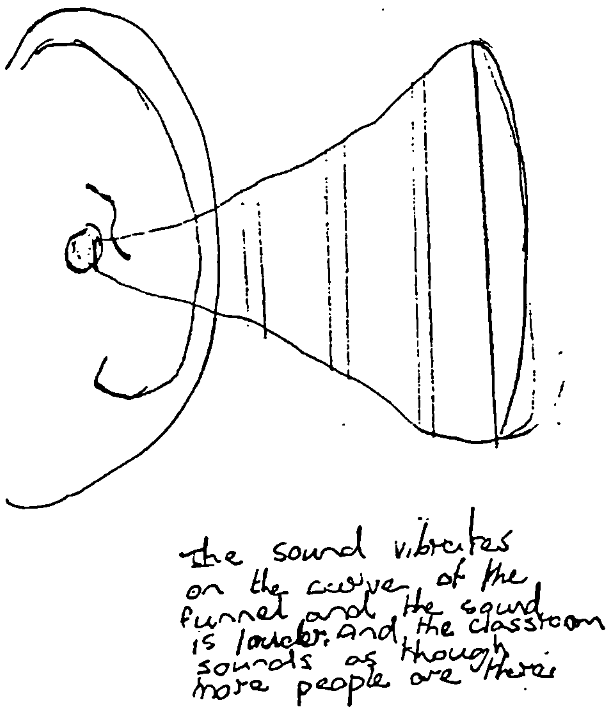
"1. When the sound waves go into the funnel and it has nowhere else to go but into the ear.
2. Some of the sound waves go into the ear. But most go past or bounce off the ear."

Fig. 3.48 illustrates how one child did not seem to see the external ear as a smaller funnel, also capable of collecting sound; the drawing suggests that if the sound did not line up exactly with the hole into the ear, then, rather than being collected by the external ear, it was bounced back and lost. It is possible that the most perceptually obvious feature of the funnel was the wide opening, while the ear was considered to be flat rather than a very shallow dish which itself had a large mouth.

ii. The funnel as a sound box

The second mechanism which children suggested was that the funnel provided surfaces off which the sound could bounce. This description is very close to the conventional explanation of one of the ways in which the funnel did affect the manner in which sounds were heard.

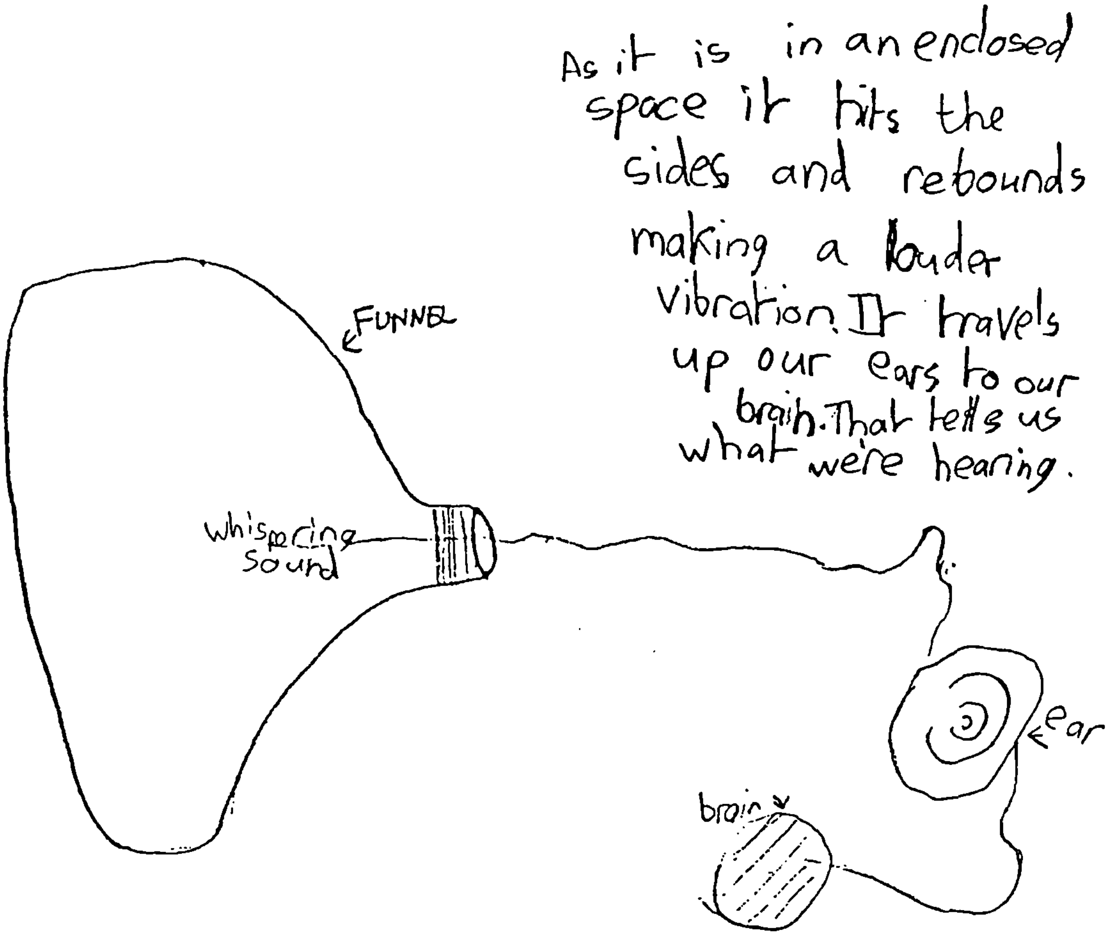
Fig. 3.49



(Age 8 years)

"The sound vibrates on the curve of the funnel and the sound is louder, and the classroom sounds as though more people are there."

Fig. 3.50



(Age 10 years)

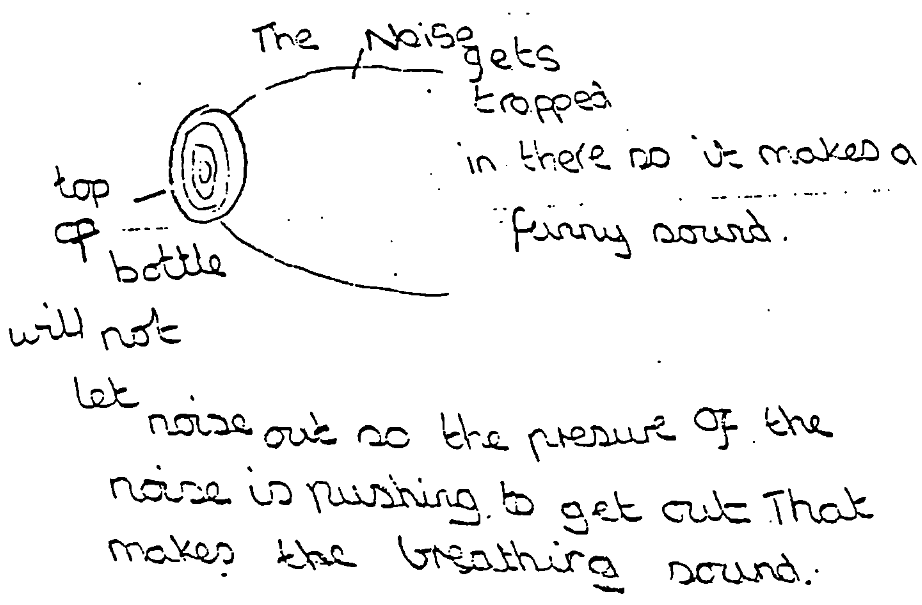
"As it is in an enclosed space it hits the sides and rebounds making a louder vibration. It travels up our ears to our brain. That tells us what we're hearing."

It is possible that the example shown in Fig. 3.50 was suggesting that sound multiplied each time it rebounded, and the existence of more copies of the same sound would mean that the cumulative result would be a louder sound. Those children who suggested sound being less clear might have felt that the existence of more copies of the sound would lead to them all being jumbled up rather than them adding neatly together to enhance the sound. A correctly proportioned ear trumpet should not have produced the effect of muffling the sound.

iii. The effects of pressure and compression of sound

The third mechanism was suggested as another explanation for less clearly heard sounds. Approximately one-tenth of upper juniors thought that the narrowing of the funnel would result in the sound being distorted to fit through the opening into the ear.

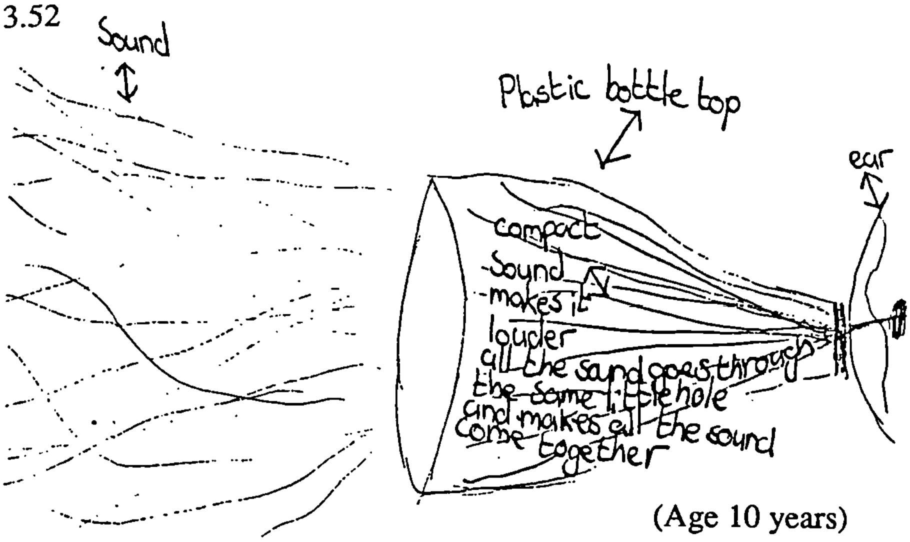
Fig. 3.51



(Age 9 years)

"The noise gets trapped in there so it makes a funny sound. Top of bottle will not let noise out so the pressure of the noise is pushing to get out. That makes the breathing sound."

Fig. 3.52



(Age 10 years)

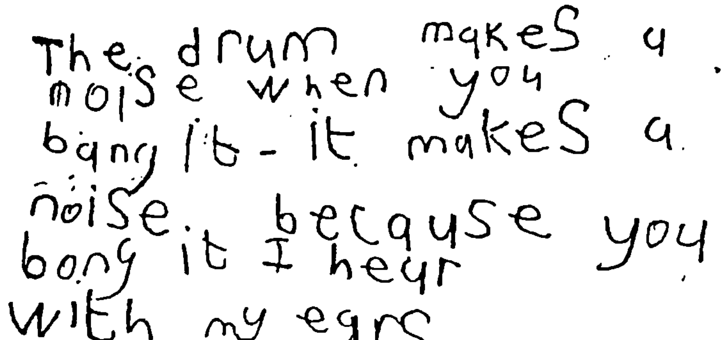
"Compact sound makes it louder. All the sound goes through the same little hole and makes all the sound come together."

These examples in which children mention pressure or compression are fairly close to the scientific description of the way in which sound is amplified by the funnel. Whereas in Fig. 3.51 the reasoning is in terms of distortion of the sound, Fig. 3.52 is an excellent description of the phenomenon phrased in intuitive language.

b. Sound perception after sound has entered the ear

The idea that sounds are not heard simply by the external ear is a complex one and is dependent to a large extent on learning from secondary sources. As previously mentioned, only one-third of infant children mentioned ears in connection with hearing. A few responded in a manner similar to Fig. 3.53, that they hear with their ears.

Fig. 3.53

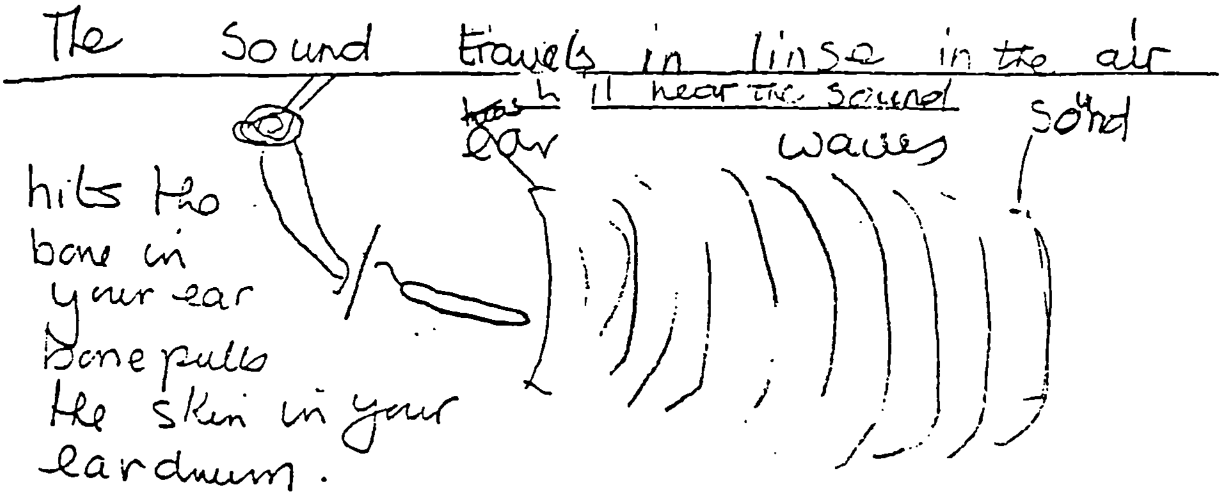


(Age 7 years)

"The drum makes a noise when you bang it - it makes a noise. Because you bang it I hear with my ears."

The apparatus contained within the inner ear to translate sound vibrations into neural impulses which travel to the brain was not mentioned in detail by any child. The ear drum was mentioned by one-fifth of upper juniors (n = 84) and one-tenth of lower juniors (n = 74), and one child described bones within the ear (Fig. 3.54).

Fig. 3.54

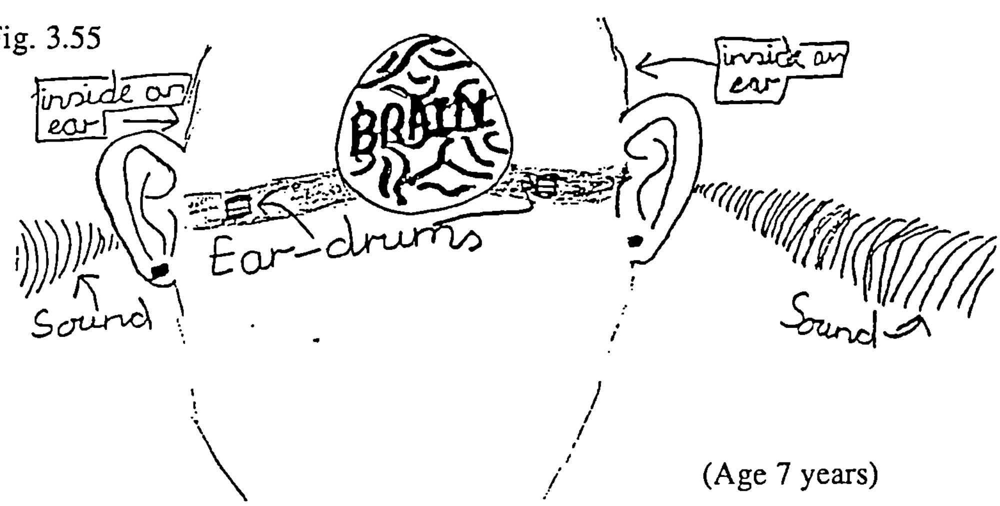


(Age 10 years)

"The sound travels in lines in the air - hits the bone in your ear-bone pulls the skin in your eardrum." *(Some teacher annotation)*

The role of the ear drum and its appearance were speculated upon by some children (Figs. 3.55 and 3.56) and the brain was mentioned by one-tenth each of lower and upper juniors. The ear drums in Fig. 3.55 appear to be very small versions of the musical instrument with which the word 'drum' would be associated.

Fig. 3.55



(Age 7 years)

Fig. 3.56

as I beat the drum the Sound waves reach my ear drum, and as my ear drum slowy picks up the Sound waves I'm then able to hear the drum Sound.

(Age 10 years)

"As I beat the drum the sound waves reach my ear drum, and as my ear drum slowly picks up the sound waves I'm then able to hear the drum sound."

The need for sound to enter the ear was mentioned by only one infant. A substantial number of junior children considered the form taken by sound when it reached the ear drum and the brain, and some quite elaborate pathways were suggested. In the junior age range, one-tenth of lower juniors and half of the upper juniors reported sound entering the ear. The upper junior sample was divided between those children describing 'sound' and those who talked about 'sound waves' or 'vibrations'. Over a quarter of the upper juniors suggested vibrations. The notion of vibrations being set up in the ear drum (including the sound banging on the ear drum) was also given only by upper juniors. Vibrations/sound waves were mentioned by approximately 11% of the whole sample (n = 184) in connection with hearing sound.

Fig. 3.57

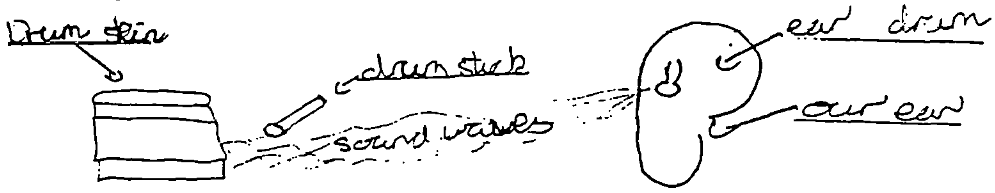
When the sound gets to your ear, it makes our ear drums vibarate and then we can hear the sound.

(Age 10 years)

"When the sound gets to your ear, it makes our ear drums vibrate and then we can hear the sound."

Fewer children included the step from ear drum to brain in the mechanism and the majority of those who did were upper juniors. Equal numbers (approximately 5%) of these juniors considered that the signal went to the brain in the form of 'sound', vibrations (Fig. 3.58) or some other form of signal (Fig. 3.59).

Fig. 3.58

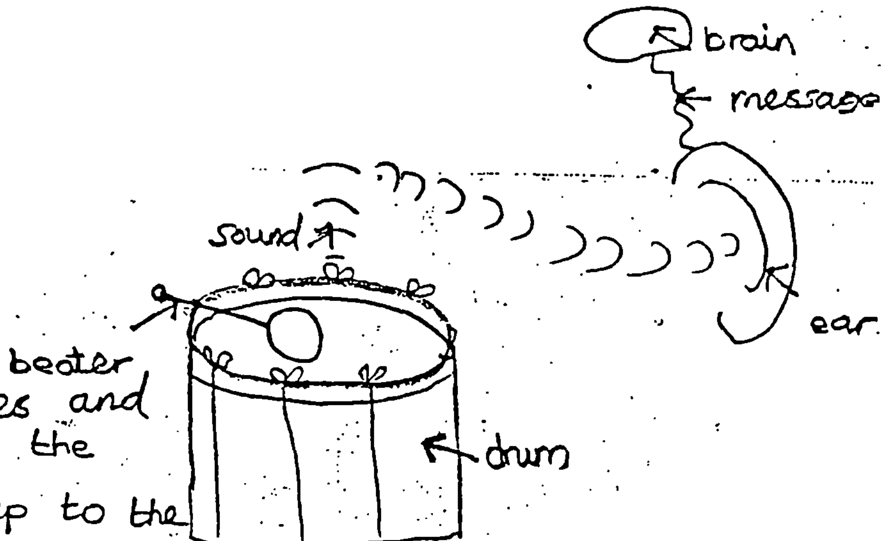


When the air goes into our ear and hits our ear drum. The ear drum vibrates all the way to the brain then the brain translates it.

(Age 10 years)

"When the air goes into our ear and hits our ear drum, the ear drum vibrates all the way to the brain then the brain translates it."

Fig. 3.59



sound vibrates and echoes round the drum and up to the ear and to the brain it tells the brain the sound and we hear, this all happens in a split-second.

(Age 10 years)

"Sound vibrates and echoes round the drum and up to the ear and to the brain. It tells the brain the sound and we hear, this all happens in a split-second."

Fig. 3.58 also indicated that the brain was thought to undertake a translation of the signal it received, and this final step was suggested by a small number of upper juniors.

3.1.5 Children's Representations of Sound

The appearance on diagrams of any representations of sound was more common the older the children and also appeared to be more common for boys than girls. In the upper juniors over half of the sample (n = 66) used a representation, three quarters of whom were boys. The four main issues which the diagrams informed were:

a. Whether the sound was portrayed as continuous or discontinuous from source to receiver.

b. Whether the sound was depicted as lines approximately parallel or perpendicular to the shortest line from sound source to receiver.

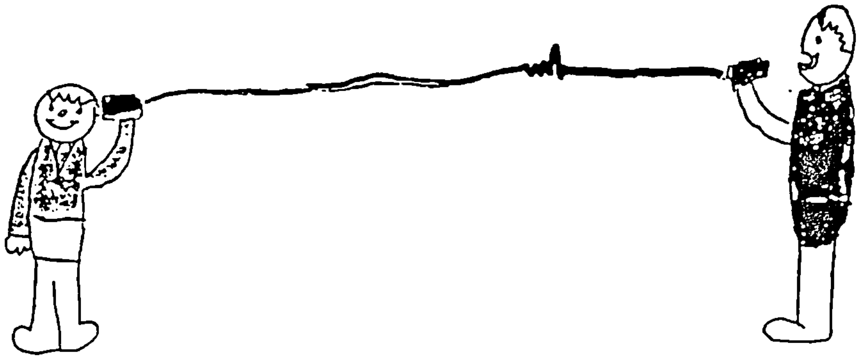
c. Whether the sound diverged as it travelled or remained on a path of constant width.

d. The form of notation chosen by the child to represent the sound.

a. Continuous or discontinuous sound

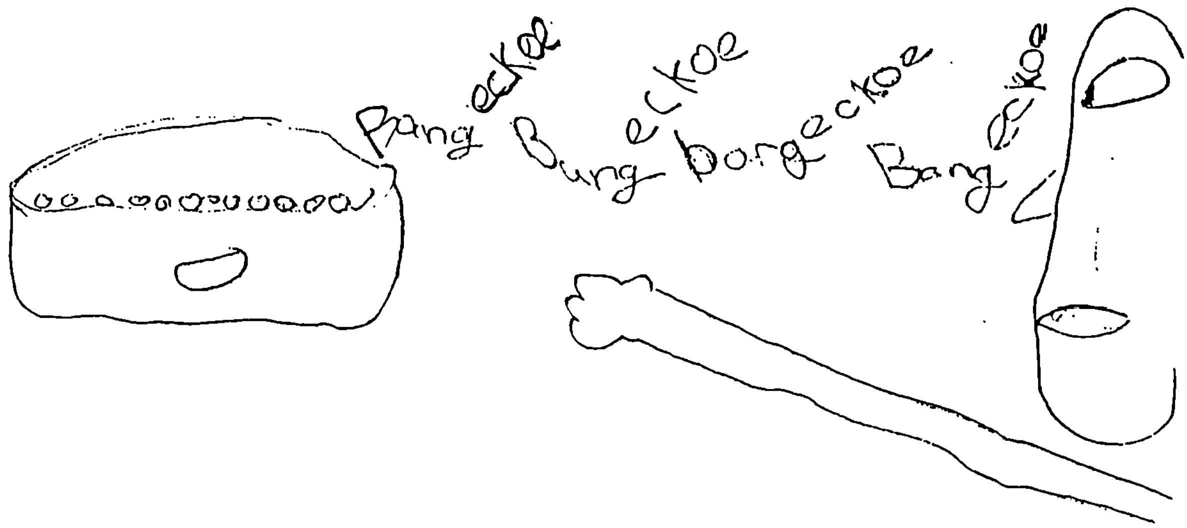
Children either showed the sound as happening once, as a discrete entity which then travelled to the receiver (Fig. 3.60) or as a continuous line from source to receiver (Figs. 3.61, 3.62).

Fig. 3.60



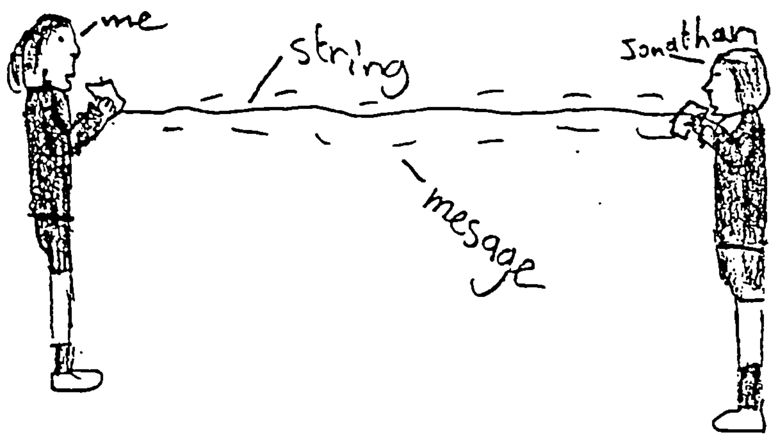
(Age 7 years)

Fig. 3.61



(Age 7 years)

Fig. 3.62



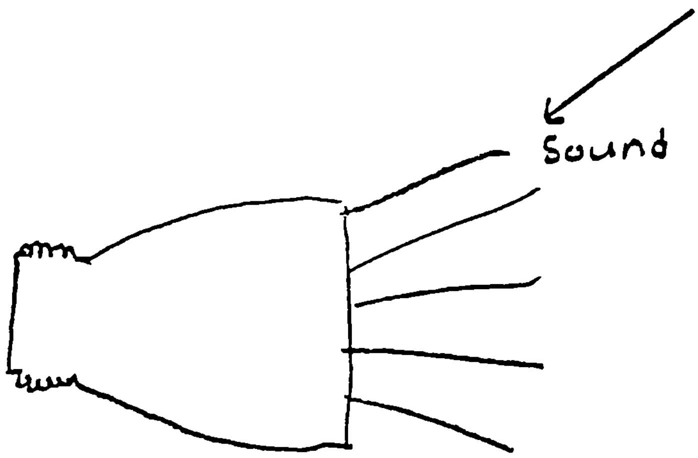
(Age 9 years)

The discrete representation of sound could be considered to be an intuitively governed response to the question of how to show sound travelling. This form of representation would be compatible with a notion that 'sound' is an entity which travels through space. The continuous representation is ambiguous and could be interpreted in several ways. The idea that sound is a continuous series of vibrations would not be very accessible to children since sound travelling can neither be seen nor easily timed. While it is possible that the children were portraying a series of vibrations it seems likely that children were attempting to portray the position of the sound over a period of time.

b. Parallel or perpendicular orientation of sound lines

The most common depiction of sound for both lower and upper juniors was in a direction broadly parallel to the direction of sound travel (Fig. 3.63). This was the only type of representation elicited from lower juniors.

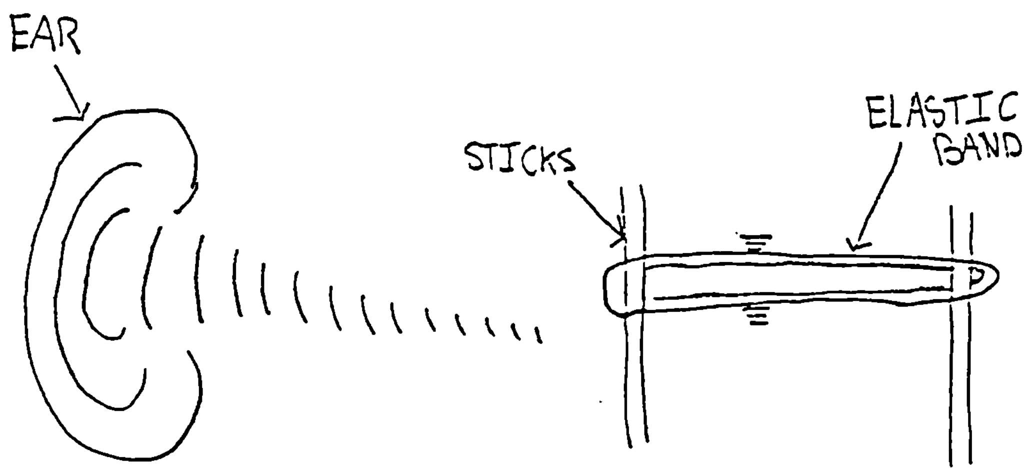
Fig. 3.63



(Age 9 years)

A quarter of the upper juniors who used a representation showed sound as lines perpendicular to the direction of sound travel (Fig. 3.64). This suggests a response which has been learned from secondary sources since the intuitive response would seem more likely to indicate the direction of travel rather than the wave form.

Fig. 3.64

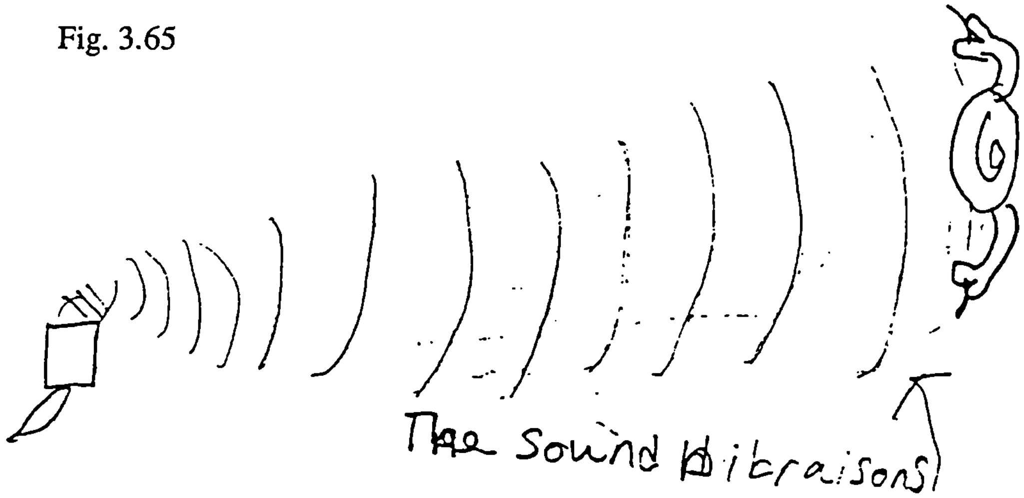


(Age 10 years)

c. Divergent or non-divergent paths of sound travel

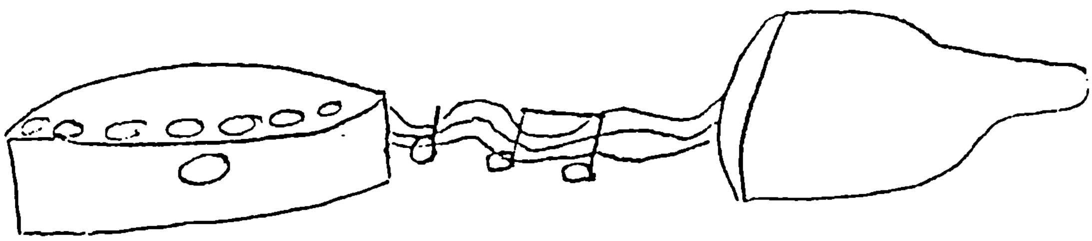
The notion that sound spreads out from its source was held by some children (Fig. 3.66) and was found in conjunction with sound depicted both parallel and perpendicular to the direction of sound travel. A large number thought that the sound went only to the intended listener, and remained in a path of constant width (Figs. 3.66 and 3.67). This latter response may be a component of the active listening model whereby the sound goes straight to the person who is attending to it; it might be regarded as an egocentric type of response.

Fig. 3.65



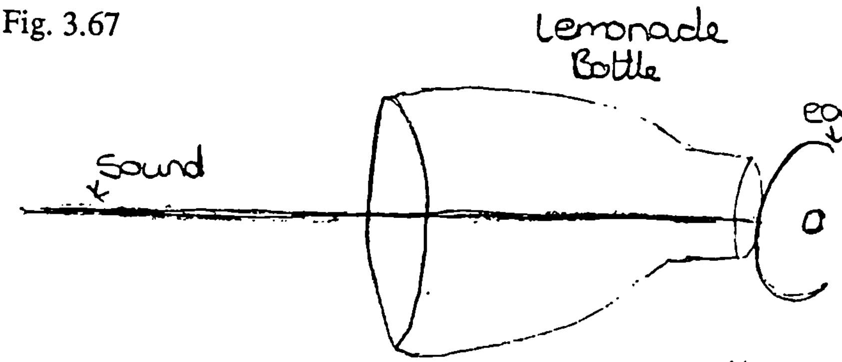
(Age 9 years)

Fig. 3.66



(Age 10 years)

Fig. 3.67

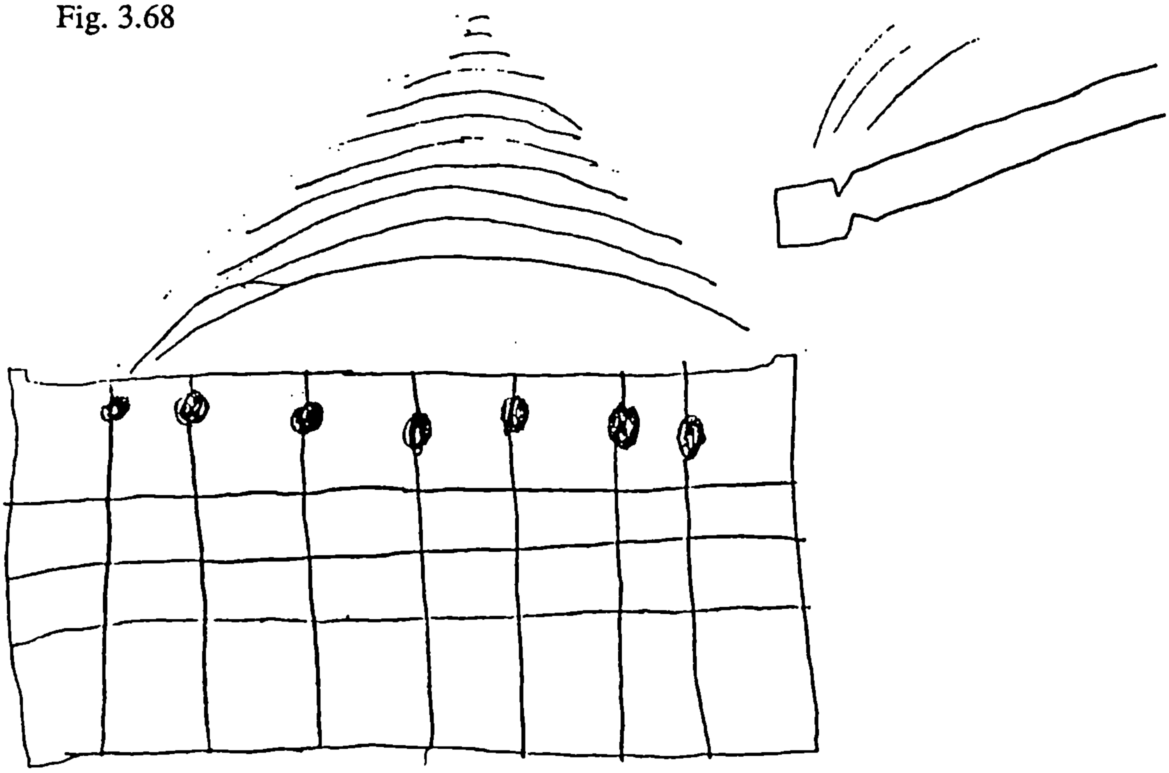


(Age 7 years)

The illustrations shown in Figs. 3.66 and 3.67 were each drawn by children who suggested that the ear trumpet affected the way they heard, but their representations of sound do not make any effect clear: the sound appears to pass unimpeded through the centre of the funnel and into the ear.

One child depicted sound converging from the source, a drum, which might again suggest that some secondary source has led the child to make a response which had not been completely assimilated (Fig. 3.68).

Fig. 3.68

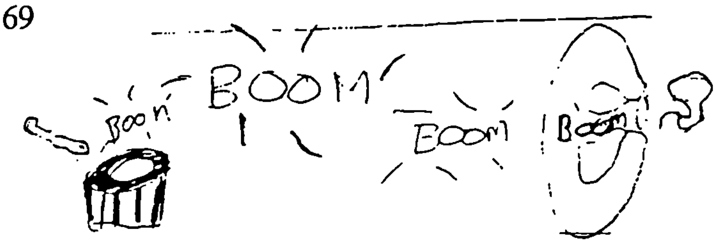


(Age 7 years)

d. Notation used for sound

A wide range of notations was used to represent sound. Words were used (Fig. 3.69), as well as lines (Fig. 3.68), arrows, musical notes (Fig. 3.70), and shading.

Fig. 3.69



(Age 10 years)

Fig. 3.70

(Age 10 years)

The interpretation of these different notations of sound is open to speculation. The formal representations, such as perpendicular lines, seem likely to be used in what the child remembers to be the accepted manner from pictures or diagrams which have been seen. The more intuitive notations, the words and musical notes could also have been acquired by children from other, less formal secondary sources such as comics or they could demonstrate the child's own attempts to represent sound. An inspection of some children's comics revealed examples of all of the notations used by children, except for sound waves, perpendicular to the direction of sound travel. In comics, these perpendicular lines appear to denote movement rather than sound.

3.1.6 Vocabulary

The word 'vibration' was used by a very large number of children and it appeared to be used to mean several different things. The child whose drawing is shown in Fig. 3.71 appears to use 'vibrate' to mean 'does not resonate'.

Fig. 3.71

I stretched a rubber band
between my finger and
thumb and plucked it with
my other hand. I noticed
— it dosnt make very much
noise, it vibrats and it hurts
my hand. I cant play a
tune. I plucked a rubber
band that was on a box
I noticed — it makes a
loud noise and it dosnt
vibrat. I can play a tune

(Age 7 years)

"I stretched a rubber band between my finger and thumb and plucked it with my other hand. I noticed - it doesn't make very much noise, it vibrates and it hurts my hand. I plucked a rubber band that was on a box. I noticed - it makes a loud noise and it doesn't vibrate. I can play a tune."

Some children appear to use 'vibrating' as an adjective (Fig. 3.72) or a verb (Fig. 3.73) to qualify the word 'sound'. This usage of 'vibrating' as a qualifying term suggests that the children's definition of 'vibration' is restricted to particular types of sound, possibly where the movements of the sound producer are visible, as with the rubber band.

Fig. 3.72

The bit of elastic band thats being plcked hits the bottom part of the band and makes a vibrating sound.

(Age 10 years)

"The bit of elastic band that's being plucked hits the bottom part of the band and makes a vibrating sound."

Fig. 3.73

By the elastic band moving it makes a noise by vibrating the sound, If tighter band you get a high note. If you slacken the band you will get a lower note.

(Age 9 years)

"By the elastic band moving it makes a noise by vibrating the sound. If tighter band you get a high note. If you slacken the band you will get a lower note."

'Vibration' also seems to be used to imply repetition so that children attempting to understand the notion of sound travelling might be doing so by having the sound repeat its way along.

The word 'echo' was used by upper and lower junior children in connection with several of the Exploration activities, particularly those which incorporated a resonating chamber - the funnel and the drum and the rubber band on a box. A commonly expressed definition of 'echoing' was that the sound was repeating itself (Fig. 3.61, p. 34.) Perceptually, an echo would intuitively suggest a repetition of the initial sound. Some understanding of sound transmission would be necessary for children to consider sound to bounce back from a surface.

Appendix 7

Appendix 7

Analysis of children's ideas: Sound research report pp. 72-81

Interestingly, an equal percentage of infant and lower junior children thought that nothing could affect their hearing. All upper juniors mentioned at least one condition. The majority of infant responses were concerned with volume and distance, as well as background noise. The relatively high percentage of infants compared with juniors suggesting this latter condition might be due to the open plan design of one of the schools. Every child interviewed from that infant class mentioned background noise, and no other infants gave that response. This experience could certainly have coloured their observations of sound.

A comparison between the pre-Intervention sound activities

Each of these activities made a particular aspect of sound more explicit than others, and because of this context-related issue the questions which were asked about each activity were specific to that one. However, it is possible to compare the different activities by using a number of super-ordinate categories which are common to all the activities. These categories are concerned with:

a. sound production

b. sound transmission

c. sound reception

a. Sound production

Children's ideas about how sounds were made seem to fall into three main groups:

i. Some children gave explanations which related to physical properties of the sound-making object, or made tautological statements about sound production. There was no mention of any action being associated with sound-making.

e.g. Q *Where was that noise coming from?*

R *Off the rubber band.*

Q *How was it doing that?*

R *It stretched.*

Q *What do you think made the band make a noise?*

R *Because it's an elastic band and it's bouncy.*

ii. Other children's explanations did made an association between an action/movement and sound production. Mention of talking was included in this category.

e.g. Q *What do you think makes the drum make a noise?*

R *It makes a noise when you bang it*

Q *What makes the rubber band make a sound?*

R *You pull it and it hits the other side and makes a sound*

iii. Some children answered in a way that suggested that sound production was linked to the vibrations of an object.

e.g. Q *What do you think makes the drum make a sound?*

R *You bang it - the skin vibrates and the sound goes round inside and then comes out.*

Q *Do you think you could tell if the rubber band was making a sound if you couldn't hear it?*

R *You'd see it shaking. When it shakes it always makes a sound.*

The production of sound was the most prominent aspect of two of the activities, the rubber band and the drum, and children were questioned directly about sound production in those contexts: with regard to the string telephone, the ear trumpet and the everyday sounds children's mention of sound production as part of their answers to other questions was scored.

Table 4.14 A comparison of the number of children holding particular ideas about sound production across activities (Percentages)

(infant, n = 13; lower junior, n = 14; upper junior, n = 17)

	String telephone			Rubber band			Ear trumpet			Drum			Everyday sounds		
	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ
No mention of action associated with sound production	38 (6)	29 (6)	12 (6)	31 (4)	-	6 (1)	85 (11)	50 (7)	82 (14)	15 (2)	-	-	77 (10)	-	18 (3)
Some mention of action associated with sound production	62 (8)	57 (8)	65 (11)	69 (9)	50 (7)	41 (7)	15 (2)	50 (7)	18 (3)	85 (11)	79 (11)	53 (9)	23 (3)	100 (14)	82 (14)
Sound production associated with vibration	-	14 (2)	24 (4)	50 (7)	53 (9)	-	-	-	-	21 (3)	40 (8)	-	-	-	-

Across all activities, with the exception of the ear trumpet, there is a trend towards more scientific ideas related to increasing age, and the main differences seem to be between infants and juniors. No infants mentioned an association between sound production and vibrations and a substantial number did not mention a link between any action and sound production.

The vast majority of responses to each of the four activities (excluding the ear trumpet) fell into the category of some action being associated with sound production. The ear trumpet and everyday sounds both gave children less opportunity to mention sound production, particularly the ear trumpet. These two activities both focused upon sound reception and it was not necessary for children to identify and mention a particular localised sound source in order to answer the questions. The data should not be interpreted in terms of context specificity but in terms of differing opportunities to respond during the interview.

As might have been expected, the two activities in which movement was observable as the result of an action (the drum and the rubber band) led to the most mention of vibrations. Interestingly, the string telephone also elicited similar responses. It is possible that, since a medium for transmission ws explicit, children were more likely to speculate about how that pathway could be used. Children might also have felt the yogurt cups vibrating as they spoke into them.

The notion of vibration

It was felt that any mechanism which was associated with sound production could be made apparent by using a means of categorising the information which would draw out the perceived relationships between sound production and vibrations. Children's responses which either mentioned the word 'vibration' (whether it was in connection with sound production, transmission or reception) or used a synonym, for example 'wobble', were all included in this analysis.

Table 4.15 Children's ideas about the perceived link between vibration and sound production (Percentages)

(lower junior, n = 14; upper junior, n = 17)

	String telephone		**Rubber band**		**Ear trumpet**		**Drum**		**Everyday sounds**	
	LJ	UJ	LJ	UJ	LJ	UJ	LJ	UJ	LJ	UJ
Sound cause vibrations	21 (3)	41 (7)	-	-	-	-	7 (1)	35 (6)	7 (1)	-
Vibrations cause sound	-	-	43 (6)	29 (5)			21 (3)	24 (4)	7 (1)	-
Sound is vibration	-	6 (1)	-	12 (2)	-	-	-	-	-	-
Unclear/ inconsistent use of word	-	12 (2)	7 (1)	6 (1)	-	-	-	6 (1)	-	-
Vibrations not mentioned	79 (11)	41 (7)	50 (7)	53 (9)	100 (14)	41 (7)	71 (10)	35 (6)	86 (12)	100 (17)

There are interesting differences in responses here which might suggest that children are considering mechanisms of sound production which are specific to particular activities. Children who mentioned vibrations in connection with the string telephone suggested that the sound caused the vibrations, whereas the opposite pattern was found with the rubber band where the vibrations were thought to cause the sound. The drum, on the other hand, elicited both of these mechanisms. It is possible that the string telephone might be a special case since the sound being produced is the child's own voice which children might not consider to be an example of their definition of sound. The vibrations in the pharynx, which are easily felt, might thus be associated with voice production, as distinct from sound production. The vibrations could be an attempt to explain voice transmission rather than sound production. The rubber band might lead children to suggest that the vibrations cause the sound because of the nature of their observations while plucking the band. The children stretch the band and let it go before any sound is heard, so the larger movements, causing band to be stretched and let go, might be observed rather than the smaller vibrations. The drum head, on the other hand, is stationary until the stick hits it and the moment that the stick hits the drum appears to be exactly the same as the moment at which the sound is produced. These simultaneous events might make the choice of mechanism less evident from observation. These could have led to both being suggested with approximately equal frequency.

b. Sound transmission

Children had a variety of ideas about how sound travelled and they can be put into three main groups:

i. Some children made no mentioned at all of sound travelling. They explained being able to hear a distant sound in one of several ways; either in terms of the force used to produce the sound, the proximity of the sound, its volume, or as a characteristic of the listener.

e.g. Q *How do you think the sound gets to you so you can hear it?*

R *Because I've got ears and I can listen.*

R *Because you make it bang*

R *Because it's loud*

ii. Another group of children had some idea that sound travelled, but seemed to have no notion about the medium through which sound passed. Some of these responses suggest that sound can only travel without a medium, i.e. that it will only go through holes.

e.g. R *Tunes are very small and they can get through the gaps in the doors*

R *The sound comes to your ear; I don't know how*

iii. Some children seemed to know that sound travelled through a medium.

e.g. R *The message goes through the stretched wire to your ear*

R *The air brings the sound up to your ear.*

Table 4.16 A comparison of the number of children holding particular ideas about sound transmission across activities (Percentages)

(infant, n = 13; lower junior, n = 14; upper junior, n = 17)

	String telephone Inf LJ UJ	Rubber band Inf LJ UJ	Ear trumpet Inf LJ UJ	Drum Inf LJ UJ	Everyday sounds Inf LJ UJ
No mention of sound travelling	46 21 - (6) (3)	100 43 53 (13) (6) (9)	77 29 35 (10)(4) (6)	77 36 47 (10)(5) (8)	100 57 76 (13) (8)(13)
Some mention of travel, no mention of medium	7 7 6 (1) (1) (1)	- 43 29 (6) (5)	23 57 47 (3) (8) (8)	23 50 41 (3) (7) (7)	- 29 6 (4) (1)
Mention of sound travelling through a medium	46 71 94 (6)(10)(16)	- 14 18 (2) (3)	- 14 18 (2) (3)	- 14 12 (2) (2)	- 14 18 (2)(3)

Sound transmission through a medium was made explicit in only one activity, the string telephone. Children spoke into one yogurt pot and the message was received through the other, the observable connection between the two pots being a piece of string. It can be seen from Table 4.16 that the number of children mentioning that sound travelled through a medium was substantially greater for each age group when talking about the string telephone than about any of the other activities. Between activities, the largest differences were found with the upper junior sample where they were significant with respect to each activity: rubber band ($p < 0.01$), ear trumpet ($p < 0.05$), drum ($p < 0.001$) and everyday sounds ($p < 0.001$). There were also differences in infant responses between the string telephone and the rubber band ($p < 0.01$) and everyday sound ($p < 0.01$), though the lower junior responses were not significantly different than would have been expected.

A comparison, between activities, of numbers of children who mentioned that sound travelled shows a consistent pattern of responding, with the exception of the string telephone. This pattern shows fewer infants than juniors mentioning travel, and also very little difference between the lower and upper junior samples. The majority of children at each age also make no reference to a medium through which sound travels (with a non-significant exception for upper juniors concerning everyday sounds). This pattern suggests that the majority of children have little or no notion of sound travelling through a medium. The example of the string telephone, where the medium is visible, encourages far more children to mention a medium, but this response seems to be specific to that particular context.

Another angle which should be considered is whether the children who mentioned sound travelling through air regarded air as a medium, as something with a volume, mass and density, or whether they were giving the accepted name to the empty space around. Children made very few attempts to explain sound transmission.

Three quarters of the infant children who mentioned that sound travelled could give no further explanation. This number fell to around half in the upper and lower junior samples. The idea that sound travelled as words was more prevalent in infant children. This representation could be due to the inability of these infants to abstract the notion of 'sound' from that of the message which they had spoken or received. As might be expected, the use of words which tend to be part of a scientific vocabulary was restricted to junior children, with nearly half the upper junior sample referring to vibrations. The use of the word, 'vibration', does not necessarily imply that the term is being used in a scientifically acceptable way. When asked for clarification, some children talked about 'wobbling' or 'moving up and down' while others could not define the term at all.

Table 4.17 A comparison of ideas about how sound travels across activities (Percentages)

(infant, n = 13; lower junior, n = 14; upper junior, n = 17)

	String telephone			**Rubber band**			**Ear trumpet**			**Drum**			**Everyday sounds**		
	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ
Sound travels, no further explanation	38 (5)	43 (6)	65 (11)	-	57 (8)	29 (5)	23 (3)	64 (9)	65 (11)	23 (3)	50 (7)	35 (6)	-	36 (5)	24 (4)
Sound travels as words	15 (2)	14 (2)	6 (1)	-	-	-	-	7 (1)	-	-	-	-	-	7 (1)	-
Sound travels as sound waves*	-	7 (1)	-	-	-	6 (1)	-	-	-	-	-	6 (1)	-	-	-
Sound travels as vibrations*	-	14 (2)	47 (8)	-	-	12 (2)	-	-	-	-	-	12 (2)	-	-	-
Sound travels as echoes*	-	-	6 (1)	-	-	-	-	-	-	-	14 (2)	-	-	-	-
No mention of sound travelling	46 (6)	21 (3)	-	100 (13)	43 (6)	53 (9)	77 (10)	29 (4)	35 (6)	77 (10)	36 (5)	35 (6)	100 (13)	57 (8)	76 (13)

*child has actually used the word

The use of 'sound waves', though restricted to a very small number of children, seemed to be associated with an interesting model of sound transmission. The sound waves appeared to be present in the air, possibly like waves on the sea, and to pick up the sound when it was produced. An analogy could be that sound waves were like buses and they picked sound up, carried it and put the sound down again. Whether the sound waves were thought to float in the air, or to be air in a certain form, was not clear from the children's comments.

c. *Sound reception*

There seemed to be a smaller range of ideas concerning reception though again they can be divided into three groups.

i. Some children made no mention of a receptor, refering simply to 'hearing'.

e.g. Q *How can you hear the sound from the drum?*

R *You can hear it*

ii. Some children specified that the ear is necessary for sounds to be heard.

e.g. R *The sound goes to your ears and you hear.*

iii. A few children thought that the ear drum had to vibrate for sound to be heard.

e.g. *There's an ear drum in your ear and every time something makes a noise it's like it's banging on your ear drum.*

Table 4.18 A comparison of the number of children holding particular ideas about sound reception across activities (Percentages)

	(infant, n = 13; lower junior, n = 14; upper junior, n = 17)														
	String telephone			**Rubber band**			**Ear trumpet**			**Drum**			**Everyday sounds**		
	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ	Inf	LJ	UJ
No mention of a receptor	92 (12)	64 (9)	76 (13)	100 (13)	36 (5)	71 (12)	62 (8)	7 (1)	6 (1)	62 (8)	36 (5)	65 (11)	77 (10)	50 (7)	76 (13)
Mention of the ear as the receptor	7 (1)	36 (5)	24 (4)	-	57 (8)	29 (5)	38 (5)	93 (13)	35 (6)	38 (5)	57 (8)	35 (6)	23 (3)	43 (6)	24 (4)
Mention of vibrations being set up in the receptor	-	-	-	-	7 (1)	-	-	-	-	-	7 (1)	-	-	7 (1)	-

The main activity to emphasise sound reception was the ear trumpet, and an inspection of Table 4.18 shows that the main significant differences in response are concerned with junior children and the ear trumpet. It is perhaps surprising that the string telephone did not elicit more reference to ears. This lack of mention might be due to the sounds involved in the string telephone activity being speech, and speech being considered to be distinct from sound. This explanation would be consistent with the interpretation of vibrations as a mechanism of voice transmission rather than when mentioned in connection with the string telephone.

The three mentions of vibrations being set up in the receptor were all from the same eight-year-old boy. His responses did not in fact refer to vibrations but to 'sound banging on the eardrum', a notion which could be a direct analogy with producing sound on a drum by hitting it with a stick. (Mention of the ear drum was not uncommon but this case is the only one where an attempt was made to explain its function.)

A small number of children in each age band mentioned listening either as a part of all of or their explanation of how they could hear sounds. These children considered their attending to the sound to be a necessary condition for hearing sounds.

Table 4.19 Prevalence of the notion of Active Listener (Percentages)

	(infant, n = 13; lower junior, n = 14; upper junior, n = 17) **String telephone** Inf LJ UJ	**Rubber band** Inf LJ UJ	**Ear trumpet** Inf LJ UJ	**Drum** Inf LJ UJ	**Everyday sounds** Inf LJ UJ
Active listening	23 14 18 (3) (2)(3)	7 - - (1)	7 14 - (1) (2)	31 7 - (4) (1)	15 7 12 (2) (1)(2)

These 'active listeners' each tended to give this explanation for only one activity; one infant girl, however, used this psychological model for every activity, and one lower junior girl applied it to the string telephone, everyday sounds and ear trumpet which are the three activities making most reference to sound reception.

Appendix 8

Appendix 8

Summary of children's ideas pre- and post-intervention:

Sound research report p. 53, pp 126-7

3.1.7 Summary

1. 'Sound' and 'vibration' were not intuitively linked by young children but an association developed as children's experiences broadened. Whether sound caused vibrations or vibrations caused sound seemed to depend upon the context. Some children suggested that sound and vibration were the same.

2. The production of sound from an object was often attributed to the properties of the object or to an impact. Children suggested mechanisms for the generation of sound from a drum. These mechanisms often involved vibrations and the site of sound production was either inside the drum or at the surface.

3. Sound transmission was not an idea which was expressed by many young children. Infant children said they heard sounds because of the volume, the proximity to the sound source or because of a characteristic of the listener. Where sound travel was mentioned there was a prevalent idea that sound needed an unobstructed path along which to travel. Some older children considered sound to travel through the string on the string telephone, or through air. What was meant by 'air' was often unclear.

4. Sound reception was frequently associated with the ear. A funnel ear-trumpet was thought to affect hearing by either collecting orconcentrating sound so that more reached the ear. A small number of junior children mentioned the ear drum and the brain in connection with hearing. Some of these children mentioned vibrations being set up in the ear drum.

5. A wide range of representations was used, some idiosyncratic and parallel to the direction of sound travel, and others more like the accepted scientific notation, perpendicular to the direction of travel. A small number of children portrayed sound spreading out from the source. The idiosyncratic notations could have been influenced by the representations of sound shown in children's comics.

6. Junior children made frequent use of words such as 'vibrate', 'echo', 'travel' and 'sound wave' in association with descriptions of ideas about sound. Both 'vibrate' and 'echo' were often used in a manner which implied a meaning of 'repeat'.

Summary

1. The post-Intervention interviews centred upon the Intervention activities with which the children had been involved in the classroom, and the questions which were addressed were:

    i How do the sounds around reach you so you can hear them?

    ii What makes a difference to how well you can hear?

2. There were significant changes in the ideas which children expressed about sound. These changes were largest in connection with sound transmission. The age group in which changes were most pronounced was the upper juniors.

    i More junior children mentioned that sound travelled (lower junior $p<0.05$, upper junior $p<0.001$).

    ii More upper junior children referred to sound travelling through a medium ($p<0.01$)

    iii More upper junior children used descriptions to elaborate their discussions about sound travelling.

3. An examination of the changes within individual children showed that a large number of children had developed their ideas in a way which could help them to develop more scientific thinking. While many children's ideas remained unchanged there were very few children whose ideas were less explanatory than prior to the Intervention.

4. Through participating in the SPACE Project many teachers had developed skills in non-directive classroom techniques and some were becoming more analytical in their approach to teaching.

Appendix 9

Appendix 9

Super-ordinate categories: Sound research report pp. 118-124

5.2 Changes in Individual Children

It was possible to identify the changes in the type of response given by individual children, pre- and post-Intervention, using the broad groupings of ideas about sound production, transmission and reception which had been identified during the Exploration phase.

Sound production

1. No action There is no mention that an action/movement/input of energy is necessary in order for sound to be produced.

2. Action — There is a clear indication that an action/movement/input association of energy is necessary in order for sound to be produced.

3. Vibration — There is considered to be an association between vibrations and sound production.

Sound transmission

1. No travel — There is no mention of sound travelling.

2. No medium — Sound is mentioned as travelling, but there is no mention of a medium through which it travels.

3. Travel through air — Sound is described as travelling through air.

Sound reception

1. No receptor — There is no mention of a sound receptor.

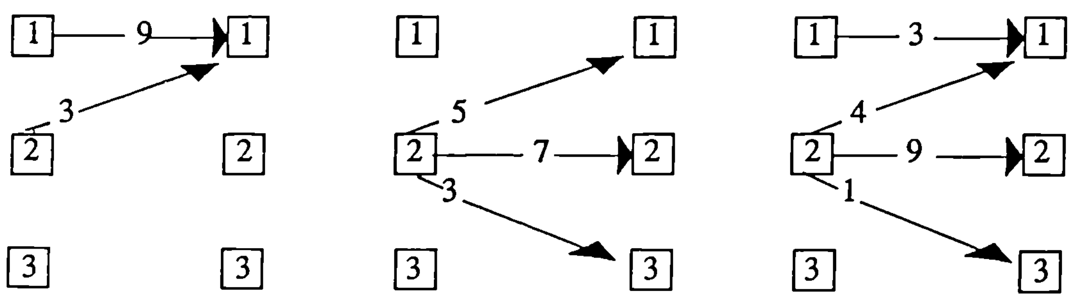
2. Ear as receptor — The ear is mentioned as the sound receptor.

3. Receptor vibration — Vibrations are thought to be set up within the receptor.

Sound Production

Table 5.7 The direction of changes in the ideas of individual children about sound production, pre- and post-Intervention.

Infant n = 12	**Lower Junior** n = 15	**Upper Junior** n = 17
pre- post- Intervention	pre- post- Intervention	pre- post- Intervention



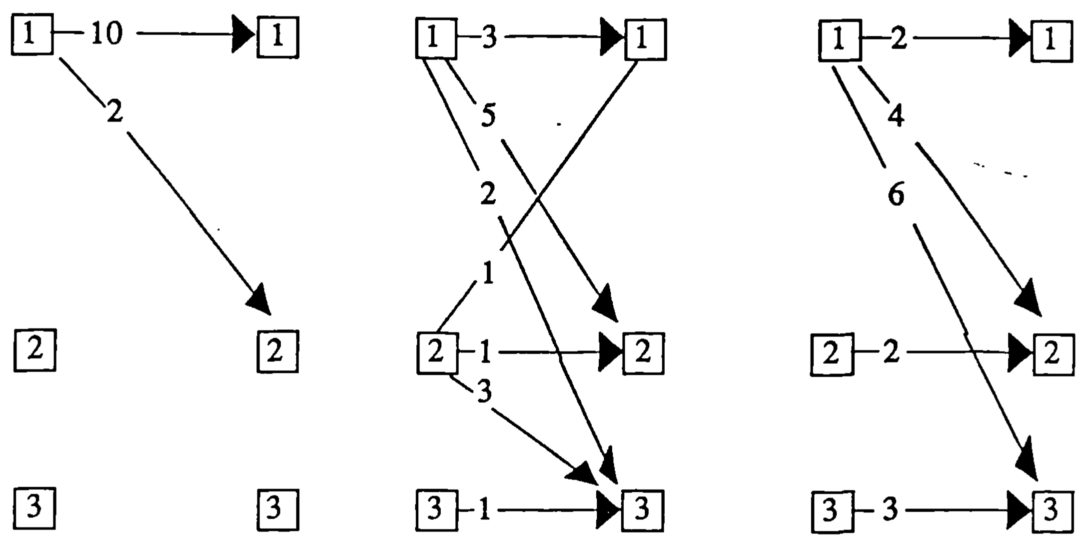
From Table 5.7 it can be seen that the age group in which there was most change (53%) is the lower juniors.

Some of these changes were towards more scientifically acceptable responses (20%) while others were not obviously in that direction. Once again, it must be stressed that the Intervention activities and interview questions did not focus directly on sound production, and any mention was incidental. From these limited data it appears that 'action association', mention of the need for energy/action/movement in order for sound to be produced, is the idea from which all of the change occurs. This suggests that children need to understand that sound production requires an action before they can understand about vibrations.

Sound Transmission

Table 5.8 The direction of changes in the ideas of individual children about sound transmission, pre- and post- Intervention.

Infant n = 12	LJ n = 15	UJ n = 17
pre- post- Intervention	pre- post- Intervention	pre- post- Intervention



From table 5.8 it can be seen that there was very little change (17%) in the ideas which infants held about sound transmission. Both of the junior groups showed a high percentage of change from a 'no travel' response to a 'no medium' or 'travel through air' 3 response. Only one lower junior changed from a 'no medium' to a 'no travel' response. A quarter of the junior sample expressed ideas which were of 'no travel' pre-Intervention and post-Intervention were of 'travel through air'. This apparent omission of 'no medium' responses is ambiguous. It could suggest that the 'no medium' response, that sound travels but without any mention of a medium (or in the absence of any obstacles) need not be a precursory idea to the notion that sound travels through air. Alternatively, the 'travel through air' response might indicate learning from a secondary source, including peers (transcript 5.4), and may in some cases be indistinguishable from a 'no medium' response except for the label 'air'.

Transcript 5.4 Timothy, age 10

Q *How do you think we hear?*

R *By the sound which is coming into the ear.*

Q *Can you explain that to me?*

R *The person claps and it travels to the ear. It goes to the ear drum and into the brain.*

Q *Can you explain 'it travels'?*

R *It goes by air to the ear.*

Q *Can you tell me a bit more about that?*

R *I don't really know.*

Q *Can you explain travels?*

R *It doesn't mean like I travel in a car it means - oh I don't know - but it's not travelling in a car or like me on a bike - it's something else.*

Each of the children who suggested that sound travelled through a medium post-Intervention but not pre-Intervention had been engaged in an investigation which could have encouraged the children to consider sound travelling:

. the effect of distance from the sound source on hearing (three children)

. blocking the reception of sound (two children)

. the effect of the orientation of the listener to the sound source

. the effect of interference

. whether sound could be heard under water (transcript 5.5)

Transcript 5.5 is taken from an interview with a child who was trying to reconcile the findings of his investigation with his previous ideas.

Transcript 5.5 Daniel, age 10

Q *Have you learned anything from your investigation?*

R *I didn't think sound travels as far in water as it did.*

Q *Did it travel as far in air?*

R *About the same.*

Q *Why did you expect it not to travel as far in water?*

R *Probably because water is like a block - it still gets through but not as clear.*

The post-Intervention interview data does not allow even tentative conclusions to be drawn about the context specificity of these responses since the interviews were mainly about children's Intervention activities and it would be necessary to re-interview the children about the Elicitation activities to estblish whether children could generalise the effects of the Intervention to the different contexts of the interview. Of the two infant children who were re-interviewed about the Elicitation activities and who changed their response there was little evidence of a generalization in understanding. Transcript 5.6 records a child's ideas following an investigation on the effect of distance on hearing.

Transcript 5.6 Neal, age 6

Questions about child's investigation on the effect of distance on hearing.

Q *What did you find out?*

R *The sound got lower when I went further away. It was still there even when I couldn't hear it.*

Q *What happens to the sound when you can't hear it?*

R *The sound will bounce away. At the 'Backs' there's a wall and the sound comes back because it can't get away from the wall. The sound bounces off the walls - they're too strong for the sound to get away.*

Q *So what happens if you go too far away to hear the sound?*

R *The sound must have bounced back.*

Q *How does the rubber band make a sound?*

R *The air must make the sound as well because the air's in the middle and it must make the air go so fast that it makes a noise as well. The rubber band pushes the air and it makes a sound. If you swing anything like a belt or a bit in front of you it makes a noise because the air's being pushed.*

Q *How do you think that sound gets to you so you can hear it?*

R *I don't know.*

Sound Reception

Table 5.9 Changes in children's ideas about sound reception, before and after Intervention.

Infant n = 12	**LJ** n = 15	**UJ** n = 17
pre- post- Intervention	pre- post- Intervention	pre- post- Intervention

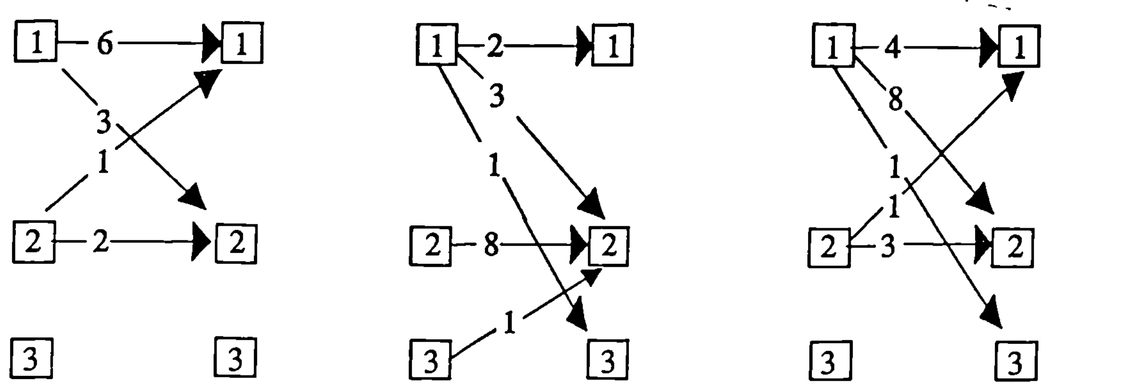


Table 5.9 shows that the proportion of children whose ideas about sound reception changed was approximately one half in each age group. Most changes occurred amongst the upper juniors where 53% of children changed the type of response they gave. Post-Intervention, 42% of infants and 75% of juniors mentioned the ear during interviews about 'sound'. Very few children mentioned the need for vibrations to be set up in the ear in order for sound to be heard. The lower junior who had given that response before Intervention did not repeat it post-Intervention; his investigation was

concerned with blocking the transmission of sound. The two children who stated this idea for the first time post-Intervention had carried out investigations into:

. blocking the reception of sound

. the effect of distance, and using one or two ears, on hearing

Both of these investigations encouraged children to focus on the reception of sound. It is not possible to perceive sound waves hitting the ear drum and making it vibrate so the Intervention might have meant that the children were motivated to seek out the information for themselves in books.

Appendix 10

Appendix 10

Criteria for good questioning practice (Watt, 1992)

1. Respond verbally to any answer with equal interest

2. Use tone of voice in a manner which reinforces the interest in any answer

3a. Give a child ownership of an answer by using words such as, "What do you think...?" to begin a question

3b. Cue a child to the cognitive level of response required by using words such as, "What do you think...?" to begin a question.

4. Invite an answer from any child who wishes to contribute.

5. Encourage children to respond to each other's views.

6P Seek clarification of a child's answer relating to scientific procedure

6C Seek clarification of a child's answer relating to scientific understanding

6P/Ca. Seek clarification by repeating a child's words back to them

6P/Cb. Seek clarification by asking the child what they mean

6P/Cc. Seek clarification by reflectively rewording the child's response back to them

7a. Extend a child's answer by asking for a hypothesis or for evidence to support one.

7b. Extend a child's answer by challenging their hypothesis.

7c. Extend a child's answer by asking them to generalise

8. Word questions so that the intention behind them is clear.

9. Be sure of the area (rather than the specific content) of the discussion.

10. Allow a child sufficient time to formulate a response

11. Ask questions according to a considered sequence.

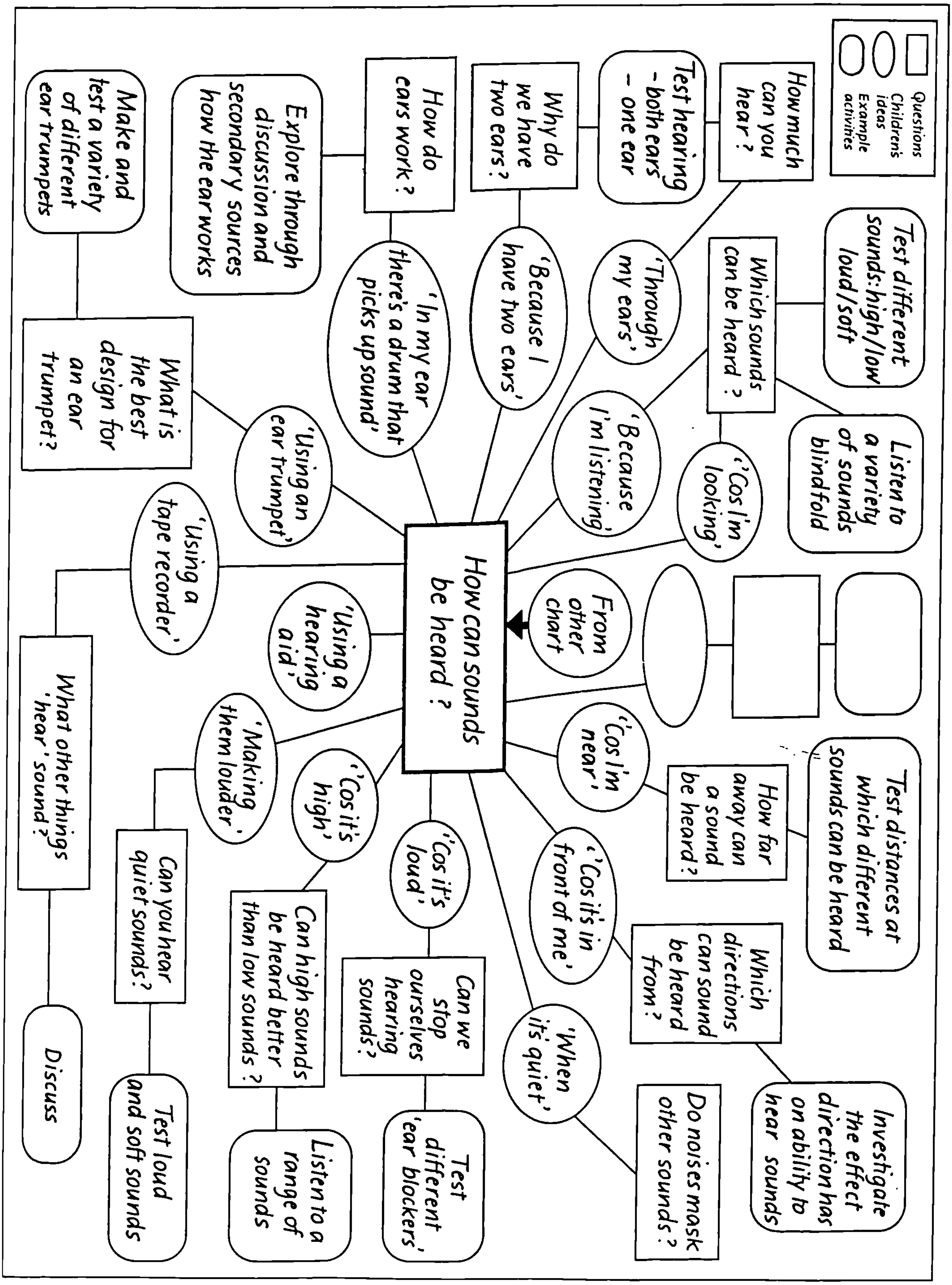
12. Listen to a child's answer and use it as the basis for the next question

Appendix 11

3.1

Intervention planning chart:

Nuffield Primary Science KS2 Teachers' Guide 'sound and music' p39



Appendix 12

Appendix 12

Pilot elicitation and elicitation: Growth research report pp. 3-18

2. *ACTIVITIES PRIOR TO INTERVENTION*

2.1 Pilot Activities

As one of the first topics to be researched within the Primary SPACE Project programme, the work on 'Growth' was preceded by a fairly extensive pilot phase. The pilot phase enabled the researchers to refine procedures in the light of exposure to classroom conditions as well as to gain some broad insights into the kind of information which it might be possible to collect. The pilot phase also gave the participating teachers time and opportunity to clarify their own roles by discovering what was viable and useful for them. Because of its importance, the pilot phase is reported in some detail in the first part of this section. The guidelines provided for teachers, the exploration activities and the elicitation techniques are all described. The second part of this section describes the refined activities as they were deployed in the study proper. The quantified data presented in later sections is based on these latter activities and techniques.

The Pilot phase activities to which children were exposed were as follows:

a sprouting potato tuber

a sprouting carrot top

germinating mung beans

maize seeds grown in soil

maize seeds grown in water

broad beans grown in water

monitoring stick insect's growth

incubating hens' eggs

children measuring their own height and weight

These activities were chosen with particular criteria in mind: it was important that the materials would grow reliably and that the amount of growth over the three week period prior to interviewing would be sufficient to be appreciated and measured by the children. Stick insects, while maybe not very widely experienced by the children previously, would grow about two centimetres during that time and might shed a skin as well. The mung beans were soaked, drained and placed in a jar in a dark cupboard. The broad beans were grown on trays of damp cotton wool. This was to enable the root growth to be observed more easily. These species of seed were chosen for their relatively short germination period, and for their rapid development. Potato tubers and hens' eggs were included as examples of growth which is relatively 'self-contained' and would proceed without the addition of extraneous materials, given suitable conditions.

The activities were set up in the classroom for a period of five weeks, during which time teachers were asked to encourage their children to observe the activities carefully. The teachers were each visited by the group co-ordinator and research co-ordinator during this period to iron out any difficulties with materials or procedures.

Teacher Guidelines

Teachers were provided with guidelines about how to set up the activities, and how to introduce them to their classes. These guidelines contained lists of equipment, details of preparation of the activities including germination times, suggestions for methods of recording the children's ideas and observations, and possible questions to ask the children about the activities. The guidelines may be found in Appendix II.

Teachers were asked to make the activities accessible to children in their classrooms and to encourage the class to take an interest in them, without actually teaching the children anything about them. It was suggested that the activities might be introduced in terms such as:

> "Here are some things we're going to have around in the classroom. Have a careful look at them every now and again and make a note of anything that's changed."

The growing materials all changed gradually over the period they were in the classroom and were not incorporated into any classroom work that the teachers were undertaking.

Classroom Implementation of the Activities

The teacher guidelines were interpreted and put into practice in slightly different ways, from teacher to teacher. This was in keeping with the policy of encouraging teachers to incorporate project work into their normal teaching style, and it did not effect the range of experiences which was available to each child. The efficacy of particular activities varied to some extent from class to class and from one age group to another, as did the different techniques for finding out the children's ideas. The brief outline which follows summarises the reactions to the activities and methods of elicitation.

Activities

Sprouting potato tuber

■ This was the only activity to be mishandled by the children. In several classes children removed the shoots and roots from the potatoes (perhaps inadvertently, due to rough handling) as soon as they sprouted, making them very uninteresting. Even where this did not happen the potato evoked little interest - except in one class, where children appeared to be fascinated by its growth.

Sprouting carrot top

■ These proved unreliable as they often failed to sprout. Those carrot tops which did sprout leaves did not produce roots.

Germinating mung beans

■ The mung beans proved to be interesting for the children: they changed noticeably in both size and colour when they were soaked in water, and on germination both root and shoot were clearly visible after a comparatively short time. These were grown successfully by all teachers, though sometimes two attempts were necessary. The main problem was that the beans had to be rinsed every day and then drained of water; if any water was left with the beans they tended to start rotting and smelling.

Maize seeds grown in soil

■ Maize was selected for its rapid, straight growth. Unfortunately, it did not germinate very well in a classroom environment, perhaps as the result of low temperatures.

Maize seeds grown in water

■ Germination was very slow, and the swelling of the seed in water did not tend to be as noticeable as with other seeds.

Broad beans grown in water

■ These swelled noticeably on soaking and germinated well though they tended to dry out with the shoot often going black. Once well established, the growth of both shoot and roots was sufficient to hold children's interest.

Monitoring stick insect's growth

- The stick insects were immediately interesting for the children to watch, even though they moved very little. Unfortunately the stick insects, an ideal shape for measuring, invariably started moving very fast whenever children tried to measure them. This diversion proved to be time-consuming and rather frustrating. Most of the stick insects moulted at least once, providing another tangible, if puzzling, piece of evidence of growth occurring.

Incubating hens' eggs

- This activity generated the most excitement and interest. The care of an incubator full of eggs was demanding for the teachers, but the value to the children of watching the eggs hatch was considered to be so great that the anxieties were forgotten. Every teacher except one managed to hatch and rear at least one chick. This activity was the one which the teachers found hardest to stand back from so as to avoid giving the children any input. The development inside the egg was a golden teaching opportunity which they were reluctant to miss. (An initial problem of locating incubators which worked and could be borrowed, and suppliers of fertile eggs who would be prepared to accept the chicks back once they had hatched, was overcome after diligent searching.)

Children's own height and weight

- These measurements were to be used as a starting point for discussion based upon the children's experience, since the time span of the classroom work was insufficient for any observable growth to occur. These discussions proved fruitful and were not hampered by lack of available comparative measurements. Comparison between individuals was possible, and this also led to profitable discussion.

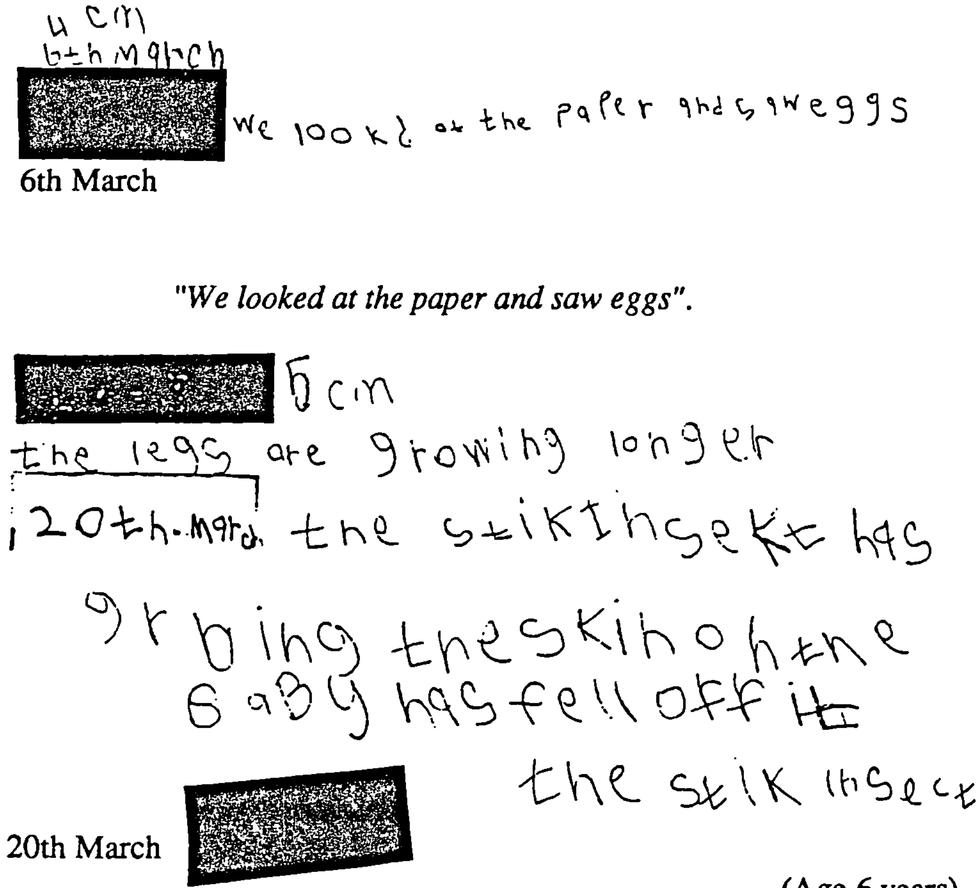
Elicitation Techniques

Diaries (free writing/drawing)

- It was suggested that children should make regular observations of the materials, the frequency depending on the rate of change; plant growth might be looked at every day, and stick insects every week. The diaries could be pictorial or written, depending on the age of the children involved, and any entries could be supplemented by teacher annotations if the children's comments needed explaining more fully. The main purposes of these diaries were to focus attention on the activities and to provide an informal record of the children's ideas.

The teachers of younger children, in particular, found that individual diaries were time-consuming since the children's skills in writing and drawing were not highly developed. The children's entries tended to be descriptive and in this respect they often provided valuable evidence of very careful observation, as in the following example from a six year old's stick insect diary. (Figure 2.1)

Fig. 2.1



6th March

"We looked at the paper and saw eggs".

20th March

(Age 6 years)

"The legs are growing longer "

"The stick insect has grown, the skin on the baby has fell off it."

There was also a large number of activities to observe and this proliterated the number of diaries for some children. Nevertheless some of these diaries provided a coherent record of children's thoughts.

Fig. 2.2

Day 5

Now John has Suggested that the Seeds are the poo and that when they eat they have to get rid of the food that they eat Because they would have very bad Stomechach. We have cept the Stick-insects for Seven days and Seven nights. We have put another leave in Wintys bottle but We took it out of the tintys bottle. The Stick-insects live for Seven or Six months. I thought that the Stick-insects where two or three months old I think they like it now. We think one of the dangers for the Stick-insects is that we have not too put them in the Sun and keep them in a cool place.

(Age 7 Years)

Day 5

"Now John has suggested that the seeds are the poo and that when they eat they have to get rid of the food that they eat because they would have very bad stomach ache. We have kept the stick insects for seven days and seven nights. We have put another leaf in Winty's bottle but we took it out of Tinty's bottle. The stick insects live for seven or six months. I thought that the stick insects were two or three months old. I think they like it now. We think one of the dangers for the stick insects is that we have not to put them in the sun and keep them in a cool place."

It was suggested that an alternative to individual diaries, particularly for younger children, might be group or class diaries. These could be placed beside the activity so that any child could make an entry (named and dated) as and when they had a comment or observation to offer . These group diaries worked very well and it was found that one child writing or drawing encouraged others to contribute.

Fig. 2.3

Fig. 2.3 Monday March 9th

One stick insect has changed colour
- Nazrin.

Longy has grown very big. - Nahida.

The Stick insects changed their colour
- Saeeda.

Today we have given the stick insects some leaves.
Longy is a differut colour. - Shaun

Monday April 6th
Longy's legs have gone red - Shaun

Longy has got stripes on his back - Saeda.

"Monday March 9th
One stick insect has changed colour. - Nazrim.
Longy has grown very big. - Nahida
The stick insects changed their colour. - Saeeda
Today we have given the stick insects some leaves.
Longy is a different colour. - Shaun

Monday April 6th
Longy's legs have gone red. - Shaun
Longy has got stripes on his back. - Saeeda"

The status of the diaries, from the teachers' point of view, was in some instances problematic. In the same way that open-ended questioning and an interest in any response might have been considered to be an abrogation of teaching responsibility so too was the acceptance of children being able to write what they chose, as and when they chose to do so. There was a very thin line to divide encouraging children to take an interest in these 'background activities' and allowing them to assume a prominence in order to provide the motivation for children to write or draw in a diary. These informal recording skills had to be developed by the children incidentally; it was not a procedure or format with which many were familiar.

It was gradually realised that the use of the word 'diary' led to an over-emphasis on regular recording, whether there had been any change in the growing materials or not. Reference to a 'diary' also, by association, probably encouraged the recording of factual details without a need being felt to take them any further. Procedures were modified as a result of this experience. The use of the term 'log-book' was substituted in later work.

Structured writing/drawing

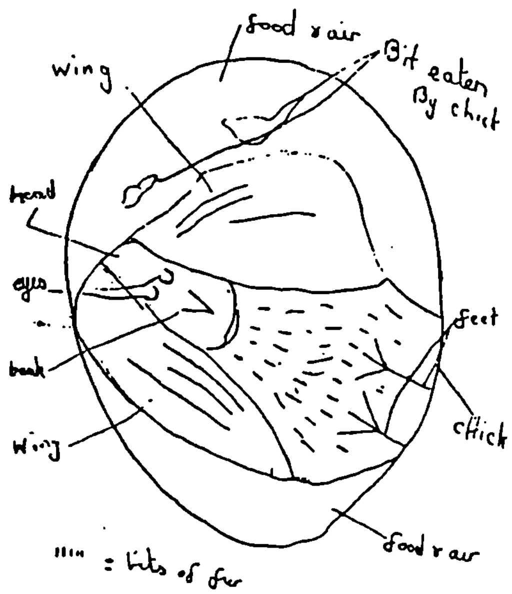
■

Structured writing and drawing was produced particularly in association with the hatching of the hens' eggs. Some classes were directed by their teacher to write about the hatching, and while these accounts were largely factual they came to life when children added details indicating their surprise at the happening, or their expectations of the outcome. One teacher asked the class of children to draw what they thought would be happening inside the egg. These drawings were extremely informative, particularly as the teacher asked children to label their diagrams with explanatory notes and comments following discussion and clarification with her.

Fig. 2.4

(Age 9-10 years)

Fig. 2.5



(Age 9-10 years)

Individual discussion

- Some teachers, especially those of younger children, found the diaries to be unproductive and so they kept their own record of children's comments in a notebook. While this procedure was itself time-consuming the teachers concerned found it easier to manage than assisting a whole class of infants with writing, or clarifying drawings.

Class discussion

- Class discussions were tape-recorded. These tape-recorded discussions were, for many teachers, their first attempt at using a tape-recorder in this way with their class. This novelty, along with what were to some teachers unfamiliar questioning procedures, meant that the dialogue was occasionally rather stilted. Some teachers indicated that their concern to ensure that each child's comment would be identifiable disrupted the flow of the discussion so that it was not as natural as they would have liked.

Classroom Organisation

Two main types of class organisation emerged in connection with this work. Teachers who preferred children to keep individual diaries tended to ask each child to look at all of the activities. Teachers who preferred group diaries tended to allocate a group of children to one activity, though they were not precluded from looking at the rest. The teachers' presentational style might have influenced this choice and on the whole it was felt that dividing the activities amongst groups was more manageable.

Individual Interviews

At the close of the Exploration phase, a sample of children from each participating class was selected, on the basis of ideas that they had expressed, to be interviewed by a member of the research team. The interviews were tape-recorded and later transcribed. The activities about which children were interviewed were selected to provide examples of plant growth in soil and water, and from tubers, as well as animal growth. The activities upon which interviews were based were as follows:

a sprouting potato tuber
germinating mung beans
maize seeds grown in soil
stick insects
hens' eggs and chicks.

Where possible, the interviews were held in the presence of the materials upon which the activities were based so as to reduce the burden on recall and give maximum support to children's attempts to express their ideas. The interviewer had a set of questions around which to base the interview but was not limited to these questions or to a particular order of presentation if further clarification was needed. Interview questions are in Appendix III.

The research team had envisaged the Exploration within the classroom as proceeding in a low-key manner. However, the relative unfamiliarity to many teachers and children of both the unstructured recording and open questioning meant that the activities had received more prominence than had been anticipated.

Estimated times for germination of seeds which were given to the teachers had been produced by growing specimens in the research office. The conditions for growth appeared to be far more favourable in the office than the classroom, with the latent period before visible growth as much as doubled in the classroom.

A vast amount of data from classroom work and individual interviews was collected during the Pilot phase and this formed a valuable bank of information about the views which primary school children hold. The in-depth interviews provided evidence for the existence of a wide range of ideas, some of which had not been anticipated. (Figure 2.5)

Transcript 2.1

(from an interview with a six year-old about stick insects)

Q. What do you think it is that's making him grow?

R. I think it's the ivy.

Q. Why do you think that?

R. *Because it eats the ivy. Every time we eat something we grow a little bit more.*

Q. Now, you said that every time we eat some food, we grow a little bit. Do you think the same happens to your stick insect every time it eats some food?

R. But when he goes to sleep, he grows a little bit as well.

That growth might occur only in particular circumstances or at particular times had not been incorporated into the interview questions and had not been anticipated. As a result of this and subsequent interviews a question about when growth occurs was added. Secondly, the ease with which teachers handled non-directive teaching experiences in their classroom increased markedly over the five week period. This was mirrored by a greater confidence in their contribution to the project and it enabled them to comment constructively upon the efficacy of particular activities and elicitation techniques within the classroom. These suggestions from teachers were incorporated along with a consideration of practical issues in developing the second exploration phase.

2.2 Exploration and Elicitation Techniques used in the study

The structure of this second elicitation period was revised considerably to take into account:

the time of year

a change in the emphasis of the classroom elicitation work

a shorter time span

the fact that this phase was to be followed by the intervention.

The time of year

Autumn is not the time of year which is usually associated with growth. Bearing in mind the importance of a child's experiences in the formation of ideas, it was felt that every effort should be made to avoid growing species of plants which are normally only grown in the Spring or Summer. To this end, it was decided to use mung beans because they can be grown indoors as food at any time of the year. Broad beans were also chosen since they germinated well during the first phase, and are often planted in the Autumn to over-winter. Regrettably, hens' eggs could not be used because of the time of year and the difficulty of finding a supplier who would be prepared to take the chicks back after they had hatched. Instead, eggs laid by Cabbage White butterflies were used, and the caterpillars which hatched were used as the example of animal growth. Teachers were also asked in July 1987 to measure the height and weight of children in the class they would be teaching in September, so that they could be measured again if required in November. This would allow a four-month growing interval so that comparisons could be made using the children's own growth.

A change in the emphasis of the classroom elicitation work

The exploration was intended to be informal but several teachers found this approach to be a departure from their normal way of working and on occasion it became formalised. It was anticipated that this might occur to a larger extent near the start of the school year when teachers were establishing a rapport with their class, even though the technique had become more familiar to them. It was therefore decided to remove the emphasis on the diaries as the main source of children's work and to suggest that children should be given a small number of diagrammatic tasks to encourage their expression of ideas. These labelled diagrams had been extremely productive during the pilot activities in connection with the hens' eggs, so similar questions were posed regarding other aspects of growth. A class 'log-book' was suggested to replace the diaries, and entries were asked for as and when children felt they had something to contribute. Group activities were not suggested as it was felt that this would raise the profile of the activities to an undesirable degree.

A shorter time span

The five-week exploration period had the advantages of enabling material to grow an appreciable amount; chicks were hatched and reared until they were two weeks old, by which age they were growing wing and tail feathers; plant material could germinate and reach a fair size; stick insects grew measurably. On the other hand, it was felt that this period could be rather long to sustain children's interest, particularly that of infants, and the exploration was shortened to two weeks prior to interviewing. This was long enough for the materials to grow noticeably and for children's ideas to be elicited. The number of activities was also reduced in response to the shorter period and teachers' suggestions regarding what was a manageable amount.

Forthcoming intervention

Since the project had an expressed belief in the importance of children's investigative activities in supporting and promoting the development of their ideas it was important that there was potential scope for investigation in at least some of the activities. The broad bean had advantages over maize in that the bean was larger and so could be more easily handled, and the swelling and associated changes which occurred during germination were more easily observable. Animal growth, whatever the organism, was felt to have restricted possibilities for investigation on ethical grounds. It was felt that a checklist based upon the categorization of ideas which emerged during the first exploration might help teachers to form a picture of their classes' ideas in preparation for the intervention.

Teacher guidelines

Teachers were requested to keep the exploratory work as incidental as possible, while establishing the ideas that the children had. The value of 'open' questioning was reinforced, as was the importance of maintaining a non-didactic stance. It was also suggested that the meanings of certain key words, e.g. 'growth', should be probed. Teachers were again provided with written details relating to each activity. These pages are in Appendix IV.

Classroom implementation of the activities

Activities

The activities set up in the classroom were:

eggs from cabbage white butterflies
caterpillars
broad beans grown in soil
mung beans
potatoes

Eggs

It was agreed that these eggs should be introduced as 'eggs which caterpillars will come out of', to avoid the potential ambiguity of describing them as butterfly eggs when what would emerge would be caterpillars. The eggs hatched very successfully though because of their size (approximately one millimetre), they had to be viewed through a magnifier. This necessity for magnification does not seem to have been problematic, even with the younger children. In fact, the hatching caused as much interest and excitement as had the hens' eggs.

Caterpillars

The possible dangers of feeding caterpillars on shop-bought cabbage in case it had been sprayed with insecticide were known to the research team who took efforts to obtain organically grown cabbage. Unfortunately, this cabbage had been treated with anti-caterpillar bacteria and many of the caterpillars which were fed on it died. Replacement batches of eggs were obtained from the supplier though these did not seem to thrive. Only six out of twelve classes managed to rear a batch of caterpillars. However, these six classes found it a very profitable activity and they were able to observe feeding followed by rapid growth. The caterpillars were kept until they pupated, over-wintered and hatched out as butterflies.

Broad beans

These germinated and grew very successfully. They were planted in transparent containers so that root growth could be seen even though they were grown in soil.

Mung beans

These again grew successfully and with less rotting than in the first phase since the teachers were familiar with the procedures.

Potatoes

These were almost completely unsuccessful since they failed to sprout.

Elicitation Techniques

Labelled diagrams

Three tasks were set which teachers were asked to introduce in as informal a way as possible so as to avoid the atmosphere of a test. The tasks were to be introduced at the appropriate point in growth or development. The tasks were as follows:

- draw what you think is happening inside the eggs.

- draw a plant in the place you would put it for it to grow very well. Show everything you think the plant would need.
(drawn when the broad beans were established)

- draw a picture of your caterpillar and what it is doing today. Next to it, draw what you think it will be like tomorrow, and the day after that ... so you end up with five pictures.
(drawn 4 to 5 days after hatching)

These proved to be acceptable and viable classroom techniques, making sufficiently modest demands on teacher time to allow them to discuss the pictures with some of the children and add clarification to the diagrams where necessary. Teachers of children at years one and two found these tasks possible with their classes, though the results were more variable and at times required extensive clarification due to the children's limited recording skills.

Group log-books

The log-books replaced diaries as informal opportunities for recording details felt to be important by the children. They were often large format 'scrapbooks' into which children could paste their entries. They were found to be unobtrusive and helpful as stimuli for individual discussion between the teacher and a child. The content was often limited to factual descriptions, though teachers were becoming more proficient at probing further to obtain elaborations and interpretations.

Individual discussion

Teachers appeared to find this increasingly useful, possibly as their familiarity with open questioning methods increased.

Organisation

The amount of 'Growth' material was felt by teachers to be manageable within the classroom situation and the structured drawings proved very easy to organise. The main concern of teachers appeared to be the lack of time available for one-to-one discussion. It seemed that they had become aware of the potential within each child and wanted to explore it. Several teachers found themselves using break times to talk to children so that they could construct a 'complete picture' of their classes to help them in the intervention.

Individual Interviews

A random, stratified sample of children was selected from each class to be interviewed individually following the exploration. The children were chosen so that there was an equal number of boys and girls from each of the three achievement bands.

The number of activities in this second exploration was small enough to allow the interview to cover all of them. This selection of activities was representative of plant growth in soil and water and from tubers, and animal growth.

The interviewer had a set of questions, similar to those used in the first phase but refined as a result of experiences gained. The interview questions may be found in Appendix V.

The structure of the Exploration proved very successful within the classroom, allowing children to express their ideas in both a structured and an unstructured way. As a result of this phase of work, teachers were able to gain an overview of the ideas emergent in their classes, and to discover similarities between their own and other teachers' children when experiences were exchanged at group meetings.

Appendix 13

Appendix 13

Intervention: Growth research report pp. 70-74

5. INTERVENTION

The Pilot Elicitation phase enabled children to express a wide range of ideas about growth. This data enabled the Project team to gain an overview of the recurrent features in the children's ideas as well as some insight into the situations and experiences which had led to these ideas developing. The recurrent features in children's ideas about growth formed the basis for a range of Intervention strategies used by teachers in the classrooms.

It was thought that the chance of conceptual change might be enhanced by allowing children to work in the area that interested them most. For this reason, teachers were presented with the Intervention strategies and encouraged to develop classroom work particular to their own classes. It was felt that, in order to attempt to influence children's ideas, it would be beneficial for the teachers to focus the children's thoughts on one particular aspect of 'Growth', rather than try to cover everything in a superficial manner. It was also suggested that the main focus of the Intervention work should be encouraging children to test out their ideas - so that teachers were using the children's ideas as starting points for classroom activity. Teachers were asked to hold a minimum of four sessions based on Intervention work over the five-week Intervention period and to ensure they included at least one activity related to vocabulary, generalisations and trying out children's ideas. They were also asked to keep a record of the Intervention work they undertook, particularly in relation to the children who were to be re-interviewed after the work. Teachers received a visit from a member of the research team each week during this period in order that support and guidance might be offered. The guidelines given to teachers are in Appendix VI.

5.1 INTERVENTION STRATEGIES

The following paragraphs describe the Intervention strategies and the way that it was advocated that they could be approached during work on growth.

Helping children to test their own ideas

Children's ideas about plant and animal growth were often context-specific, based upon observations which had been made from a limited range of experiences. Plants, for example, were often thought to need soil in order to grow. The distinction between germination and growth could be problematic with regard to the need for soil: an idea suggesting that soil is always necessary at every stage of seed and plant growth could be tested and refined. By encouraging children to test their ideas in a rigorous manner it was envisaged that children's thinking might develop along lines which might be more productive. This strategy, of children testing their ideas, was the main focus of each class's Intervention experience.

Encouraging children to generalise from one specific context to others through discussion.

The context-specificity of children's ideas has already been mentioned. Teachers were asked to provide a forum, through class discussions, for children to share their ideas and experiences so that the class members could have access to a broader range of experiences. The opportunity for peer discussion might enable children to develop their ideas and link a wider range of experiences.

Encouraging children to develop more specific definitions for particular keywords.

Certain key words were either used incorrectly or not used at all. The word 'growing' was used with several meanings by children, for example, 'getting bigger', 'being pushed out by water' and 'getting longer'. There was also evidence of some confusion with 'stretching'. Teachers were asked to encourage children, through activities, to refine the definitions and to move towards a consensus meaning for some words which were central to the topic of growth.

Finding ways to make imperceptible change perceptible.

The rate of growth is so slow as to be imperceptible but the results of growth can easily be seen as an increase in size. The fact that 'growing' cannot be observed in the normal classroom situation is problematic to many children, particularly younger ones, and a resolution of the conundrum which was commonly constructed was that growth must occur while the child is absent. Teachers were asked to explore ways of making the very slow process of growth perceptible to children.

5.2 Classroom Implementation of the Intervention

The nature of the topic 'Growth' is such that certain ethical restrictions are placed upon investigative work that can be carried out. Because of this, the vast majority of classroom interventions were concerned with plant growth, and particularly the conditions necessary for broad beans to grow.

The following are some examples of interventions which were initiated by teachers with their classes:

Trying out children's ideas: 'What Do Plants Need To Grow?' (Middle Infants)

The teacher had decided to try to explore the notion, arising from imperceptible growth, that plants only grow at night. However, during the introductory discussion the children's responses were connected with conditions for plant growth, so this alternative avenue was pursued. The discussion began in a way familiar to the children, by recalling the previous Exploration experiences with broad beans. Children suggested that broad beans need mud (soil), sun and water to grow. When asked if it would be possible to grow the beans with any of the soil, sun or water missing, three children each volunteered one set of conditions:

> *"Try it without mud"*
> *"Try it without water"*
> *"Try it without sun"*

Four pots were set up by the children, one for each of the above conditions and one control, and three beans were put in each pot. The children suggested suitable locations for the four pots and were given the responsibility of caring for them. This investigation lasted for six weeks and, in the words of the class teacher, 'The children's interest never waned throughout the Intervention and the activities were looked at spontaneously every day without prompting.' When the 'no water' beans failed to grow the children were able to suggest adding water, and when the 'no sun' beans were found to have small, yellow leaves the class suggested putting the pot in the light. The children's investigations had given them experiences which they were able to interpret and use to extend and confirm their hypotheses.

Developing Vocabulary: 'What does 'Grow' Mean?' (First Year Juniors)

The children appeared to have defined the word 'grow' in terms of 'stretching' - increasing the length of something without adding any more material to it - and they often seemed to use the two terms synonymously, e.g.

> *"I think when the plant is taking in water it is stretching the plant, stretching it from the seed as high as it can."*

The teacher made a collection of articles which increased in size by either growing or stretching, e.g. Christmas decorations, bubbles, knitting, stocking, treacle toffee, springs, and the children stretched themselves during a movement lesson. The children were able, during discussion, to explain quite clearly that stretching needed help and could not go beyond a limit, that things would break if stretched beyond a certain point or would return to normal if let go. The definition of growth was still unclear; it was thought that knitting might grow, by adding more wool on, but that as it could be unravelled and animal or plant growth was permanent, they might not be the same. The children had clearly been stimulated to think carefully about the two words even though their conclusions were incomplete.

Generalisations and Making the Imperceptible Perceptible: 'When Does Growth Take Place?' (Fourth Year Juniors)

This class had successfully reared its batch of caterpillars and the teacher decided to capitalise on the children's interest and explore animal growth through discussion. A recurrent notion during the Exploration had been that the caterpillars grow at one particular time, e.g.

> *"While they're sleeping"*
> *"They grow when they eat"*
> *"They need darkness"*

The children were encouraged to consider parts of their own bodies which grew, e.g. hair, teeth and nails, and whether these obviously changed in length at any time, for example during a meal or overnight. This theme was pursued with the use of a video film illustrating metamorphosis through time-lapse photography. The time-lapse photography enabled gradual, continuous growth to be seen by increasing the rate of change. These two activities had the effect of provoking the children to consider their ideas concerning the caterpillars critically, and to relate the caterpillar growth to their own.

5.3 The Interaction Between Science Skills and Science Concepts

The Intervention work raised some interesting and unexpected issues, as well as revealing the ingenuity of children and teachers alike. It was felt that, in order to influence concepts the main thrust of the teachers' interventions had to be through encouraging application of scientific processes to the children's investigations. This revealed a distinction between science concepts and processes which was problematic, with some teachers being reluctant to influence scientific rigour; they had become used to standing back and 'not telling' and were unsure whether or not to interfere in experimental design. The teacher meetings held throughout the Intervention (every two weeks) enabled teachers to share their work and discuss issues such as 'What is a generalization?'.

5.4 *Summary*

It will be clear that, in view of the child-centred intervention strategies which were adopted, the interventions could not be said to be standardised to any precise degree. However, the strategies were common to all groups . Teachers were also asked to keep a careful record of their intervention activities.

The Project team developed a range of strategies for Intervention which teachers implemented in their classrooms. The starting points for the classroom work were the children's ideas.

The importance of controlling children's use of process skills during investigations became very evident during the Intervention.

The Intervention strategies were:

- Using children's ideas as the starting point of investigation
- Encouraging children to develop more specific definitions for particular key words.
- Encouraging children to generalize from one specific context to others through discussion.
- Finding way to make imperceptible changes perceptible.

Appendix 14

Appendix 14

Understanding teachers' needs: Growth research report p. 92

7.4 UNDERSTANDING TEACHERS' NEEDS

A realisation of teachers' needs in relation to the teaching of science in primary schools was another area which was greatly clarified by the research. Three areas can be identified:-

(a) Conceptual understanding. Teachers' own understanding of the processes of plant and animal growth undoubtedly broadened and deepened during the course of the project.

(b) An understanding of process-based science was essential for the Intervention phase. For many teachers, their competence and experience in other areas of the curriculum did not provide solutions which generalised to science.

(c) Combining (a) and (b) above, a style of teaching is suggested which can best be described as a teacher-directed, pupil-centred, management of learning. This was in direct contrast to the assumption which many teachers held that science was pre-eminently about the transmission of knowledge - especially so in the context of a research project about conceptual development.

As the project has progressed, there has been a notable increase in the confidence of many of the teachers, not just in their attitude towards the project but also in the manner in which they approach their classes. This attitude is in many cases not restricted to science work, since teachers have become more aware of the manner in which they may enable children to learn, and also of what children bring with them to the classroom situation. As one teacher summarised her experience,

> 'The amount of information the children had acquired without being taught per se amazed me, and I was convinced that involvement, observation and experience were invaluable methods of learning.'

Appendix 15

Appendix 15

Elicitation: Sound research report pp. 3-8

2. PRE-INTERVENTION ELICITATION WORK

Prior to the Exploration phase, the teachers and Project team were involved in a total of two-and-a-half days of Project meetings. These meetings built upon the experiences the teachers had of SPACE work and enabled them to participate in discussions leading to the development of the 'Sound' Exploration activities. Additionally, teachers were asked to consider the criteria which would be important for the Exploration activities to be successful in the classroom. These criteria may be found in Appendix II.

2.1 Exploration (March 1988)

Teachers were given a pack which contained descriptions of the activities which they were asked to use with their classes. Because of the preparatory work the teachers had done at the meetings, it was possible to make these descriptions brief, containing only the amount of instruction necessary to ensure uniformity of presentation between classes. This pack may be found in Appendix III.

Activities

Teachers were asked to set up the following activities in their classrooms for a period of four weeks and to encourage children to interact with them while not teaching the class anything about them.

a. sending and receiving a message through a string telephone

b. stretching and plucking a rubber band

c. listening to sounds through an ear trumpet

d. hitting a drum which had some rice grains on the skin

e. listening to everyday sounds

Each activity is described in detail below, accompanied by an indication of the reactions of pupils and teachers to the activity.

a. Sending and receiving a message through a string telephone

A string telephone was constructed from two yogurt cartons, each with a small hole in the base, and a length of string. The string was threaded through the holes, into the cups, and knotted securely at each end. Thus, the string provided a link between the two yogurt cartons.

The children were asked to work in pairs and to hold one yogurt pot each and take it in turns to whisper a message to each other. It was suggested that younger children should make their message an instruction, e.g. draw a house, so the drawing would show whether the message had been heard correctly. Older children could, as an alternative, write down what had been said to them. The string telephone was chosen because it made explicit a pathway for sound travel between the speaker and receiver, thus exemplifying sound transmission through a medium. This activity was very popular with the children and encouraged them to express their ideas about sound travel, though several teachers remarked that the children had not known how to use the apparatus correctly: some children had tried to bend the string round a corner, while others had wanted to face their partners and had thus pressed the string against the bottom of one of the yogurt pots. Each of these arrangements would prevent the string from vibrating freely and would hamper the hearing of the message.

b. Stretching and plucking a rubber band

Children were asked to stretch a rubber band either around a carton or between their fingers and to pluck it to see whether they could play a tune. This activity was chosen to exemplify sound production and the movement associated with it. The movement could be both seen and felt as a tingling sensation in the fingers which were stretching the band. This activity produced some useful information about links which children made between movement and sound production, and also between the tension in the band and the pitch of the resultant sound. Some teachers were initially apprehensive about the potential misuse of the bands by the children but these anxieties were not confirmed.

c. Listening to sounds through an ear trumpet

The top half of a large plastic lemonade bottle was used as an ear trumpet, or 'funnel', to encourage children to focus on sound reception. Children were asked to put the funnel to one ear and to listen to the sounds around the classroom. They were then asked what difference the funnel made to the way they could hear. Some children chose to use the funnel with the wide opening towards their ear rather than away from it and this probably accentuated the effect which was noted by many children, that the funnel acted like a sea-shell: pupils often claimed that the funnel made them hear differently, that they could hear a noise like the sea. This effect might have been achieved partly because of the instruction to listen to sounds around in the classroom rather than to focus on one particular quiet sound, such as a watch or clock ticking. A different instruction might have helped children to focus more easily on the perceived amplification of the sound rather than other peripheral effects. The peripheral, distorting effects might have been exacerbated by the length of the lemonade bottle section which was used. The long length tended to incorporate an echo chamber which could have obsured the sound focusing effects. Despite this draw-back, the funnel was a very useful activity for encouraging children to attempt to represent sound diagrammatically and for suggesting mechanisms concerned with how sound enters the ear.

d. Hitting a drum which had some rice grains on the skin

Children were asked to hit a drum both before and after putting rice grains onto its surface. They were also asked to put their finger lightly onto the drum's surface while it was making a sound. This activity primarily exemplified sound production, but the children were also asked to comment on transmission and reception. Teachers reported that the drum was very popular with the children, though rather noisy within the classroom. The beating of the drum encouraged children to express a wide range of ideas about sound production and it was a valuable activity. However, the presence of the rice was a distraction for all except the oldest children who could explain the movement of the rice from their ideas about how the drum made a sound.

e. Listening to everyday sounds

Teachers were asked to take their children on a 'listening walk' around the school and the grounds, to focus their attention on sounds. This was a productive introductory activity to the work on sound but did not itself lead to the expression of very many ideas.

Elicitation Techniques

Teachers were asked to refrain from class discussion so that each child's ideas would not be influenced by their peers more than could be avoided. As the teachers were being careful not to teach the children about sound it was suggested that, as well as asking individual children to draw their ideas, there should be a class log-book into which entries could be made informally by children. This book would provide teachers with a way of showing an interest in what children were doing and in their ideas.

Class Log-book

It was suggested that teachers introduced a 'Sounds' or 'Listening' book into which children could write or draw their ideas and observations about any of the Exploration activities. It was also suggested that children might like to make entries concerning types of sounds they had heard, and also different sound makers which they had experienced recently.

In practice, many teachers chose either to use a separate book for each activity, or to leave some paper by each activity so that entries could later be compiled into one book. This book provided an informal record for teachers of the children's thoughts about the topic. The notion of a 'Sounds' book tended to be identified with children's reactions to their 'listening walk'.

Labelled Diagrams

The Project team had specified two activities for which children should be asked to draw their ideas. These were the drum and the ear trumpet. The drawings which children were asked to produce were intended to portray ideas rather than be aesthetically pleasing pictures. This distinction had initially needed careful reinforcement by teachers, since such diagrams were not a form of recording with which many children were familiar. The questions asked were:

a. Drum

Draw pictures to show:

i. how you think the drum makes a sound;

ii. how you think the sound gets from the drum to you so you can hear it;

iii. how you think you hear the sound.

b. Funnel ear trumpet

Draw how the funnel helps you to hear differently.

These questions were very productive in helping children to express their ideas.With hindsight, an additional instruction to show the sound on the picture might have encouraged more children to attempt to represent their conception of sound on paper. Teacher annotation of the diagrams, following discussion with the child, was invaluable in clarifying the children's ideas.

One interesting development in the teacher's perception of their role during this, the second topic with which they had used Project techniques, appeared to be an increasing sense of ownership of the techniques and a desire to find out for themselves the ideas which were held by their classes. This development resulted in some teachers posing their own questions to their classes and asking them to draw additional diagrams to explain the rubber band and the string telephone. One teacher, for example, asked children to draw how they thought they heard the sound from the rubber band. This instruction was very similar to that used by the Project team in connection with the drum. While it was carefully worded, it might not have been the most profitable instruction to use with the rubber band, where the most salient aspect was sound production. The majority of children's drawings appeared to be responses to a more general instruction to draw how the rubber band made a sound.

Individual Discussion

Teachers found the diagrams to be a profitable starting point for individual discussion and they were keen to question the children as much as was practicable in the classroom. Increased confidence with open questioning methods made this activity more productive and enjoyable for both teachers and pupils. This questioning, in conjunction with the other elicitation techniques, enabled pupils to clarify their ideas and to express them to the teachers in a coherent manner. Both pupils and teachers had previously worked on the 'Growth' topic together and it is likely that this experience had facilitated the participation of both parties in these discussions. Teachers were likely to have become more skilled in asking questions of a kind which offered children the opportunity to express their ideas; the children could have improved their self-expression and been more familiar with the more open role of the teacher.

Interviews with Individual Children

A sample consisting of approximately six children from each of the eleven classes was interviewed individually about each of the Exploration activities. This sample was balanced for gender, achievement and age and was selected randomly within these constraints. Each of the children interviewed had had access to the Exploration activities for at least two weeks. Members of the Project team visited the children's schools to interview and talked to children either in a quiet corner of the classroom or in an empty room, for example the library or staff room, within the school building. The interviews were conducted in an informal manner so that the children were as much at their ease as possible. The interviewers had a list of questions demonstrating the areas in which there should be an attempt to elicit children's ideas. In order to maintain informality and to supply further information these questions could be supplemented with additional ones where necessary, or re-phrased where children were unclear what was being asked. An important consideration throughout the interviews was that children should not feel pressurised into giving answers which were not their considered opinions. With this in mind, 'I don't know' was accepted as a valid response.

The length of interview varied greatly from one child to another but the modal duration was 30-45 minutes.

The questions around which the interviews were centred may be found in Appendix IV.

Organisation

The Exploration activities required minimal apparatus and so were easy to set up in the classroom. The main drawbacks, when dealing with the topic of 'Sound', were that generating sound made a noise, and that careful listening to the sound required low levels of background noise. These constraints sometimes led to work being carried out during playtimes when it was not possible to place the activities away from the main class yet in a position where the teacher could supervise the children who were involved. Some teachers found that certain activities were best used with the whole class together. Examples of suitable whole-class activities were the 'listening walk' and the rubber bands, both of which were quiet rather than noisy activities.

Summary

The Exploration activities were each very different in the experiences which they provided, but each of them was profitable in terms of encouraging children to express their ideas concerning particular aspects of sound. The activities were:

a. sending and receiving a message through a string telephone (sound transmission)

b. stretching and plucking a rubber band (sound production)

c. listening to sounds through an ear trumpet (sound reception)

d. hitting a drum which had some rice grains on the skin (sound production)

e. listening to everyday sounds.

The pupils and teachers were both more familiar with expressing ideas and encouraging their expression due to earlier involvement with the SPACE Project. This familiarity enabled teachers to feel confident about their class's ideas and to develop a picture of possible avenues which the children could profitably investigate during the Intervention phase in their classrooms.

Appendix 16

Appendix 16

Teacher criteria for exploration activities: Sound research report appendix II

APPENDIX II

Exploration Criteria

Teachers were actively involved in the construction of the programme for the second round of topics. As the lead-in to the design of activities for the Exploration phase, the criteria for suitable classroom experiences were considered by each of the three groups, and were later amalgamated under the following headings:-

Familiarity and relevance to children's experiences

Clear relationship between Exploration activity and other experiences. Relevant and familiar material, based on children's everyday experiences, relating to their awareness of the world around.

Safety

The activity should be safe. (For example, avoid the opportunity for children to put things in their ears and nostrils; avoid drinking or smelling liquids; avoid sharp objects and glassware).

Durability

The activity should be sufficiently durable to last the full extent of the Exploration phase. Plant or animal material should be robust and hardy.

Interest

The activity should be enjoyable, motivating and appealing, capable of stimulating interest and of making an immediate impact on children.

Simple Resources

The activity should be capable of being constructed from junk or easily available everyday objects and should involve simple technical processes which can be easily set up and maintained by teachers.

Accessibility

Activities should involve concrete examples, something large enough to be observed or handled easily. If the point of the resource material is that it changes in some way, the change should be speedy enough to be perceptible. The quality or degree of change must be obvious, something which the children can notice readily.

Comprehensibility

The outcome of the activities should be comprehensible to teachers and capable of eliciting clearly targetted areas of thinking in children.

Extendibility

The activity should lend itself to further activity, thinking, progression or investigation (during the Intervention phase). This may imply that obviously multi-variable situations should be avoided.

Ethical

When living material is used, it should be handled with regard to ethical considerations.

Replicability

The activity should be capable of being repeated in a similar way in all classrooms, with the means for replication between schools for research purposes.

Pupil Self-Direction

The activity should make minimal demands on teacher oversight, which implies that it should be sufficiently self-evident to be pupil-directed.

Recordable Responses

The activity should give rise to recordable pupil responses e.g. a drawing or some other brief form of recording.

Unobtrusive

The activity should be sufficiently compact to be useable in busy crowded classrooms.

Appendix 17

Appendix 17

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4. INTERVENTION

The Exploration phase encouraged children to express a wide range of ideas about sound both to the Project team, during individual interviews, and to their teachers, through less intensive elicitation work in the classroom. These ideas were the foundation upon which the classroom Intervention was built.

The Project team had developed a range of Intervention strategies as a result of ideas expressed by children during the first round of topics. The teachers, and children, were thus familiar with using these strategies in the classroom and it was suggested that they applied them to their work on 'Sound'. These strategies were designed to help teachers structure activities in four areas, each of which appeared to be capable of exerting important influences on the manner in which children form their ideas.

The teachers met for one day prior to the Intervention to allow them to discuss with each other and the Project team the manner in which they would implement the Intervention. During the Intervention, there were two half-day meetings; one towards the middle and one towards the end of the five-week Intervention period. These meetings enabled teachers to share experiences and pool ideas and were very valuable for the support they provided. The classroom Intervention took place between April 25th, 1988 and May 27th, 1988, the majority of the first half of the summer term.

Teachers were asked to enable their classes to engage with at least one activity relating to each strategy during the Intervention phase. The information which teachers were given concerning the Intervention phase may be found in Appendix V.

4.1 Intervention Strategies

The following paragraphs describe the four strategies and the manner in which they could be appropriate for the sound work.

i. Helping children to test their own ideas

Children's ideas about sound appeared to be based upon observations they had made, or upon information which they might have acquired from secondary sources, for example teachers, books or television. In either case, the ideas seemed to be very context-specific, relating just to one type of experience or observation. These observations were often incomplete or misinterpreted, leading children to reach conclusions which would not be substantiated by reference to wider contexts or by more systematic observation. It was envisaged that, by encouraging children to formulate questions which they could test in a systematic way, children might be enabled to develop their thinking along more productive lines. This strategy was the main focus of each class's Intervention experiences.

Fig. 4.1

when you stretch the elastic band tightly the noise travels fearther because its sharper

(Age 10 years)

''When you stretch the elastic band tightly the noise travels farther because it's sharper''

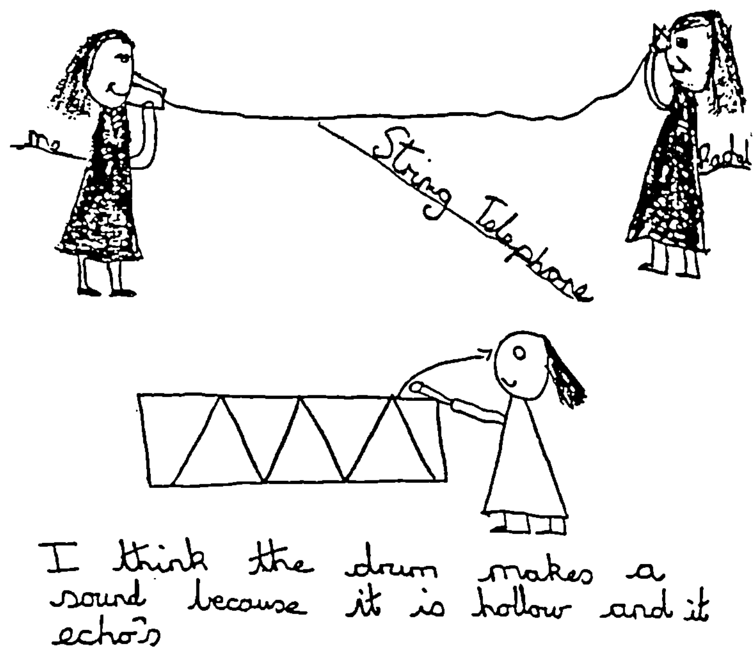
Fig. 4.1 gives an example of an observation which was made, and from which an inaccurate conclusion had been drawn. While it might not be very easy to test whether sound travels further when it is higher in pitch, a carefully constructed test might encourage the child to draw an alternative conclusion from the evidence which could be collected.

The role of the teacher was very important during such investigations and the teachers were required to develop a degree of competence in questioning children and in process science. It was through encouraging children to pose a question which was investigable, and by helping children to increase their awareness of the need to conduct rigorous scientific tests that teachers could encourage children to challenge their original notion. The pupils were being asked to put their ideas to the test and regard them as statements which could be discarded if they were found to be inadequate. These skills and attitudes, for both the pupils and the teachers, needed to be developed within the framework of a secure, open learning environment, over a period of time. The success of the investigations in helping the children to challenge their ideas might have been influenced by the extent to which the above-mentioned factors had been developed prior to and during the Project work.

ii. Encouraging children to generalise from one specific context to others through discussion

A recurrent theme throughout Section 3 was the high degree of context specificity apparent in children's responses. The same child would often give an answer that related to observations made for one activity and, because different observations had been made for another activity, a different explanation would be given.

Fig. 4.2



(Age 7 years)

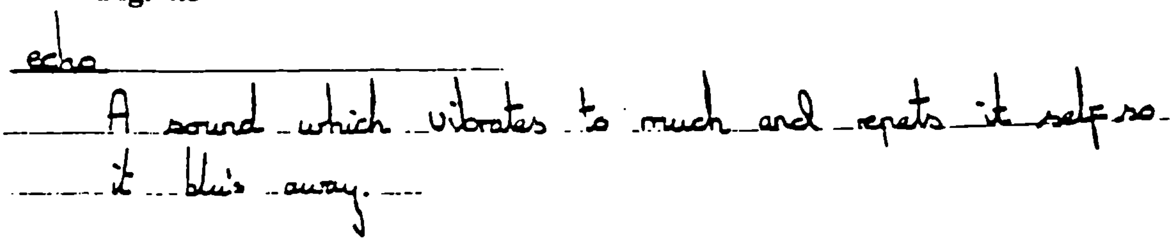
"I think the drum makes a sound because it is hollow and it echoes"

It was felt that, if the teacher provided opportunities for children to discuss their observations and encouraged them to see areas of commonality between classroom activities and their everyday experiences then children might develop concepts which were broader and less context-specific. By participating in class discussions children would be able to interact with the views and ideas which were held by their peers and this could enable children to broaden their experiences. This approach to class discussion required some teachers to reappraise their definitionof the activity. In many instances discussions had been considered to be question and answer sessions led by the teacher's questions. Over the course of the Intervention some teachers reported that their role in class discussions was changing: they found themselves to be chairing discussions between pupils. The pupils themselves were generating examples and instances from which to draw their own generalizations, within the limits of the discussion as defined by the teacher. These limits specified the general area within which the discussion should range and were defined in order to ensure that the exchange of ideas was focused enough to be profitable, and for the children to be able to see the common ground between each other's experiences.

iii Encouraging children to develop more specific definitions for particular key words

There were several instances of children using words for which there was an accepted definition in an idiosyncratic manner. 'Vibrate' and 'echo', for example, were each used on some occasions to mean 'repeat'.

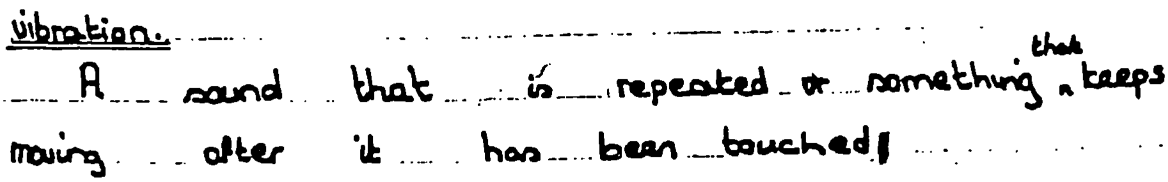
Fig. 4.3


echo
A sound which vibrates to much and repats it self so it blu's away.

(Age 10 years)

"echo A sound which vibrates too much and repeats itself so it blows away"

Fig. 4.4


vibration
A sound that is repeated or something that keeps moving after it has been touched

(Age 10 years)

"vibration A sound that is repeated or something that keeps moving after it has been touched"

This usage suggested that children had incorporated one aspect of the scientific definition into their vocabulary, possibly the one which had been observed in the context in which they first heard the word. This aspect of the word might then have been embellished by the child so that a definition related to, though not synonymous with, the dictionary would be developed and used. It was considered important that teachers clarified the meanings attached to these important words by children, and encouraged the children to reach consensus definitions by using the words in a relevant context. The emphasis of this vocabulary work was intended to be on using the words as part of an activity, so that the context was explicit and common to everyone.

In practice, the generalization and vocabulary activities were often very closely related. Where children were using words in an idiosyncratic way it was often helpful to encourage children to generalize as a means of clarifying their definition of the word. It was envisaged that such activities would clarify vocabulary which the children were already using rather than introduce unfamiliar terms. However, it was acknowledged that this latter approach could be appropriate if children obviously lacked a label for a specific process which they could describe.

iv. Finding ways to make imperceptible change perceptible

Sound is perceptible through the sense of hearing but it is not visible to the eye, except as vibrations in some sound producers. The process of sound transmission, in particular, is difficult to perceive. There were several activites which made sound visible (or tangible), for example placing rice on the drum or using a string telephone, and it was felt that the children could profitably explore these avenues.

The potential value of encouraging children to develop a form of representation for sound on paper was also considered, and was attempted by some teachers.

4.2 Preparation for Classroom Intervention

At the teacher meeting prior to the Intervention the teachers were grouped so that teachers who taught the same age children were together: thus infant teachers formed one group, lower junior teachers another and upper junior teachers a third. In these groups the teachers decided upon the open question they would present to children to begin the Intervention. This question was specific to each age group and ensured that the children's investigations would have the same starting point. The question was not intended to restrict children to one particular investigation but to provide a framework which would assist children in posing an investigable question. For example, "What do you think affects the way you hear?" could be a starting question which would enable children to suggest a particular variable to investigate.

The question decided upon by each group of teachers was very similar to the one exemplified above, though worded differently for children of different ages.

Infants - How can we make out ears better to hear with?

Lower juniors - What sort of things can alter the way you hear the sounds?

Upper juniors - What sort of things affect how well you can hear?

Teachers were asked to collate their class Intervention work on a simple record sheet, noting the activity with which children were engaged, e.g. the drum; the question which they posed to begin discussion about the investigation; the investigation which ensued; related vocabulary activities, and generalizations which were encouraged through discussion.

4.3 Classroom Implementation of the Intervention

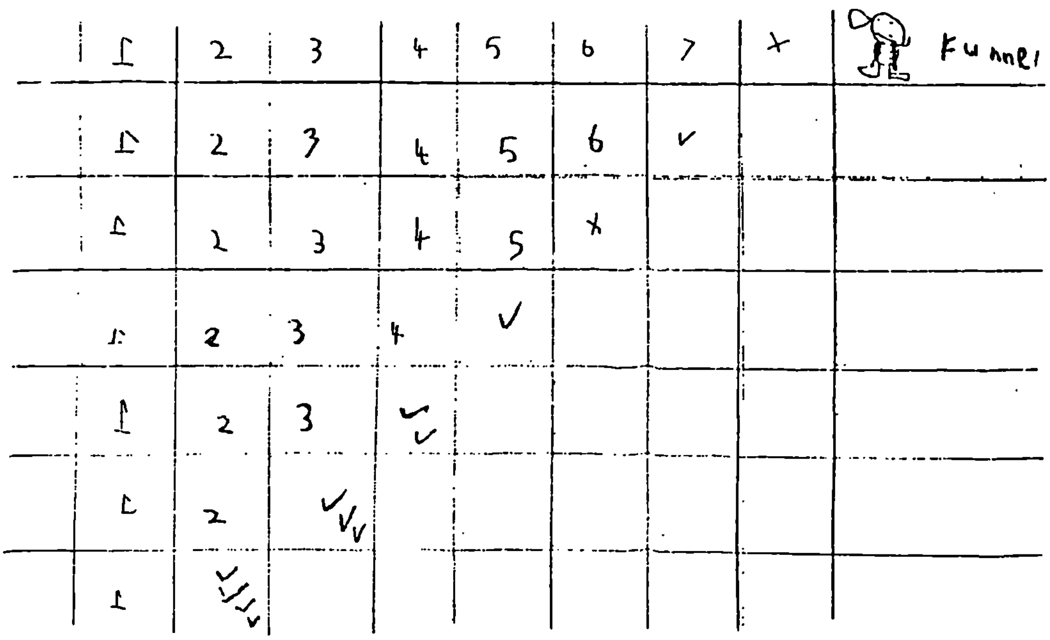
Infants

i. Helping children to test their own ideas

The investigations which were carried out by infant children were based upon the reception of sound. Children in one class made large paper ears and devised a way of fixing them round their own ears. Another class used different shapes and sizes of funnels and cylinders to see how these affected hearing. These hearing aids were all tried out using a standard sound. The distance of the child from the sound was also controlled: it was either kept constant, so that a subjective judgement of perceived loudness with and without the 'big ear' was obtained, or it was gradually increased until the noise was too quiet to hear.

One classroom happened to have a squared floor and the teacher encouraged the children to use the squares as the measure of distance. Some children were able to transfer their results onto squared paper. The diagram in Fig. 4.5 shows how well the child could hear a ticking clock with a funnel to his ear. The number of ticks indicated the perceived loudness of the clock.

Fig. 4.5



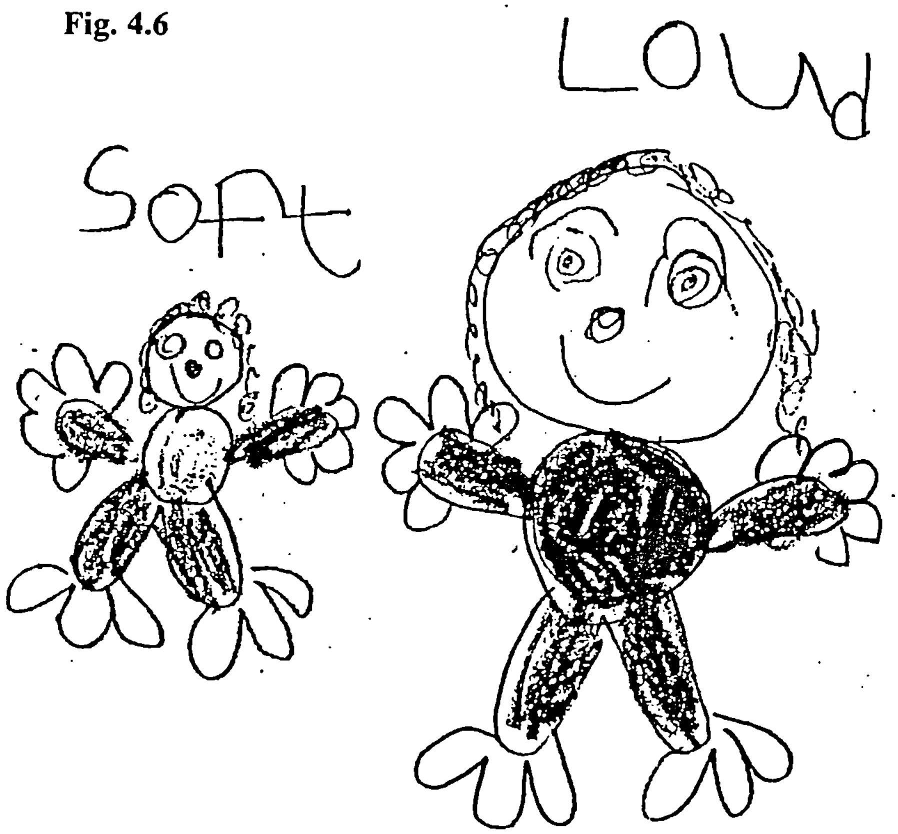
(Age 6 years)

The same class also compared different shapes and sizes of funnels and tubes. This investigation gave inconclusive results and the children were unable to suggest any reasons why the different shapes of the funnels had different effects on the volume of the sound which was heard.

ii. Generalizations and vocabulary

During the course of the investigations it became apparent to some of the teachers that many children were associating the size of an object with the volume of sound which it produced (Fig. 4.6).

Fig. 4.6

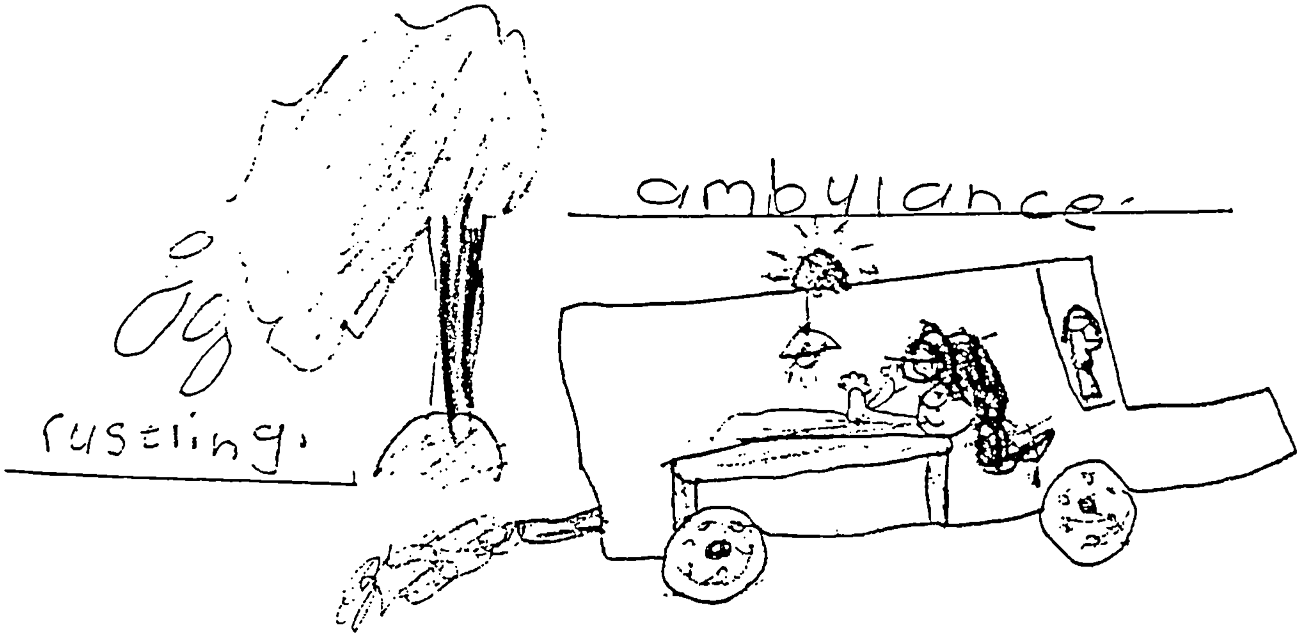


(Age 6 years)

Following discussions about loud and soft during which teachers asked children to give examples of loud sounds and soft sounds from objects of varying sizes, children again drew loud and soft sounds. There was still a high degree of correlation between size and perceived volume of noise, but some objects were depicted which were either large and made a quiet noise (Fig. 4.7) or were smaller and made a loud noise (Fig. 4.8).

Fig. 4.7

soft loud

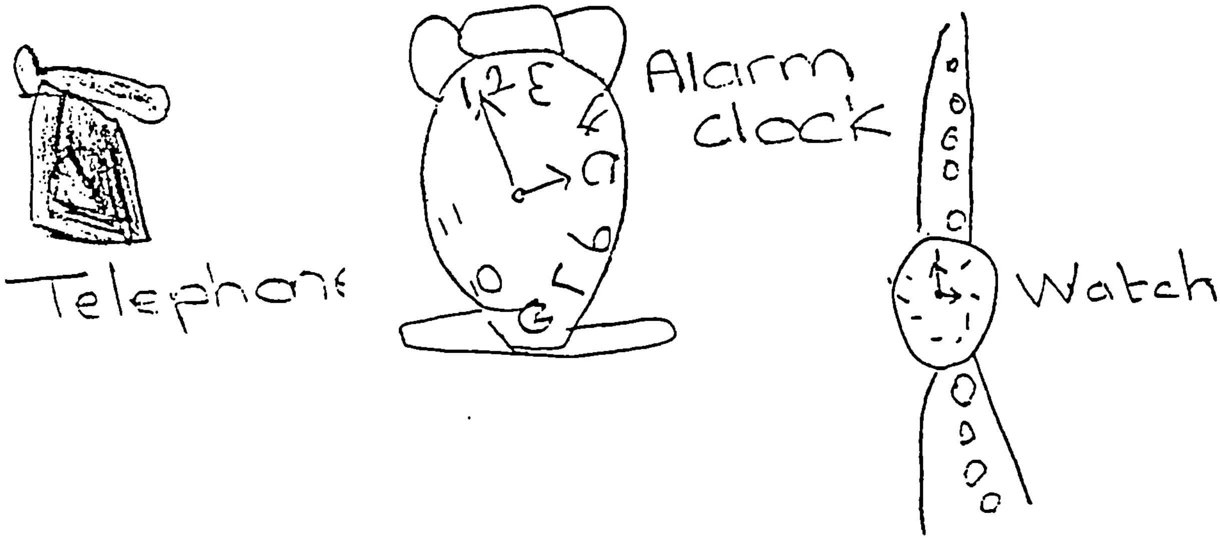


(Age 6 years)

Fig. 4.8

loud loud

quiet sounds
watch



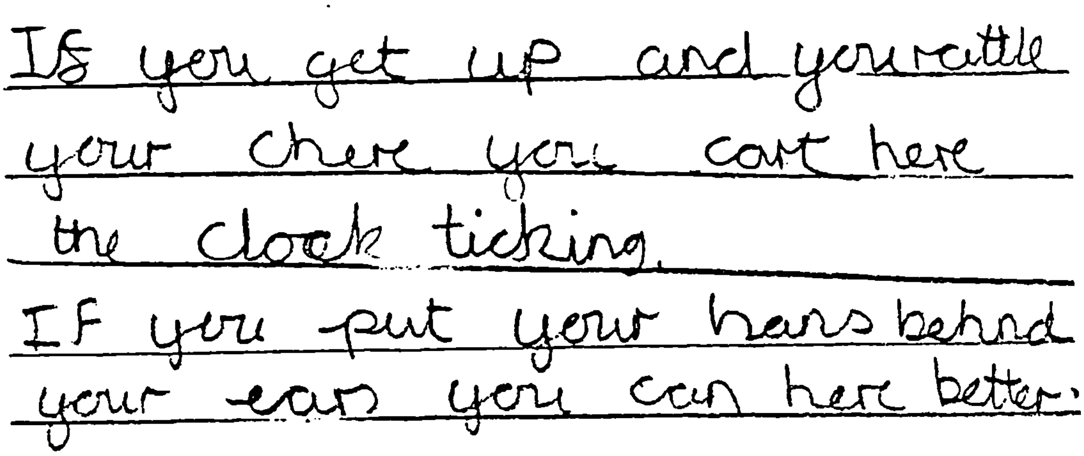
(Age 6 years)

Lower Juniors

i. Helping children to test their ideas

The lower junior class teachers introduced the Intervention period to their classes by using the stimulus of a clock ticking in a box and asking the children how they thought they could alter the way they heard the clock. The children then generated lists of variables which they thought would affect their hearing of the clock (Fig. 4.9).

Fig. 4.9



(Age 8 years)

"If you get up and you rattle your chair you can't hear the clock ticking. If you put your hands behind your ears you can hear better"

The children selected a variable to investigate from the list. The investigations concerned the effects on hearing of:

. proximity to the sound source

. blocking sound transmission at the site of production or the site of reception

. improving hearing using a funnel or other aid

Emphasis was placed upon the children conducting well-controlled tests. The children devised various methods of making a noise which could be exactly replicated in terms of volume, pitch and duration. Some methods used were an electronic keyboard, and dropping an object from a pre-determined height. Children also either kept a consistent distance from the sound source or used distance as the variable which was measured. Some children required a lot of help in planning and constructing a fair test but it tended to be matters of practicalityrather than of principle which were problematic. The recognition of the necessity to control volume and proximity suggested that children of this age understood the significance of these two variables for hearing. Children who were investigating the effects of proximity on hearing might therefore have been confirming a notion which they assumed to be true rather than testing an idea of which they were unsure.

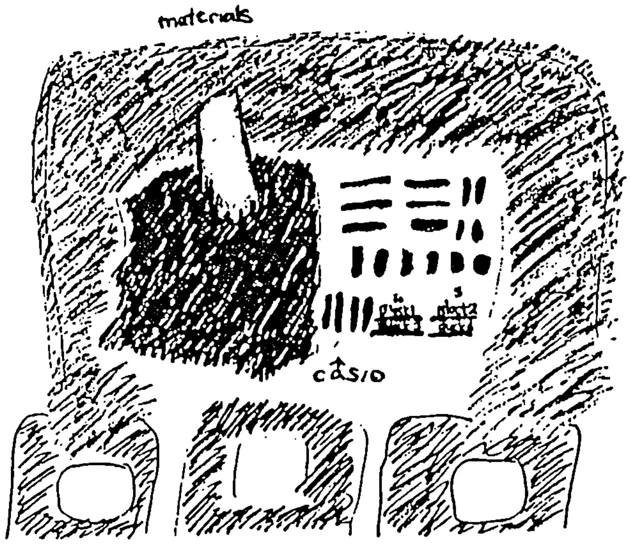
Proximity

Children decided that the further away they were from the constant sound source the harder it was for them to hear. Some children could hear the sound from much further away than others and it was suggested that the levels of background noise had been very variable and that this factor was likely to have affected the results.

Blocking sound at the site of production

In attempting to explain why sound became quieter the further the listener was from the source one group of children suggested that the sound went into the air and spread out around the room. In order to test whether the sound was moving and escaping they decided to find out whether they could trap the sound by putting obstacles in its way. They hypothesised that if the sound could be stopped by a sound blocker then what normally happened to the sound would be that it did spread out from the sound source. The children predicted that the sound would spread out and that they would be able to block the sound from a radio with one of a range of materials placed over the speaker (Fig. 4.10).

Fig. 4.10



(Age 7 years)

The children found that the sound could still be heard through a range of materials.

Fig. 4.11 first we used thin meterial then we put more layers of meterial to make it thicker and see if we can hear it we have used a carrier bag we put the carrier bag ~~over~~ were the sound was coming out and pressed a button.

Material	what happend
thin carrier	We could hear through the thin carrier.
thick carrier	✓
silk carrier	✓
and hand.	✓
Class door	✓
class	✓

(Age 7 years)

The teacher encouraged them to try an alternative avenue to challenge their conclusion that the sound could be heard because it came through thin layers.

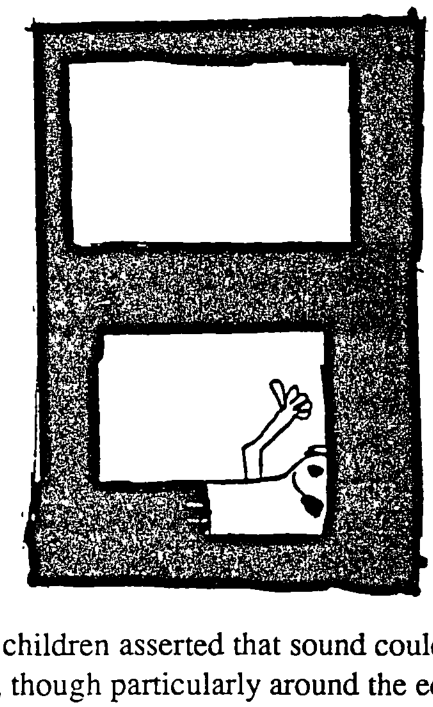
Transcript 4.1

"Child 1	*We folded it until you couldn't fold it any more. We would still hear it only slightly.*
T.	*Why do you think you could still hear it?*
Child 2	*Because it's thin.*
Child 1	*It was coming through. I thought it wouldn't have done.*
Child 3	*It came through the silk even when hand was over it.*
Child 1	*Even a quiet noise.*
T.	*Can you try anything else?*
Child 2	*Try all. Hand + material + carrier.*
Child 3	*Sheep's wool + silk + hand + carrier. you can hear it.*
T.	*Will it come through anything?*
Child 2	*It won't come through anything.*

Child 2	*Try to find something it won't come through.*
T.	*Why can we hear the recorders now?*
Child 3	*The door's open.*
Child 1	*No, it's closed - it's louder. We'll try the door.*
Child 2	*It's got a key hole.*
Child 3	*Cover the key hole. We can hear it.*
Child 2	*There's a crack at the top and the bottom - somebody lie on the floor.*
	There's a crack at the top - it won't go through there - it would have to go up and then down.
Child 3	*I can hear it. It could come through the door and my ears get cold.''*

Having blocked every hole around the classroom door the sound was still audible.

Fig. 4.12



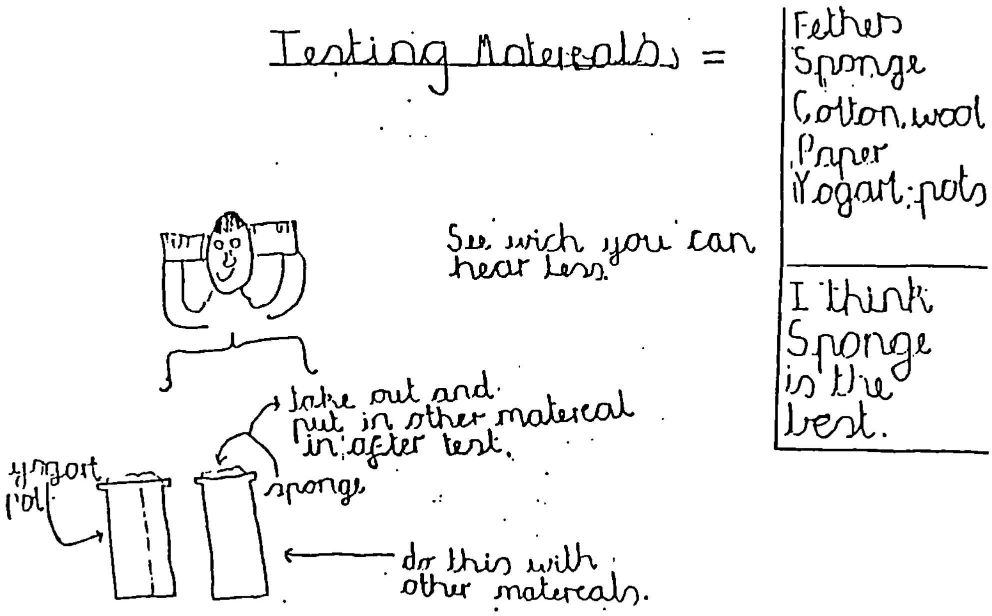
(Age 7 years)

The children asserted that sound could travel through anything, thick or thin, though particularly around the edges. This investigation had challenged their notion about the media through which sound could travel, though the children appeared to be reluctant to incorporate their findings into their ideas. Instead they suggested that the sound must have found holes or edges through which to travel. This notion that sound must travel unimpeded through a space has been mentioned in Section 3 and was most commonly found among children of lower junior age.

Blocking sound at the site of reception

Children from another class decided to investigate the efficacy of different materials in ear muffs. The materials were placed inside yogurt cartons of the same size and held in place over the ears. A ticking clock was used as the sound source.

Fig. 4.13



(Age 7 years)

Most children found that the cotton wool ear muffs were the best, and one boy's conclusions were that the cotton wool 'absorbed and trapped the sound waves'.

Improving hearing

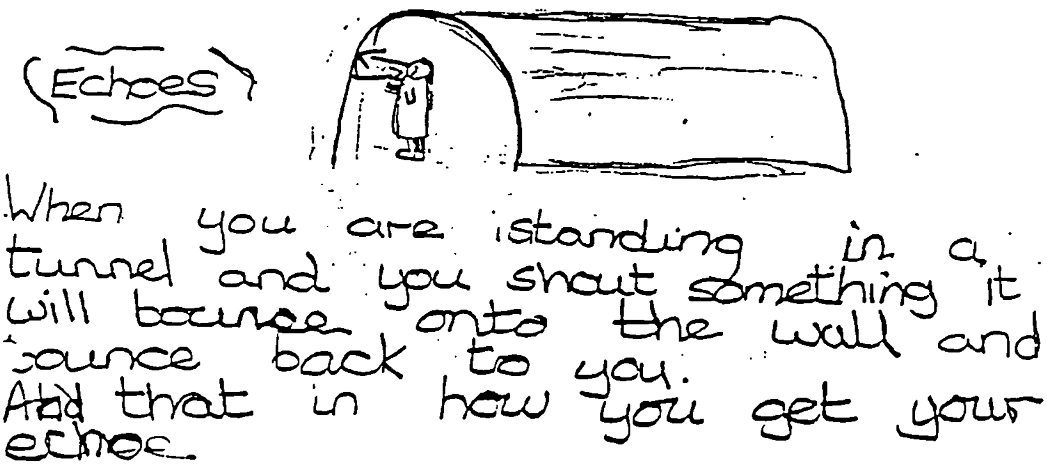
Children used funnels of different sizes to listen to sounds. They predicted that any funnel would result in improved hearing, and that a bigger funnel would be better than a smaller one. They found that the bigger funnel was more effective as a hearing aid and decided that this was because more sound could get into the larger funnel.

ii. Encouraging children to develop more specific definitions for particular key words

Two words which were used by a large number of lower juniors, and which teachers felt needed clarification, were 'echo' and 'vibrate'.

Children from one class were asked to 'Draw a picture to show how you think you get an echo. Show where the sound comes from and what happens to it'. Two main ideas emerged about the meaning of the word: some children drew themselves in an enclosed space and explained that the sound hit the boundaries of the space and bounced back so that the sound was heard again (Fig. 4.14). Other children showed themselves in an unenclosed area and mentioned the sound repeating itself as it moved further away from them (Fig. 4.15). This second explanation did not involve any notion of the sound being deflected and returning to the speaker.

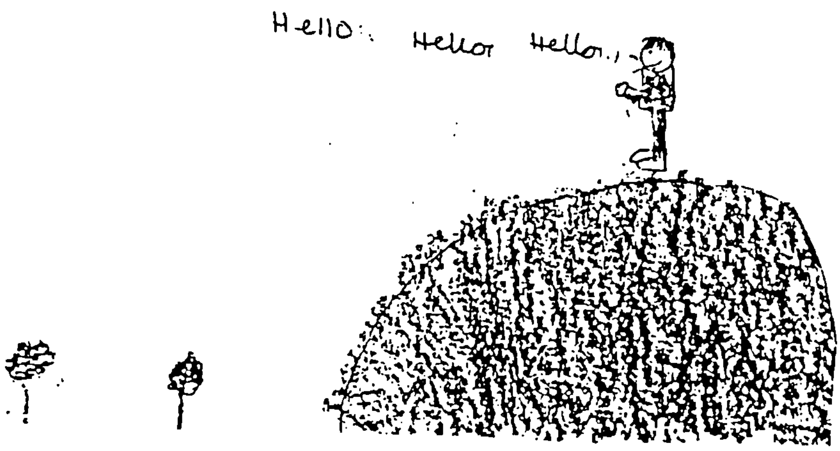
Fig. 4.14



(Age 7 years)

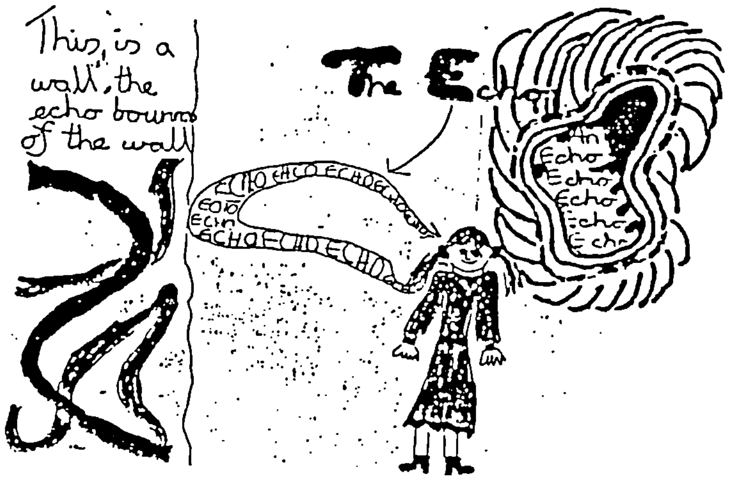
''When you are standing in a tunnel and you shout something it will bounce onto the wall and bounce back to you. And that is how you get your echo.''

Fig. 4.15



(Age 7 years)

Fig. 4.16



(Age 8 years)

A small number of children appeared to combine these models to present a repeated message which was deflected back to the sender (Fig. 4.16).

This vocabulary activity about echoes was also useful as a starting point for a discussion in which children could share their ideas about the locations in which they had experienced echoes. This discussion revealed some very specific instances of echoes (Fig. 4.17) and enabled some children to broaden their concept of an echo so that it could encompass more than one location.

Fig. 4.17

I can test echo by walking
into a room which has no
furniture in and I could
shout at the top of my
voice and my voice might
bounce of the wall
and come back to me.

Upper Juniors

i. Helping children to test their ideas

The children in the upper junior age group found the manipulation and control of variables far easier than did younger children. This aspect of the classroom work needed less teacher intervention than with younger children, and the children tended to control their investigations without being prompted.

The range of investigations which children of this age carried out was wider than in the younger two age groups, and it encompassed most of the investigations which the younger children had done. There was a noticeable difference in the understanding which children brought to their investigations and the idea of sound transmission was evident in the design and the recording of the investigations. The majority of the investigations tested ideas about the effects on hearing of one of the following variables:

. distance between hearer and sound source

. blocking sound reception

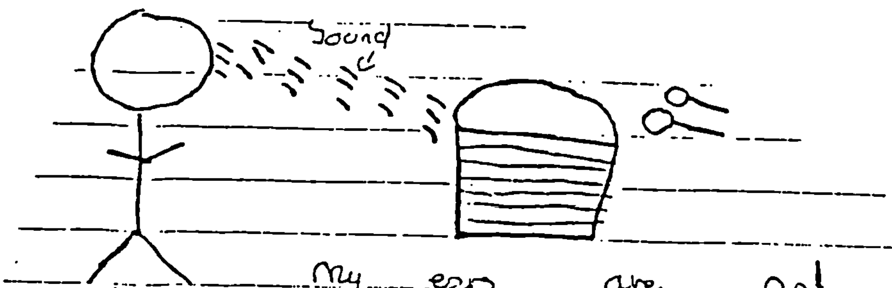
. background noise

. the positioning of the sound source relative to the hearer

. the existence of different media between hearer and sound source

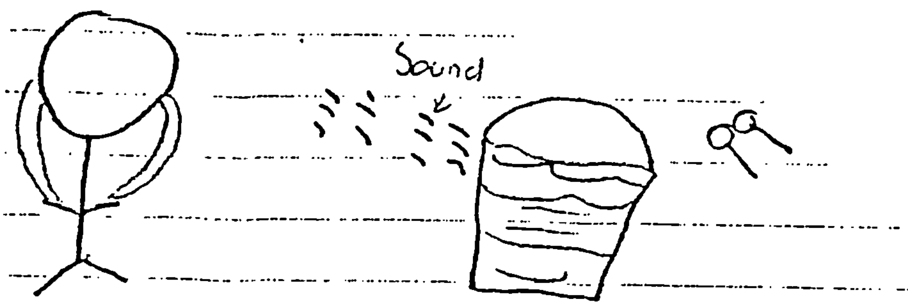
Investigations involving distance and sound reception were similar to those carried out by younger children. However, they provided children with a need to develop a pictorial representation of sound which would enable them to explain the results they had found (Fig. 4.18). The example shown in Fig. 4.18 shows that this child has depicted sound transmission being affected by the blocking of sound reception. This diagram could form the basis for further Intervention work in which the child could make predictions based upon the drawing, test them and possibly modify the notation and ideas as a result.

Fig. 4.18



My ears are not blocked.
I think the Sound comes right up to
my ear. I think the Sound is
vibrating on the drum reflecting back
to my ears and I could hear
it well.

"My ears are not blocked. I think the sound comes right up to my ear. I think the sound is vibrating on the drum reflecting back to my ears and I could hear it well."



My fingers were is my ears.
I think that the Sound does not
reach because my fingers are in
my ears. I could hear it Not
very well.

(Age 9 years)

"My fingers were in my ears. I think that the sound does not reach because my fingers are in my ears. I could hear it not very well."

Children who investigated the effect of the direction of the sound source relative to the hearer appeared to be surprised that their test was challenging to carry out (Fig. 4.19) and interpret (Fig. 4.20).

Fig. 4.19

We are testing if direction affects
the way we hear. One person sat in
a chair blindfolded. Another person claped
1 metre away because it would not be
fair if we claped nearer and then futher
away. The person in the middle pointed
to where they thought the sound was coming
from. I thought it would be easy but it
wasn't. When we'd been claping we'd been
claping on the level of the ears so we
claped above and below the level of the
the ears. We found out that most
people got the right direction but the
wrong hight.

(Age 9 years)

"We are testing if direction affects the way we hear. One person sat in a chair blindfolded. Another person clapped 1 metre away because it would not be fair if we clapped nearer and then further away. The person in the middle pointed to where they thought the sound was coming from. I thought it would be easy but it wasn't. When we'd been clapping we'd been clapping on the level of the ears so we clapped above and below the level of the ears. We found out that most people got the right direction but the wrong height."

Fig. 4.20

We are testing will the direction that the
sound comes from change the way we hear?
I thought there would be no difference.
I heard it better when I was below
I think this happened because when sound
comes down it drops. But when sound comes
up 'it' has to 'climb' and loses some of it strength

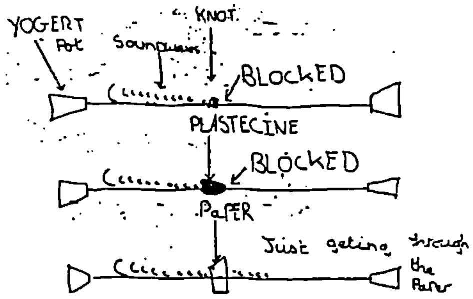
(Age 9 years)

"We are testing will the direction that the sound comes from change the way we hear? I thought there would be no difference. I heard it better when I was below. I think this happened because when sound comes down it drops. But when sound comes up it has to 'climb' and loses some of its strength."

The explanation suggested in Fig. 4.20 could indicate that the child thought of the sound as something which would behave like an object with mass, like a ball or a person. The notion of sound transmission is implicit in this explanation.

Investigations concerning the transmission of sound were not suggested by any children in the two younger age groups. The string telephone was used as the context for one investigation attempting to block transmission (Fig. 4.21).

Fig. 4.21



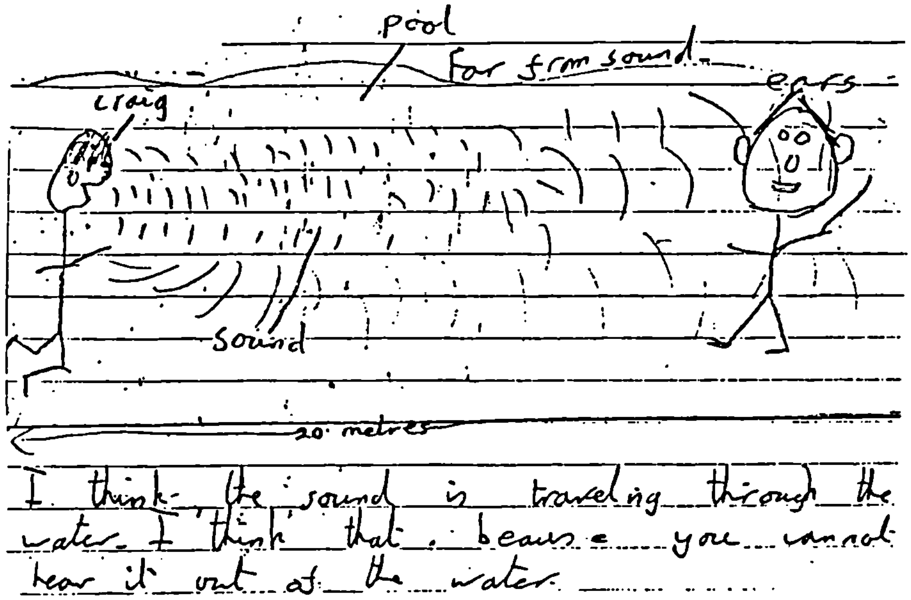
we are testing to see if a knot in a
string telephone would stop the message from
geting to the outher person
we put a knot in the string telephone
and it afected are hearing as we guest it
would. because the soundwaves can not
get through the knot. Then we put some
plastecine on. We thought the plastecine
would block it off because the soundwaves
could not get throught the plasticine.
Then we guest that the paper would
not block the soundwaves off we put
the paper on and it only just afected
our hearing

(Age 9 years)

"We are testing to see if a knot in a string telephone would stop the message from getting to the other person. We put a knot in the string telephone and it affected our hearing as we guessed it would because the sound waves can not get through the knot. Then we put some plasticine on. We thought the plasticine would block it off because the sound waves could not get through the plasticine. Then we guessed that the paper would not block the sound waves off. We put the paper on and it only just affected our hearing."

Other children considered the passage of sound through water and through glass. During a class visit to the local swimming baths a group of children were able to test their ideas about hearing under water, and compare hearing through air and water. The children concluded that, to their surprise, they could hear the sound over a greater distance under water than through the air (Fig. 4.22).

Fig. 4.22



(Age 9 years)

"I think the sound is travelling through the water. I think that because you cannot hear it out of the water."

These investigations which produced results which surprised the children were challenging the notions which the children had about sound. The experiments which confirmed children's beliefs were also valuable in the way they encouraged the children to develop their ideas of sound through pictorial representation. The role of the teacher in encouraging children to interpret and explain their findings was very important and required teachers to develop their questioning skills in a manner complementary to that required for successful elicitation of ideas.

ii. Encouraging children to develop specific definitions for words they use

The upper junior children used a large number of words specific to sound: 'echo', 'vibration', 'interference', 'sound waves' and children were asked to define their meanings for these words. The range of definitions for 'echo' was wider than that given by the lower juniors (Figs. 4.23 to 4.26) but less reference was made to sound bouncing back and far more to sounds repeating themselves in empty spaces.

Fig. 4.23

echo When you shout (a sound follows it.) the word repets. When everywhere is empty.

(Age 10 years)

"echo When you shout (a sound follows it) the word repeats. When everywhere is empty."

Fig. 4.24

echo = sound that continues ~~whit~~ with out anything making it i.e. sombody ~~mi~~ might shout "Hello" and the "echo" would probably be ooooooooooooo going quieter

(Age 9 years)

"echo = sound that continues without anything making it i.e. somebody might shout "Hello" and the "echo" would probably be ooooooooooooo going quieter."

Fig. 4.25

An echo is a sound ~~vi~~ vibrating in the air and saying the word you said over and over again ~~u~~ until it ~~q~~ quitens down and then stops

(Age 10 years)

"An echo is a sound vibrating in the air and saying the word you said over and over again until it quietens down and then stops."

Fig. 4.26

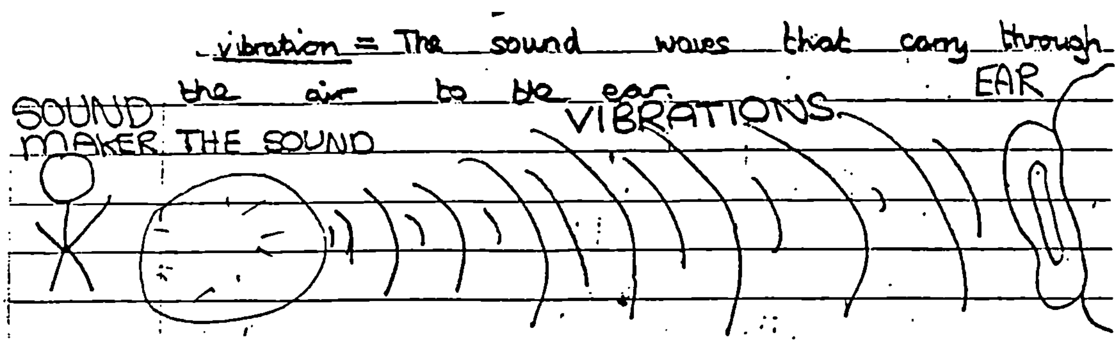
echo = the sound being thrown back to the person who made it. Like a repeat.

(Age 9 years)

"echo = the sound being thrown back to the person who made it. Like a repeat."

Definitions of vibration were far more closely linked to sound than were the lower junior definitions. Rather than emphasising the movement of the object, the term was commonly thought to be synonymous with sound, or involved with sound carrying (Fig. 4.27).

Fig. 4.27

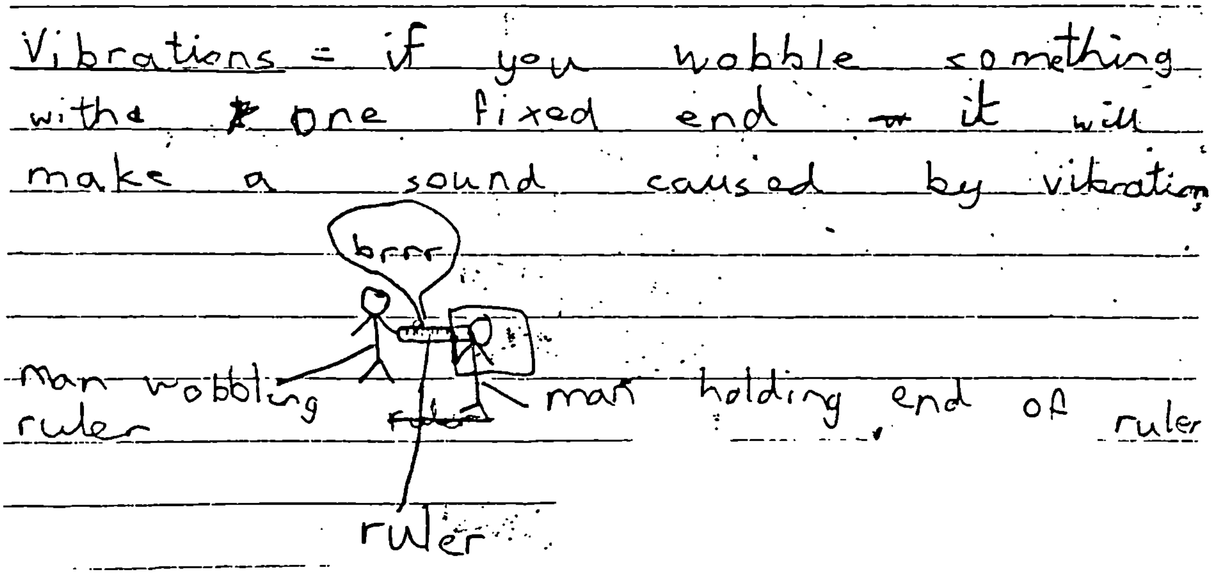


(Age 9 years)

"vibration = The sound waves that carry through the air to the ear."

Some definitions were suggestive of reference having been made to some secondary source (Fig. 4.28).

Fig. 4.28



(Age 9 years)

"Vibrations = if you wobble something with one fixed end it will make a sound caused by vibration."

These definitions were produced by children as a written exercise prior to discussion so they were not based upon activities which could haven provided a common context for definitions.

iii. Encouraging children to generalize from one specific context

The upper junior children seemed very confident in exchanging contexts in which they had experienced the effects of interference, differences in volume and other variables upon hearing.

One teacher decided to see how far the class could generalize from some of the experiences which they had had during the Exploration. The children were posed the problem of trying to hear their partner's heart beat using some or all of the following equipment: yogurt pots, string, funnels, tube, scissors. The children tackled this task in a variety of ways, some making a string telephone, some using funnels connected with string and some using a funnel or a funnel and tube. This activity provoked lively discussion between the children and gave the teacher further insights into the children's understanding of sound, particularly of transmission through string.

Summary

1. Teachers used a question similar to "How can you affect the way you hear?" to introduce the Intervention to their classes.

2. The investigations chosen by children of different ages tended to be different. Younger children explored the reception of sound, and means of altering it. Many older children were interested in the effects of distance on sound reception, and in the effects of blocks at the point of production or of reception. Some upper juniors were interested in exploring sound transmission through different media.

3. Children were beginning to use some vocabulary particularly associated with sound in the lower juniors. The words 'echo' and 'vibrate' were often used to mean 'repeat' and 'wobble' respectively. Some confusion of 'vibration' with 'evaporation' was evident, and the converse was found during the topic 'Evaporation and Condensation'.

4. Children were able to generalize their classroom experiences of sound to everyday contexts.

5. The teacher's role during the Intervention was to encourage the use of science processes during children's investigations. With children who were more proficient in carrying out investigations the teacher was important in encouraging them to interpret their findings.

6. Investigations provided a helpful context in which children could develop a pictorial representation of sound.

Appendix 18

Teacher reaction to Intervention: Sound research report pp. 124-126

concerned with blocking the transmission of sound. The two children who stated this idea for the first time post-Intervention had carried out investigations into:

. blocking the reception of sound

. the effect of distance, and using one or two ears, on hearing

Both of these investigations encouraged children to focus on the reception of sound. It is not possible to perceive sound waves hitting the ear drum and making it vibrate so the Intervention might have meant that the children were motivated to seek out the information for themselves in books.

5.3 Teacher's Reactions to Project Involvement

Changes in attitudes and classroom practice in teachers need to be considered in the context of the whole research programme, rather than the Intervention alone.

The main areas in which teachers reported change, or the Project team perceived it, were:

1. Open questioning techniques

2. Use of annotated diagrams

3. Role in class discussion

4. Familiarity with science process skills

5. Identification of Intervention strategies

1. Open questioning technique

Teachers were asked to talk to individual children to find out their ideas. The teachers initially found it very difficult to phrase open questions which would allow the children to express their ideas. With practice this became easier, and as a result the teachers were more relaxed about the questioning and this enabled them to listen more carefully to the children's responses. The teachers' ability to build upon these answers in the developing dialogue and to clarify the children's meaning also improved. Some teachers began to find this technique so valuable to their science work that they took every opportunity to question children, including informal conversations during breaks in the school day. Other teachers began to incorporate it into their work in other curricular areas, using it as a way of increasing children's participation in language and art work (transcript 5.7).

Transcript 5.7

"As this project has progressed I have become increasingly aware of the effect it has had on me as a teacher. Initially, I had to think very carefully when talking to the children about the questions I was asking. This made the task very difficult, as years of different approaches had to be avoided i.e. the teaching situation. However, as time has passed it has become part of my technique and in my opinion an invaluable part.....

"By the use of careful questioning you are able to extend these ideas without feeding them information they are not ready for. In science, in particular, it is difficult to know how deeply to go into a topic, but by using this approach the children give you the boundaries. This must be a far more relevant approach.....

"Certain areas of the curriculum will have to be taught but by adapting this technique a much more flexible and interesting approach can be made to many of the subjects. It is certainly going to have an effect on my methods.

" This week I am taking an artefact into school to look at with the children. Before this project I would have told the children all about it and expected them to sit and listen. Now, I shall use this method of questioning to find out the children's ideas and hopefully use their imagination too....."

2. *Use of annotated diagrams*

The Project team requested that teachers asked their classes to draw particular diagrams as part of the Project work. As the Project progressed, some teachers began to extend the number of diagrams which children were asked to draw during the Elicitation phase in order to give themselves a fuller understanding of what were their children's ideas. Other teachers extended the use of the technique into the Intervention phase, using drawings as a starting point for vocabulary work. Some attempt was also made to use the diagrams as an assessment tool, asking children to draw a diagram in response to the same question both before and after the Intervention.

3. *Role in class discussion*

Many of the teachers who were involved with the Project felt that class discussion was something with which they were familiar. However, these discussions were often very teacher-directed and tended to be question and answer sessions where the answers were either right or wrong. By posing a more open question, teachers found that the children were able to contribute far more to discussions, and that they listened more to the contributions others were making. The children began to spark off ideas in each other, and the discussions became far more self-sustaining. The role of the teacher became more that of a chairperson, ensuring that more reticent children could participate, and asking a few, well-chosen questions to demarcate the area to be covered during the discussion. Class discussion therefore became another opportunity for the teacher to learn about the class by listening to their contributions.

4. Familiarity with science process skills

Teachers themselves become more conversant with the process approach to science. This increased their confidence in intervening when children were planning and carrying out investigations and enabled them to ensure fair testing, reliable data collection and valid interpretations.

5. Identification of intervention strategies

During Phase 1 of the Primary SPACE Project the teachers were at times unsure of what would constitute a 'vocabulary' activity or a discussion to encourage generalizations. With the experience of the 'Growth' Intervention (in which all 'Sound' teachers had participated) the teachers became far more confident in identifying different components within one complex classroom activity. 'Generalizing' was identified as being a natural part of many discussions and 'vocabulary' was often closely linked with it.

Appendix 19

Appendix 19

The analytical framework: an adaptation of Barnes and Todd's model;
The criteria for good questioning practice linked to the framework
(from Watt, 1996)

The analytical framework

	Social attributes of discussion	Cognitive attributes of discussion
Level one	i. General management of discussion	ii. Maintaining logical continuity in discussion
Level two	iii. Enabling greater participation in discussion	iv. Monitoring the development of ideas in discussion

i. General management of discussion (discourse moves)

Teacher behaviours which enable discussion rather than a teacher-controlled question-and-answer session.

ii. Maintaining logical continuity in discussion (logical processes)

Teacher behaviours which try to ensure the discussion proceeds in a clearly understood, logical sequence.

iii. Enabling greater participation in discussion (social skills)

Teacher behaviours which encourage learning by increasing the number of ideas being discussed.

iv. Monitoring the development of ideas in discussion (cognitive strategies)

Teacher behaviours which encourage children to generate hypotheses and justify them with supporting evidence

Criteria for good questioning practice linked to the levels of the analytical framework

A. Social attributes of discussion

i. Level one: General management of discussion

1. Respond verbally to any answer with equal interest

2. Use tone of voice in a manner which reinforces the interest in any answer

3a. Give a child ownership of an answer by using words such as, "What do you think...?" to begin a question

10. Allow a child sufficient time to formulate a response

ii. Level two: Enabling greater participation in discussion

3b. Cue a child to the cognitive level of response required by using words such as, "What *do you think...?" to begin a question.*

4. Invite an answer from any child who wishes to contribute.

5. Encourage children to respond to each other's views.

B. Cognitive attributes of discussion

i. Level one: Maintaining logical continuity in discussion

6P Seeking clarification of a child's answer relating to scientific procedure

6C Seeking clarification of a child's answer relating to scientific understanding

6P/Ca. Seeking clarification by repeating a child's words back to them

6P/Cb. Seeking clarification by asking the child what they mean

7a. Extend a child's answer by asking for a hypothesis or for evidence to support one.

9. Be sure of the area (rather than the specific content) of the discussion.

11. Ask questions according to a considered sequence.

ii. Level two: Monitoring the development of ideas in discussion

6P/Cc. Seeking clarification by reflectively rewording the child's response back to them

7b. Extend a child's answer by challenging their hypothesis.

8. Word questions so that the intention behind them is clear.

12. Listen to a child's answer and use it as the basis for the next question

Appendix 20

Appendix 20

Interview schedule for Veronica

The classroom practicalities of teaching 'sound'

1. How do you think 'sound' went as a topic?

2. Was there anything which surprised you about the science sessions?

3. What preparation did you do in terms of your own knowledge and understanding?

4. What would you say were your main aims/objectives for this topic?
   probe: key ideas in NPS, National Curriculum PoS and ATs

5. You had obviously thought about what you wanted the children to find out from their investigations. To what extent had you pre-planned what the children would do to answer the question you gave them?
   probe: guidance given to children in planning

6. Whole class discussion seemed to be a central aspect to your planning. To what extent did they go according to plan?
   probe: how easy was it to lead to generalisations?

7. The 'ideas board' was very effective as part of your 'sound' display. What was your thinking behind incorporating it into the topic? How did you introduce it? How did the children use it? Would you use the same technique again?
   probe: use once on wall?

8. Those children who did extra 'vibration' activities (drum & rice, cymbal & salt) must have had some qualitative difference between their ideas and those of the rest of the class. What was it that was absent in their drawings?
   probe: How easy was it to analyse the children's ideas?

9. The grouping of the children for investigations seemed to become more flexible as the topic progressed. What was the reasoning behind that?
   probe: benefits of same/different ideas together?

10. You seemed to make less use of prepared worksheets for questions and investigations as the weeks went by. What was the thinking behind that?
    probe: control over investigations?

11. When you did the concept map at the end of the topic you asked the children to brainstorm the words which would be used. What made you decide to focus on children's words for the concept map?
    probe: checking they were aware of the important words
    additional teaching opportunity - links between words

The children

1. You mentioned that the children were being made to think more using the 'Nuffield' approach. Were there any other changes for them?
   probe: searching questions
   not doing 'beautiful work'
   diagram not picture
   unguided use of Sc1
   no right answers
   more freedom to plan own investigations
   ideas valued
   group work
   role of T

2. NPS teacher's guide says that high achievers are often the most reluctant to express their ideas because they are "trapped in a history of being right". Was that the case in your experience?
   Victoria, James, Jonathan

NPS Philosophy

1. You said that the 'Nuffield' approach should give the children a better chance at understanding science. What do you think it is about the 'Nuffield' approach which leads to this improved understanding?
   probe: rote vs understanding
   reinforcement of key ideas
   use of Sc1

2. How does the 'Nuffield' approach of 'starting where the children are' by finding out their ideas relate to your teaching approach in other curriculum areas?
   probe: role of T
   implications of any differences

3. You said you expected to get better at using this approach to science teaching as time went on. What particular aspects are you finding challenging?
   probe: not challenging when eliciting children's ideas
   helping children structure own investigations

4. How much do you feel the children were able to develop their understanding through investigation?
   probe: competence at Sc1
   role of discussion?

5. To what extent do you think the children have given up their ideas in favour of a more scientific understanding?
   Or has constant reinforcement led children to 'learn' right idea?
   Does it matter?