INTERACTIVE WHOLE CLASS TEACHING IN SCIENCE LESSONS IN KEY STAGE 2 CLASSES

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Abstract

This study aims to contribute to the development of models of teaching science at Key Stage 2 (pupils aged 7-11 years) by considering the role of 'interactive whole class teaching', a teaching strategy advocated by the UK government's primary literacy and numeracy strategies in the late 1990s. An exploration of the meaning of 'interactive whole class teaching' brings a sociocultural perspective on the role of talk to the predominantly social constructivist models of teaching science in primary schools.

Two case studies of primary teachers' practice have been constructed, each consisting of a sequence of lessons that make up an entire science topic, providing a rich, situated account of the role of interactive whole class teaching in science lessons over an extended time. A key method of enquiry has been the analysis of video data and respondent validation through video stimulated reflective dialogues. The meanings of dialogic and authoritative episodes of whole class teaching are considered in terms of the development of conceptual and procedural scientific knowledge on the social plane of the class over episodes, lessons and sequences of lessons. The findings indicate that whole class teaching has a role in the ongoing elicitation and discussion of children's ideas about concepts and procedures, creating and maintaining an intermental development zone for the class. It also has a role in modelling scientific procedures, and in exploring the relationship between phenomena, experiment and explanations to construct a version of science.

Recommendations are made as to how the existing models of teaching science could make the relationships between the nature of whole class interactions, type of teaching activities and pedagogical aims more explicit. The case studies raise questions about determining an appropriate balance between dialogic and authoritative talk in primary science to develop a discourse that values both existing scientific knowledge and children's appropriation and transformation of this knowledge through negotiation within the social plane of the primary classroom.

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The notation and conventions used in the transcripts

- Where utterances or parts of utterances could not be transcribed reliably they are shown as: (inaudible).
- Interruptions and simultaneous speech are explained as such by the use of brackets, for example; (interrupting).
- Comments in italics in brackets provide selected additional contextual information such as accompanying gestures, actions or tone of voice e.g. *(raises arm)*.
- In Chapter 2, contemporary comment is in square brackets [ ].
- Underlining (<u>This</u> one) indicates an emphasis on the word.
- Question marks (?) indicate a questioning intonation.
- Commas (,) mark short pauses in speech.
- Three dots (…) indicate a longer pause.
- A hanging question is shown by two dots and a question mark: (..?).
- Morphemes (ahs and hmms, etc.) and misspoken words have been indicated through the spelling.
- Where the child speaking could not be identified, the abbreviation C is used, otherwise a pseudonym has been given to each child in the cases, retaining gender and ethnicity.
- The teacher's utterances are denoted by 'T' and my own by 'KM'.

Chapter 1: An Introduction to the Study

1.1 Introduction

This study emerged from my concerns, firstly as a primary school teacher and then as a lecturer in primary science, about how teachers should talk with children during whole class discussions while teaching science. As I attempted to implement the advice on how to teach science that I had received through my own training and further reading, I found that I was making more use of whole class teaching than appeared to be advocated in the literature and decided to explore this issue in more depth. As a lecturer and author of texts on how to teach science, I was concerned that I was presenting models of teaching that were not considering the role of interactions between teacher and children during whole class teaching, nor the particular contribution that whole class teaching could make within a repertoire of possible forms of classroom organisation.

Providing further stimulus for the study, Galton et al. (1999) reported an increase in the amount of whole class teaching in primary schools compared with their study ten years previously and noted a particularly high proportion of whole class teaching in science lessons with 50% of interactions taking place in a whole class setting compared with around 34% in English and Maths (p. 71). They described how in science lessons there was limited opportunity for children to explore their own ideas or to raise questions and twice as many teacher statements dealt with facts rather than ideas and suggested that this emphasis on whole class teaching was not in line with constructivist theories of learning in science as put forward by Driver (1983) and Harlen (1992). The amount of time spent in whole class teaching makes it worthy of enquiry in relation to the models of teaching advocated in primary science literature.

This thesis has developed over a period of time during which the dominant social constructivist theories of teaching science have been challenged by sociocultural approaches (Leach and Scott, 2003). While undertaking the research for and writing this thesis, I have been on a journey both to understand these challenges and to change my own views. During the course of my research, there have been many government interventions and policy changes affecting primary schools. Acknowledging this continually changing context has been a challenge in developing and writing this thesis, but this has also served to validate my central theme of focussing on what happens in interactions between children and their teachers, which are at the very heart of education in schools (Tharp and Gallimore, 1988).

Through the development of case studies, I aimed to understand how teachers were using the existing models of teaching science in the literature to inform their teaching and to make sense of interactions during whole class teaching across a sequence of lessons. This emphasis on interpretation places this thesis within an interpretivist paradigm, in which the meanings constructed by the participants are taken as the reality to be explored. Exploring the impact on the dominant constructivist models of teaching in primary science of emerging sociocultural approaches meant considering learning as occurring not only in individuals, but also in situated communities (Lave and Wenger, 1991), defined for the purpose of this study as classes during science lessons. The Piagetian approach, with its focus on the minds of individuals, has dominated the study of children's thinking (Mercer, 1992) but has been challenged by sociocultural approaches that focus on 'situated action' – action situated in a cultural setting, and in the 'mutually interacting intentional states of the participants' (Bruner, 1990, p. 19). In this study, interactive whole class teaching is understood in Vygotskian terms as a location of a social plane and analysed in terms of the creation of shared understandings in an intermental space (Mercer, 2000; Vygotsky, 1962).

1.2 Interactive Whole Class Teaching

The 'Three Wise Men' report (Alexander et al., 1992) initiated the discussion which led to an increased emphasis in primary education on whole class teaching strategies, suggesting that there was an overemphasis on group work and individual programmes with teachers spending more time managing activities than 'direct teaching'. International comparisons of children's attainment found high achievement in mathematics in Pacific Rim countries (Reynolds and Farrell, 1996; Reynolds and Muijs, 1999) and identified the greater emphasis on whole class teaching as a significant factor. The teaching was described as lively and interactive and conducted at a brisk pace with expectations that all children would participate. Stevenson and Lee (1995) described whole class teaching in cities in Japan and China as characterised by three part lessons, in which the children's opinions were sought and valued by the teachers because they wanted the children to consider a range of points of view. The authors described a high level of participation and attention in these lessons.

These international comparisons, in a political climate which focussed on 'standards' in education, influenced the development of the National Literacy Strategy (NLS) (DfEE, 1998) and National Numeracy Strategy (NNS) (1999b). Both placed a strong emphasis on 'interactive whole class teaching' at the start and end of each lesson, with group or individual tasks in the middle, establishing the ideal of a 'three part lesson'. There was no similar prescription for the teaching of science or expectation of this three part lesson (Ofsted, 2002), but as primary teachers are generalists these recommended patterns may have also been applied to science lessons. However, studies since the introduction of the NNS and NLS suggest that there is little evidence of a change in how teachers are approaching whole class teaching in terms of the patterns of interactions with the children across the curriculum (Hardman et al., 2003; Smith et al., 2004; Moyles at al., 2003), with low level question and answer routines, as described by Galton et al. (1999) still dominating.

1.3 What is Distinctive about Key Stage 2?

Primary education in the UK has distinct origins from secondary education and a culture influenced by its historical roots in elementary education aims for mass literacy and numeracy and the influential Plowden report (CACE, 1967) with its recommendations for a 'child centred' approach to teaching based on Piagetian principles, whereas secondary education followed a focus on timetables and the internal logic of the different subjects (Alexander, 2000). The renaming of the categories of 'infant' and 'junior' as Key Stage 1 and Key Stage 2 maintained the echoes of the stages of cognitive development in the work of Piaget (Piaget and Inhelder, 1969). Piaget proposed a pre-operational stage from 2-7 years, in which children are seen as being 'egocentric' in their thinking, only coming to consider the perspective of others towards the end of this stage and exploring the world primarily through objects; and the concrete operations stage from 7-12 in which objects are utilized in mental operations, but those operations still remain largely object dependent. Piaget's research was challenged (Donaldson, 1978) for not taking into account the social contexts and meanings children brought to the tasks he used and others have argued that children are capable of more complex mental tasks much younger than Piaget found (Smith et al. 1986). However, the notion of a qualitative difference in the kind of education that is appropriate for children younger and older than the age of seven remain embedded in the discourse of primary education, as evident recently in a review of the primary curriculum (Rose, 2009).

The National Curriculum (DfEE, 1999a) defines programmes of study for each Key Stage, rather than for individual year groups, so Key Stage 2 is defined not only as a broad age group, but also in terms of the curriculum content deemed appropriate for that age group. At the time of writing, science is still specified as a distinct 'core' subject within the curriculum at Key Stage 2, which currently requires children to go beyond experiences of phenomena towards explanations held by the scientific community, but with limited use of abstract models. For example, children are to know about 'the role of the leaf in producing new material for growth' (ibid, p. 85) but not a molecular view of photosynthesis. They should also know about factors that affect dissolving, but not explain this in terms of a particle model. These examples are consistent with a view of children at Key Stage 2 as being in a 'concrete operational' stage of development (Piaget, 1954).

1.4 Assumptions about the Nature of Science

In writing this thesis I frequently needed to refer to the 'scientific knowledge' that the teacher held to be the canonical knowledge that the children should come to know. I have used the term 'scientific knowledge' in the understanding that it refers to a selection from and simplification of the current understanding of communities of scientists working in particular domains. I take the ontological view of science that there is an external physical reality and the epistemological view that science develops by humans experiencing and interpreting that reality in ways that are limited by perceptions of phenomena mediated by the available technological and semiotic tools. Scientific knowledge is not a 'discovery' of pre-existing truths, but a culturally and historically situated construction of explanations for selected phenomena. Those explanations remain tentative, but have been validated by empirical testing and discussion of alternatives.

1.5 Outline of Chapters

In this chapter, I have introduced the focus for this thesis: 'interactive whole class teaching' in science lessons at Key Stage 2 with the aim of identifying its role in existing models of teaching science, understanding its use in practice and thus developing the models available to guide teachers. I have highlighted the contexts for the study, including my personal experiences and explained how teaching science at Key Stage 2 is defined and located within education in England.

In Chapter 2, I develop this contextualisation by explaining how this focus emerged from my own experience as a teacher attempting to implement models of teaching science in my own classroom and present an exploratory case study. Through this study, I identify areas and themes for the research and introduce my research questions.

In Chapter three, I examine the relevant literature that contextualises the study and informs the theoretical framework that I have adopted. This includes a discussion of the term 'interactive whole class teaching and its significance. In this chapter, I consider the relationship between constructivist and sociocultural perspectives on science education and position this thesis in relation to them.

Drawing on this discussion of theoretical perspectives in Chapter 4, I develop an analysis of models of teaching science at Key Stage 2 evident in the literature and identify how 'interactive whole class teaching' sits in relation to them.

In the fifth chapter, I explain the methodology and the epistemological and ethical premises that underpin it. I draw briefly on a pilot case study and explain how this contributed to the development of my research methods. I explain how the analytical framework adopted both emerged from the literature and was developed during the course of the field work and the data interpretation.

The sixth chapter will report on Case Study 1 and the seventh chapter examines Case Study 2. Each case comprises an analysis of the teachers' espoused views on science and teaching science and an account of the whole class teaching that took place in a sequence of lessons.

In Chapter 8, I reflect on the methodology and discuss the issues arising from the cases developed. By undertaking a cross case comparison of findings, I deepen my interpretation of their significance for developing models of teaching science at Key Stage 2.

In Chapter 9 I draw conclusions and situate the study in relation to recent policy developments before making recommendations for further research.

Chapter 2: An Exploratory Case Study - Contextualising the Problem and Raising Questions

2.1 Situating the Thesis within My Own Experience

The purpose of this chapter is to explain the origins of the study and how my research questions emerged through my experience as a teacher trying to implement models of science teaching with my own class of 9-10 year old children, and in the process offer a validation of the focus of the study as a concern for teachers. Through this process of making my own experiences, interests and preconceptions available for the reader, I will also develop reflexivity (Seale, 1999; Stake, 1995).

Writing this chapter presented me with the dilemma of returning to my previous experiences with new insights and, in order to maintain the narrative of this thesis, I have preserved my earlier analysis of the transcripts here, and accepted the frustration of wanting to comment on them in the light of understanding gained through the process of this research. My writing at that time is shown in italics. Some transcripts from this exploratory research have been published elsewhere (Howe et al. 2009; McMahon, 2006; McMahon and Davies, 2001) with other earlier interpretations and for other audiences.

When I first embarked on this area of enquiry in 1999, I was teaching a class of Year 5 (9-10 year old) children. I had been aware of a shift in my own science teaching to the use of more whole class discussions, partly as a response to Alexander et al. (1992). I had also been using the 'circle time' approach (Mosley, 1993) for personal, social and health education (PSHE) and found that I could usefully extend this to science sessions. The ethos of circle time is that everyone listens respectfully to everyone else's contributions and is encouraged to respond to them.

At the same time, I was trying to teach by using models of science teaching based on constructivist theories (Harlen, 2000; Ollerenshaw and Ritchie, 1993). My interpretation of these was that it was important to begin a topic with an elicitation activity to find out about the children's existing ideas, and then to devise activities as interventions to develop these. I saw the activities as being 'investigations' in which children undertake scientific enquiries designed to test out their existing ideas leading to conceptual change. As I attempted to incorporate whole class teaching into these models, I found myself questioning Galton et al.'s proposition that the use of whole class teaching was not in line with constructivist theories of learning in science (Galton et al. 1999).

In order to analyse the interactions going on in my classroom, I audio-taped whole class science discussions and transcribed the tapes. This allowed me to analyse the dialogue between myself and the class to find out how I was using questioning and other strategies. I attempted to capture the flavour of the lesson by annotating the dialogue with my interpretations of what was taking place and any reasons for my actions. I compared whole class discussions in four lessons at different points while teaching a topic on plants, but only two extracts are considered here.

2.2 Petals and Pollination

I initiated a discussion about flowers by presenting a photograph of a tulip and referring back to the real daffodils we had examined two days previously. After two children had described their experiences of pollen, Cameron, who had been sitting quietly, suddenly put his hand up. His question showed that he had been thinking about the flower.

Cameron: The petals, are they to block the sun from getting around there?

KM: What a good question. Cameron's wondering what the petals are for, what they do and if it's anything to do with the sun. Has anyone else got any suggestions? Sarah, what do you think?

Alisha: I think the petals are to attract bees.

KM: You think the petals are to attract bees. *[I grabbed the idea and affirmed it]* Ah ha, [ ] Anyone else want to add anything? Polly.

Polly: You can make perfume out of petals.

KM: Perfume out of petals, how can you make perfume out of petals?

Polly: You put them in water.

(Several children, all girls, start talking about methods of making perfume from petals.)

KM: Oh, right, so how come you can get perfume from petals? What do you think? Anna? *[I was hoping to make the connection between the scent and attracting the insects]*

Anna:	I think the petals are for a runway, 'cos when the bee lands and it wants, it wants some nectar or whatever it is, pollen,
C:	*(interrupting)* it zooms down and goes bbbbzzzz runway!!!
C:	(makes aeroplane noises.)
KM:	So a petal is a landing and taking off place. Could be.
Luke:	If it didn't have the petals the water that went up the stem would go out the top. *[A quiet boy, it was unusual for him to call out.]*
Rosie:	It holds it in. *[Rosie has picked up on Luke's idea and explained it further.]*
KM:	Hang on, it's to..? *[An unexpected idea, I needed to give myself some thinking time and also check I had understood Luke properly.]*
Luke:	The water that goes in the roots and up the stem would go out the top if it never had no petals.
	[ ]
KM:	Carla
Carla:	You know Polly said you can make perfume out of petals, I reckon that some petals smell different from others and that's why you get different smells of perfume.

There was evidence of the children listening to each other's ideas, but no sense of building to a clear conclusion; it was a more a general collecting of possibilities. Various ideas were suggested: petals block the sun, petals attract insects, petals are for insects to stand on, and petals keep the water in.

Any class of children has a shared set of past experiences that are not also shared by the teacher: from previous classes, the playground and the locality (Pollard, 1985). This means that, in terms of relating new knowledge and understanding to previous experience, other children provide useful links and 'hooks' that the teacher cannot. By allowing children to express out loud the ideas that occur to them, other children were drawn into the discussion. An example of this from the above transcript is when a group of girls became animated as Polly describes how she made 'perfume' from petals. This experience had a particular resonance for them.

I then used a story-like approach, along with hand gestures on the photograph of a tulip and drew a diagram of a flower to explain the process of insect pollination. The switch into a more transmissive mode was signalled by how I introduced it and the children's acknowledgement of this was evident in the responses shown below:

> KM: Right I'm just going to give you a piece of information that I want you to hang onto.
>
> C: Do we have to write it down miss?
>
> Hannah: No you have to put it in your brain and remember it.

Throughout my explanation, children were putting up their hands, bidding to speak, with some calling out, to the extent that it was quite difficult to sustain the narrative and I broke it several times to engage with their comments. Having just moved from a phase of interaction in which children's ideas were welcomed, it was difficult for them to shift out of this and for me to maintain control. Edwards and Mercer (1987) explain how teachers' authority is bound up with their status as holders of knowledge and here I felt that in allowing a more open-ended discussion I had lost control of the direction and struggled to get it back.

At the end of the explanation, some children asked questions that demonstrated their engagement. These are presented in chronological order, but did not follow each other directly.

> Anna: So what happens if there's two plants in the middle of a field and they've got just stamens and what happens if a bee went to a stamen and got just pollen and went to the next one and wiped it off what would happen?
>
> Simon: How do you know if it's *[the plant]* male or female?
>
> Anne: How come on a plant male and female can be together all the time and if you're a person we have to go and you're not together in your life?
>
> Polly: Why is the stigma like thicker? Is that 'cos the eggs are inside it?

As the teacher I had separated the discussion into two phases – firstly encouraging speculation and eliciting the children's ideas and then I followed this with what was intended to be a non-interactive, didactic explanation. At the time, this felt unsatisfactory: a resort to the transmissive view of teaching that constructivist approaches opposed. I wanted to find better ways of talking through the children's initial ideas that would connect them to a more scientific view using a logical sequence of questions and responses in a discussion.

The children seemed to understand the explanation, however, and accepted that they had been asked to speculate about the purpose of flowers while knowing that I knew the right answer all along. This game playing is as described by Edwards and Mercer (1987) – the children have learned to accept forms of interaction in the classroom that would not be part of relationships outside of schools. This process, if in some ways dishonest, did have the effect of constructing a version of science in which imagination and collaborative speculation were valued to some extent. This contrasts with the case described by Kreuger et al. (2002) in a secondary classroom, in which a pupil became very frustrated with the teacher not providing 'the right answer'. That some children were asking questions of me as the 'expert' appears to be a way in which they regained power within this exchange and so, in this case, the culture of the class seemed to support these children in working to make their own sense of my explanation rather than accepting it as facts to be learned by rote.

2.3 Investigating Seed Germination

The quote below illustrates how I had interpreted a constructivist model of teaching science and the tensions I experienced in attempting to teach according to the model:

I want to help children to carry out their own investigations, but also choose investigations that I know will develop their skills and ideas. There is also a limited amount of time available. Together these factors create a tension between how much decision-making I allow the children to take over investigations and what control I retain. (Contemporary notes)

A major issue was the difficulty of responding to the ideas of individual children when teaching a whole class (39 children) with a limited amount of time available for science (2-3 hours per week). Another issue was what the learning objectives of the lesson might be and which would be dominant – would the focus be on the development of conceptual understanding, on particular scientific skills, or a more holistic experience of undertaking a scientific enquiry?

My response to this dilemma was to take a whole class teaching approach to focus on an aspect of procedural knowledge – data interpretation - and on an aspect of conceptual development: factors affecting seed germination. In doing so, I made a judgement about the needs of the class as a whole rather than considering the children as individuals. In whole class discussions we planned and set up an experiment to investigate the factors affecting germination. Since the children had repeatedly suggested "light" as a requirement for germination, this led me to direct the investigation towards challenging this 'misconception'. Cress seeds were put on filter paper in Petri dishes and covered with transparent, translucent and opaque materials. My contemporary notes summarise the pedagogical choices and decisions made:

> *I could have picked up on the various ideas that had been suggested and different groups could have chosen their own variables to control and test. This would have given the children more ownership of the test and allowed them to follow up their own ideas more. The discussions about their results could have been held in groups or with individuals. However, by modelling the process of a specific experiment with the whole class I had the time to focus on the aspect of data interpretation in some depth.*
>
> (Contemporary notes)

The results showed insignificant differences between the number of seeds that germinated in each dish and, having established this through discussion, I led the children to compare this outcome with their prediction that those with more light would germinate better.

One girl suggested that it might not have been a fair test and other children then proposed various possible problems with the test design; for example, that one container may have been closer to the window. I prompted the children to offer an alternative explanation:

KM: Mmm, it might not have been quite as accurate as we might have hoped, so that could be one explanation. Suppose it was accurate. Suppose it was a fair test. What would our results tell us? Sophie?

Sophie: That plants don't really need light that much so...

KM: That's what our experiment's telling us isn't it? That they don't need light that much to get started on growing, to germinate. *[Here, I have decided on an interpretation of the experiment that I consider to be the correct one. It might have been better if I had continued to treat it as tentative.]*

Mike: They need water really

KM: Just water

Adrian: And food really

KM: What do plants use the light for? *[This was a critical question in getting the children to apply their developing understanding of photosynthesis to explain what they had observed.]*

Pete: *(Gasps)*

KM: Pete

Pete: To make food

KM: To make food. Is there any reason, why seeds when they begin germinating might not need to make food? *(long pause)*. What do you think Carla?

Carla: Well, I think there's some food in there, like

KM: In where?

Carla: Like the seed like saves, like got a bit of food, already made like water and everything

KM: Sort of trapped inside the case

Carla: Yes

After a few more comments, Tracey, a child with a statement of special educational needs for learning difficulties, makes a vital connection between real life and our experimental setup:

KM: Tracey, what do you want to say?

Tracey: When you plant them [*seeds*] in the soil, they can't get any light

KM: And you're saying when, if they're planted in soil, they couldn't get any light could they? ...Oh that's a thought, so, maybe, they don't need light to start growing, because, if you bury a seed underground, which you often do when you plant it, it doesn't get light. Good point. Polly, you've been waiting patiently.

Polly: In the, haven't got leaves right ...you can't get light, so you can't get food

KM: Aahh, so it's because the leaves aren't really there yet doing their job, the seed has to have the food ready instead. That's a really good thought, I like that.

Susan: There's no need to make food yet, because the food's in the seed.

At the time, I felt confident that the whole class context had been successful in challenging the idea that seemed to be widely held in the class – that light was needed for seeds to germinate. An assumption of a collective understanding was made judging by the comments of a few children; these children's ideas have been taken as representative. Of course, there are other indicators such as body language and facial expression that provide information about whether or not children are 'with you', and these were not available for retrospective analysis in audio-tapes.
There was evidence of the children building on each other's ideas and this seems to have contributed to the sense of it being a collective enterprise. There were several key questions that shaped the direction of the discussion considerably, as noted at the time:

> *I am sometimes concerned that too much challenge will close the discussion down, but when I have used challenging questions they seem to have been effective. Perhaps my use of challenging questions could be increased without damaging the trust between myself and the children.*
>
> (Contemporary notes)

My comments here about being concerned about the use of 'challenging questions' is very much in line with the findings of Alexander (2000) who described teachers in England as being so concerned for the self-esteem of their pupils that they protected them from 'failure' and the discomfort of having their ideas confronted as inadequate in some way. Alexander suggests that, against their intentions, this teacher behaviour actually reinforces a classroom culture in which ideas are not freely expressed and openly debated without fear of ridicule.

The way that links were made between the experimental conditions and everyday contexts - cress growing on filter paper and seeds in soil - and with a previous lesson about leaves 'making food using sunlight' had not been planned for and anticipated; they were generated through the whole class discussion.

2.4 Themes that Emerged from the Exploratory Study

Galton et al. (1999) found that teachers engaged in fewer sustained discussions with classes of 10-11 year old children in science than in English and maths. The exploratory studies suggested that whole class discussions could provide an opportunity for the teacher to model the thinking processes of science, for example, considering what function petals might fulfil, making connections between ideas - as in the case of the germination of seeds in the dark - and supporting sustained dialogues - as in the case of photosynthesis.

There seemed to be some shared ownership of ideas between myself and the class. Evidence for this comes from the way the children referred to each other's comments and ideas, either directly or by building on them in their own utterances. Social constructivist theories of learning emphasise the importance of interactions between children in developing a shared understanding (Vygotsky, 1962; Wood, 1988) and the influence of the culture and social context (Bruner, 1990; Mercer, 1992). My exploratory study suggested that whole class interactive discussions can play a positive role in creating shared understanding and a classroom culture in which ideas can be raised, questioned and developed.

2.5 Research Questions

The exploratory study raised questions about the ways in which whole class interactions could be analysed more rigorously and how they related to currently advocated models of teaching in primary science education. Consequently my main research question is:

> How can an understanding of 'interactive whole class teaching' make a contribution to the development of models of science teaching at Key Stage Two?

This question takes the concept of 'interactive whole class teaching' as problematic and seeks to understand it and further define it. By looking at the range of literature available that makes recommendations for practice, I intended to identify what role whole class teaching plays in these. This is summarised in the sub-question:

> What is the role of 'interactive whole class teaching' in models of teaching science in the literature?

A literature review and analysis alone would not develop an understanding of how these models are being applied in real classrooms, with their conflicting demands and tensions, and how they are developed and modified by teachers as a result of their own ideas and the contexts in which they are working. This leads to the sub question:

> How are teachers using 'interactive whole class teaching' in science lessons and to what extent is this consistent with the models of practice in the literature?

Bell and Qualter (2000) suggest that:

> ...rather than beginning with a model of 'good practice', it is necessary to consider what teachers do and build up a model of effective practice grounded in actual classroom practice. (ibid., p. 8)

A problem with this approach is how to define effective practice. If we use the existing models to define good practice, then the process becomes tautological. I decided to explore teachers' views on the use of whole class teaching and to establish how these relate to their beliefs about teaching science and their practice. I aim to establish links between the use of different forms of 'interactive whole class teaching' and different pedagogic purposes by identifying how teachers use whole class teaching within science lessons, where they occurred in the lesson, for what purposes and the nature of interactions within those episodes. I will then be able to make judgements about the outcomes and assess their value in terms of my views of the purposes of science education at Key Stage Two. This then suggests further research sub-questions:

> What are teachers' understandings of how 'interactive whole class teaching' contributes to their teaching of science?
>
> What is the nature of interactions within 'interactive whole class teaching' in science?
>
> How does 'interactive whole class teaching' contribute to teaching about the nature of science and scientific processes and scientific knowledge and understanding?

To what extent are strategies within 'interactive whole class teaching' evident in classrooms supported by the models of teaching science identified in the literature?

2.6 Summary of Chapter 2

In Chapter 2, I have presented an exploratory case study and explained how this research has emerged from my concerns as a Key Stage 2 teacher attempting to implement models of science teaching in real classrooms. This should also enable the reader to understand my previous experiences and their possible impact on my later interpretations.

The issues emerging from the case study suggest that 'interactive whole class teaching' might serve to provide models of scientific thinking and that a collective and supportive class culture, in which children are expected to listen and respond to each other's ideas, support this process. This has provided some tentative themes for further exploration in the literature and through empirical study and led to the formulation of my research questions.

Chapter 3: Literature Review

3.1 Introduction to the Literature Review

This chapter has four main themes:

- Interactive whole class teaching – a culturally situated concept
- Perspectives on learning and teaching in science
- Insights from Discourse Analysis and Sociocultural Studies for Talk in Science Lessons
- Dialogic Teaching

I will begin with an exploration of definitions of 'interactive whole class teaching', and discuss how international comparisons have raised concerns about the quality of classroom dialogue and provided insights into reasons for the current patterns in the UK. Mortimer and Scott (2000) suggest that the application of sociocultural theory to science education research has led to a shift away from a focus on the ways in which individuals develop ideas to a consideration of the role of the social context of the classroom. In this section, I will first review Piagetian constructivist and social constructivist perspectives and then explore sociocultural perspectives on science education and position this thesis in relation to them. This includes a discussion of the concepts of the Zone of Proximal Development (Vygotsky, 1978) and scaffolding (Wood et al., 1976). I will then provide an overview of the contributions of discourse analysis and sociocultural perspectives to research into talk in science teaching and, in the final section, I will examine the particular contributions that Alexander (2004a), Mortimer and Scott (2003) and other related research have made to defining how classroom talk can be 'dialogic' or 'authoritative'.

3.2 Interactive Whole Class Teaching – a Culturally Situated Concept

The use of the term 'interactive whole class teaching' has emerged partly from international comparisons of primary pedagogies (section 1.2). One critique of this is provided by those who consider that the wider cultural context of education, particularly in Pacific Rim countries, had not been acknowledged (Galton et al., 1999; Alexander, 2001). Alexander (2000) provides an insight into culturally rooted beliefs about children's self-esteem: for example, unlike in Russia, France and India, children in UK classrooms are rarely challenged about their ideas in the public forum of whole class teaching. Instead, such feedback is largely restricted to interactions between individuals and small groups. Alexander suggests that this concern for self-esteem may present a barrier to extended interactions of a higher cognitive level. He describes how, in Russian classrooms, there were extended dialogues with one child in which the teacher's questions scaffolded his/her developing understanding and the other children were expected to listen to this process and learn from it. Alexander (2000) makes a useful distinction between 'interactive pace' and 'cognitive pace': in order to maintain participation and engagement, teachers may focus on interactive pace rather than intellectual depth.

English classrooms have focussed on the concept of the child as an individual, learning at his own individual pace. The corollary of this is that teaching should be different for each child and teachers understandably find this hard to reconcile with whole class teaching (Moyles et al., 2003). Black (2004) argues that a combination of time pressure and teachers' ideas about differentiation has meant that, in order to encourage participation, low level questions are directed at children perceived to have low ability. In her view, whole class teaching can perpetuate and exaggerate the effects of different teacher expectations of different children.

Another explanation for the relatively low level of cognitive engagement evident in whole class interactions in the UK is the difficulty of reconciling the demands of a prescriptive and overloaded curriculum with a more open-ended discursive approach (Black, 2004; Moyles et al., 2003; Galton et al., 1999). In the case of science, primary teachers' lack of confidence in their own understanding of science can also result in teachers restricting the discussion to areas in which they feel comfortable, 'closing down' avenues that seem to lead into unfamiliar territory (Wragg, 1993; Harlen and Holroyd, 1997).

A further difficulty in implementing 'interactive whole class teaching' is the lack of a shared understanding of the term. Moyles et al. (2003) found a great deal of uncertainty amongst teachers they interviewed for the SPRINT Project as to what 'interactive' teaching means, with most relating it to notions of 'good practice'. Smith et al.'s findings (2004) confirm this. The SPRINT Project categorised the teachers' ideas about 'interactive teaching' into what they termed 'surface' and 'deep' features:

Surface:

- Engaging pupils
- Practical and active involvement
- Broad pupil participation
- Collaborative activity
- Conveying knowledge (though few identified this, and all who did were Key Stage 2 teachers)

Deep:

- Assessing and extending knowledge
- Reciprocity and meaning making
- Attention to thinking and learning skills
- Attention to pupils' social and emotional needs

These features suggest a range of purposes for 'interactive whole class teaching'. They indicate values congruent with social constructivist premises; active involvement of children and attention to children's ideas. The concern for social and emotional needs identified by Alexander (2000) is also evident. However, seeing interactive teaching as supporting reciprocity and meaning making suggests it has a role to play in locating some power with the children and valuing the meanings that children are constructing. Moyles et al. suggest that teachers were making a shift in their thinking; rather than seeing broad participation in terms of an individual's response to a teacher's question it was increasingly being seen as important that children explained their ideas to each other and discussed their ideas in 'time out' with a partner.

3.2.1 Whole Class Teaching and Lesson Structures

Alexander's cross-cultural study also examined the role of whole class teaching in structuring lessons. Primary teachers in England are able to determine the length and structure of lessons and this flexibility is more evident in subjects other than literacy and numeracy, including science. Alexander (2000) suggests that the lack of prescriptive structure and the value teachers place on negotiation and self-direction means that children are in a position to extend parts of the lessons and have control over some of the timing. He uses the terms 'fixed' or 'elastic' to describe the flexibility of lesson length and internal structures. The openings to lessons can be *procedural* – usually brief and concerned with organisation, or *instructional* – about the focus for learning. The middle sections of lessons can be characterised as *unitary* – involving one main task, or *episodic* – involving a sequence of shorter tasks. Alexander (2000) describes how sequences of episodes can be self-contained or linked in different ways. When they are self-contained the episodes may be *reiterative*, in which the same point is made, or *cumulative*, in which different points are made. If the episodes are linked, this may be cumulative if the episodes are closely related but could also be *developmental*, in which ideas are developed progressively, each building on the previous one. As with the lesson openings, the endings of lessons could be either *procedural* or *instructional* or both.

Alexander (2000) describes how the lessons in French and Russian classrooms tend to consist of short tasks alternating with direct instruction in whole class teaching, or single tasks broken into stages, again alternating with direct instruction (p. 302). The patterns in English classes were found to be diverse, but frequently involved lessons with brief procedural openings in which activities were introduced, long unitary central sections where the pupils undertook the activities and the teacher circulated, and brief procedural conclusions. In making these intercultural comparisons, Alexander suggests that there is a relationship between the lesson structure and the nature of the discourse within the lesson:

> ...the conclusion that there is a connection between the content of interactions and the organisational frame within which they are set is irresistible.
> (Alexander, 2001, p. 402)

He argues that classroom discourse is shaped by the power imbalance between teacher and pupils, but also by time constraints and the large size of the group. Necessarily, classroom talk is managed to 'orchestrate events, people and time as well as knowledge' (p. 393). He tentatively suggests that it is structured talk that keeps pupils on task and that this leads to higher pupil achievement in terms of developing understanding of the curriculum. However, he is careful not to suggest a direct causal relationship between lesson structure and the nature of interaction.

Whilst Edwards and Mercer (1987) found that teachers use the power of their authoritative knowledge to maintain discipline, Alexander is arguing that the culture of negotiation and democracy by English teachers results in time being spent on matters of discipline and behaviour, rather than cognitive development. Taken together, this suggests that the apparent flexibility and responsiveness to children in English classrooms is more about time and organisation, while the knowledge content is less debated.

3.3 Perspectives on Learning and Teaching in Science

Although the focus of this study is on teaching science, this is of course linked with theories of learning and in this section I will examine the theories of learning and teaching that are prevalent in science education literature.

3.3.1 Constructivism

The central premise of constructivism is that knowledge is constructed in the mind of the learner rather than transmitted by someone already in possession of that knowledge (Scott, 1987). This opposition means that approaches to teaching based on constructivist theories of learning are based on providing experiences for learners to make sense of, instead of 'telling' the learner what they should know. The underlying epistemological assumption of constructivism is that knowledge is a construct of the mind and not a set of absolute truths (Piaget, 1930; Bruner, 1986; Von Glaserfeld, 1988). It is associated with notions of understanding instead of recall of information, with understanding being seen as the capacity to apply and create knowledge in new situations rather than solving problems by following protocols learned by rote or mimicry. Constructivism assumes the centrality of the mind of the individual (Von Glaserfeld, 1988) and, as such, it is rooted in Western psychological accounts of learning (Gergen, 1997).

The Children's Learning in Science (CLIS) project (Scott, 1987; Needham, 1987) identified a further premise of constructivism as seeing learners as 'active' agents rather than passive recipients. Fox (2001) questions whether learning is an 'active' process, and suggests that learning is not always active, but can be subliminal and unconscious. This focus of constructivism on the agency of individuals can thus be seen as congruent with a political view of the purpose of education as to empower individuals (Millar,

1998) and goes beyond providing an account of learning to valuing the kind of learning that leads to this empowerment.

Piaget's account of the child making sense of the world according to his own logic, and of the importance of interaction with the physical environment, has been influential in science education with the conception of the 'child as scientist' (Bruner, 1985). Piaget proposed that, when faced with new evidence, children may either assimilate it into their existing mental frameworks, or be obliged to change those mental frameworks in order to accommodate the new information. Two Piagetian ideas central to the constructivist view in science education are that knowledge is held as mental structures in the minds of individuals and that children's prior ideas are critical in mediating the ways in which new experiences are interpreted. However, unlike Piaget, in the context of science education: 'Constructivists focus on prior knowledge in the content domain, rather than universal operational knowledge.' (Erickson, 2000, pp. 277-8). Although some researchers, notably Adey and Shayer (1994), examine more generalised logical thinking, much constructivist research has been undertaken into the ideas children have within specific domains. Driver et al. (1985) sought to find out, for example, what ideas children held about heat and temperature and electric circuits. Piaget's universals; objects, space, causality, have a direct relationship with the material world and, in the Piagetian view, are developed through an individual acting on the material world (Piaget 1954, p357). Erickson argues that a problem for constructivism is applying Piagetian ideas to teaching and learning knowledge that is not independent of context, but created by scientists.

The congruence between constructivist ideas about how children learn by relating existing mental models to new evidence and ideas about the processes of science in developing knowledge has been identified by primary science educators as further reason to advocate teaching strategies in which the child is encouraged to learn through the processes of science – exploration, hypothesis formation and testing (Harlen, 1985; Ollerenshaw and Ritchie, 1997). The focus on learning through the processes of science in this interpretation of constructivism reflects the tradition in primary education of emphasising the child as the central agent, as encapsulated by the Plowden Report with '...special emphasis on individual discovery, on first-hand experience and on opportunities for creative work.' (CACE, 1967). Driver (1983) was concerned that an inductive view of science, if held by teachers and by children themselves, could lead to an overemphasis on learning through the 'process' of science conceived in a naïve empirical way, at the expense of other teaching strategies and Leach and Scott (2003) argue that this empirical view dominates science education.

Solomon (1995) argues that children do not act like scientists testing ideas, but that actually they acquire their ideas from language. She suggests that if there are contradictions or conflicts with a learner's own ideas perhaps sometimes they are neither accommodated nor assimilated, but compartmentalised, ignored or suppressed. Solomon also argues that curriculum designs based on constructivist models have not yet produced significant results, and that the focus on individuals' constructions of knowledge is incongruent with most learning settings in which the curriculum is based on culturally-defined and valued knowledge.

3.3.2 Social Constructivism

The role of social interaction in learning as discussed by Bruner (1996) and Vygotsky (1962, 1978) has been incorporated into constructivist theories, as it was not seen to challenge the core constructivist premises of the active, individual learner constructing mental models from their experiences (Erickson, 2000). 'Social constructivist' theories of learning in science maintain a central role for first hand experiences and interaction with objects, but also see interactions with others as important. Advocates of this view see the role of the teacher as engaging children in the processes of science by questioning them about their ideas, challenging their logic, providing new evidence and helping them develop practical investigations that put their ideas to the test (Harlen, 2000; Ollerenshaw and Ritchie, 1997). A detailed analysis of this can be found in the next chapter.

Driver (1983) provides an insight into the dilemma of teaching science both as an accepted body of knowledge and as a process of genuine enquiry and the tension this creates for teachers. This is resolved by Driver et al. (1994) who view learning science as enculturation into a scientific discourse and argue that as scientific knowledge is itself a human construction, albeit constrained by the material world, an entirely empirical approach to learning science is not sustainable; scientific concepts do not emerge from phenomena, explanations are developed by scientists. It follows from this that the role of the teacher must include introducing those conceptual ideas to children. They label this approach social constructivism rather than personal constructivism. The authors are careful to distinguish this from a transmissive view of teaching in that individual construction of knowledge is still required. This version of social constructivism has the same Vygotskian premise that learning involves individual internalisation of socially constructed knowledge that is further developed in sociocultural perspectives discussed in the next section.

3.3.3 Sociocultural Perspectives

Sociocultural perspectives emphasise the 'situatedness' of the mental activity of an individual within a specific cultural context (Wertsch and Tulviste, 1992). Knowledge is viewed as inseparable from the social and historical contexts in which it is constructed. A consequence of this view is that meaning is not seen as existing inside the minds of individuals as in constructivist models, but that it exists between people as they engage in activity together (Lave and Wenger, 1991).

The contribution of semiotic theorists to sociocultural perspectives is that sign systems such as language act as tools to mediate socially shared meanings and that they do not act to simply represent and express ready-formed thoughts, but shape the construction of those ideas (Bakhtin, 1981). Wells (1999) explicitly sets out to develop a sociocultural theory of education, drawing together the work of Vygotsky and the social semiotics of Halliday (1993) to explain the 'co-construction of knowledge'. He notes that, although Vygotsky saw speech and thinking as having separate origins – speech arising as the child comes to understand how language is a symbolic system and thinking arising through manipulating objects – Halliday has a different premise, that:

> Language is the essential condition of knowing, the process by which experience becomes knowledge. (Halliday, 1993, p. 94)

However, within this view, Halliday identifies two strands of knowledge development - through interacting communicatively and interpreting experience. The ongoing debate about the relationship between thought and language in early childhood development is not central to this thesis, but the relationship between experience, its interpretation and language is important in attempting to understand how 'interactive whole class teaching' could contribute to learning in science because the basis of science is seeking to provide explanations for observable phenomena. According to Wells (1999), by appropriating the adult culture, including language, children develop a set of tools with which to think.

In Vygotskian versions of the sociocultural perspective, learning is seen as the 'internalisation' by the individual of meanings constructed on the social or 'intermental' plane resulting in the creation of an 'intramental plane' within the minds of individuals (Vygotsky, 1978). This process is not seen as a simple transfer, but rather as a complex, two-way, 'dialogic' process in which the individual contributes to the construction of the social plane and so, as well as internalising it, changes it. Wertsch (1993) considers that the term 'internalization' implies an internal/external dualism that is often assumed in cognitive psychology, but is not helpful as it reinforces a culturally transmissive account of learning. He emphasises the active use of tools by the individual in developing the intramental plane, and terms this process 'productive transformation'. To avoid the notion of transmission that is implied by 'internalisation', Wertsch suggests the term 'mastery', but I prefer the term 'appropriation' (Rogoff, 1990) to convey a sense of the learner taking ownership and control of ideas.

This view of the learner as an active agent in the process shares common ground with Piagetian ideas of the learner 'constructing' and 'reconstructing' knowledge in response to the environment. However, in Piagetian accounts, the emphasis is on logic and evidence of the physical environment, and in sociocultural accounts on the role of language, culture and meaning.

Wertsch's (1991) interpretation of Vygotsky emphasises the social mediation of thought, of the mental actions of individuals. Wertsch is not denying the existence of the individual:

> This is not to say that there is not an individual moment of mental action: in the end, my interest here is in the psychological processes in individuals as they carry out such action. (ibid. p. 15)

However, he argues that in attempting to understand it, it does not make sense to isolate that mental action from the mechanism that mediates it. He seeks to connect psychological processes to sociocultural settings:

> Thus, even when mental action is carried out by individuals in isolation, it is inherently social in certain respects and is almost always carried out with the help of tools such as computers, language, or number systems. (ibid. p. 15)

Cole and Wertsch (1996) reflect on the discussion that has existed in which Piaget is characterised as locating development in individual children who construct knowledge by acting on the world, and Vygotsky for whom learning is located in social processes. For Cole and Wertsch the distinction is less clear cut and has more to do with the way in which an active individual and an active environment are engaged in 'co-constructionism'. They also emphasise the importance of a culture as the medium within which the active parties interact – in their view learning involves cultural mediation. They use the term 'mediated action in context' – meanings arise in a specific context and are mediated by the particular social language being used. Wertsch (1991) does not suggest that this focus on situatedness means that there are no universals, on the contrary, he argues that they play an important role, but that it is also important to be able to theorise about human action in context. He argues that current research that starts from Piaget's universal ideas of schemata and the processes of assimilation and accommodation have placed the social context as of secondary importance.

Wertsch (1991) explains how Vygotsky argues that the 'sense' of a word is dependent on the context in which it is used. The tools of communication do not just facilitate, they transform the action. Vygotsky also emphasised the role of talk in creating generalisations; in order to communicate an idea it needs to be typified, creating an abstraction, the meaning of which is shared by both participants. Vygotsky argued that this abstraction is central in supporting higher order thinking and began to develop a discussion of the role of formal schooling in the transition from individual 'complexes' to 'scientific' concepts, through a 'decontextualization of the mediational means' (Wertsch, 1991, p. 47).

Bakhtin (1981) took the primary unit of analysis of language to be the utterance as this is where language systems are used to create a unique, situated meaning. A key idea for Bakhtin is that of 'voice' – the notion that the speaker will have a point of view and a position; this encompasses the tone of voice, but goes further in that it considers the speaker's intentions and world-view. He also considered the role of the listener – the person to whom an utterance is addressed affects the meaning, as it is situated in the relationship, and builds on previous interactions between them. So any utterance involves at least two 'voices'. A speaker will always invoke a particular social language in producing an utterance, and this will shape what the individual is saying. The words will, in part, belong to someone else and the speaker appropriates them to express their own meaning. So, in any utterance there will also be at least one 'voice' – that of the speaker, and of previous users of the words. Bakhtin suggested that when listening to an utterance, understanding is developed as the listener produces a set of counter words in their own mind, almost as alternating lines of dialogue. This 'multivoicedness' is Bakhtin's version of 'dialogicality' and is different from the Vygotskian use of the term which centres on the creation of the intermental plane.

Wertsch identifies how a 'transmission model' of communication, in which information is simply coded by a sender and decoded by the receiver, has dominated much research. He suggests that texts fulfil two functions: to convey meanings adequately, and to generate new meanings (Wertsch, 1991, p. 74). The first requires the codes of the speaker and listener to coincide – it requires univocality. The second involves multivoicedness. So, rather than being a breakdown in the decoding, it involves thinking, and the generation of new meaning. This can occur on both the intramental and intermental planes.

Wertsch then identifies two forms of discourse: authoritative discourse characterised by fixed meanings, not to be modified by new voices, and internally persuasive discourse which is open to new meanings. In an authoritative discourse, the main locus of change will be with the person with less authority. This relates to Solomon's (1995) critique of the constructivist assumption of the child engaging with ideas and evidence in a logical, somehow neutral way, which, she argues, ignores the reality of the ways in which more powerful people can impose their understandings on others. According to Wertsch (1991) the key Bakhtinian questions are: who is doing the talking, and who owns meaning?

Another concept that Wertsch develops, is that of the heterogeneous nature of 'voice' (Wertsch, 1991, pp. 93-118). This is helpful in illuminating Solomon's (1995) critique of constructivism when she argues that children acquire their ideas from language, not just practical experience, and also that they use their constructions differently in different contexts. She proposes that children maintain two domains of thought –

everyday thinking and school science thinking - which are able to coexist so that children need appropriate 'cues' to be able to move between them and decide which is the appropriate domain. Wertsch (p. 99) argues against a hierarchical view of ways of thinking, taking an instrumental position, he argues that different ways of thinking are more effective in different situations and draws on Bakhtin in using a tool box analogy in which different forms of language are used for different purposes. However, some of those speech genres are privileged in certain situations, so in a classroom, the speech genre of 'official science' is valued over everyday speech genres (Lemke, 1999), perhaps, particularly in secondary schools.

3.3.4 Theorising Teaching: Scaffolding, The Zone of Proximal Development and an Intermental Development Zone

Through 'scaffolding' (Wood et al, 1976) the teacher holds the external knowledge and makes it possible for the child to internalise it (Bruner, 1978). The gradual withdrawal of support by the teacher as the child takes on the responsibility for the task has been termed 'handover' (Bruner, 1983). The detailed conception of scaffolding (Wood et al., 1976 p. 90) remains popular as it seems to encapsulate what it is that teachers do (Mercer and Littleton, 2007). Wood et al. describe six functions of teachers as scaffolders:

1. Recruitment – engaging interest in and commitment to the task.
2. Reduction in degrees of freedom – the task is simplified, perhaps by breaking it into simple steps, or by the teacher carrying out some of the steps for the child.
3. Direction maintenance – having engaged interest at the start, the teacher's role is to maintain this and to keep the intended goal in mind.
4. Marking critical features – the teacher signals that some aspects of the task are particularly significant.
5. Frustration control – this may relate to reducing, or possibly increasing, the number of degrees of freedom or providing feedback and encouragement.
6. Demonstration – modelling for the learner how the task can be solved.

There is a need for caution in the use of the concept of scaffolding in the context of schools as the assumed adult-child ratio and the nature of the adult-child relationships are different from those in the home context in which the concept was developed (Askew et al., 1995) It is possible to conceive of 'recruitment', 'direction maintenance', 'marking critical features' and 'demonstration' as being possible in a whole class context, but 'reduction in degrees of freedom' and 'frustration control' seem more applicable to individual children, or possibly small groups. Wood (1986) developed the notion of scaffolding to incorporate guidance for teachers on the process of 'handover': that teachers should respond to failure on the part of the learner with immediate increase in help or control – a reduction of the degrees of freedom. Scott (1997) argues that 'it is teacher responsiveness to student learning which lies right at the heart of scaffolding' (p. 230) and that the problem of student numbers means that it is not possible for teachers to be responsive to individuals in most school classes. He suggests that during whole class teaching the teachers in his case studies in secondary school classrooms were not scaffolding, but were:

> making interventions to enable the development of the teaching narrative. (p. 232)

However, there may be differences between primary and secondary classrooms: typically primary teachers teach the same children for most of the day and are more familiar with them and so are in a better position to identify individual responses, although the challenge of doing so is still considerable.

Notions of scaffolding have been theorised by linking them with what Vygotsky defined as the 'Zone of Proximal Development' (ZPD):

> ... the distance between the actual development level as determined by individual problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more able peers. (Vygotsky, 1978, p. 86)

Scott (1997) compares how the concept of the ZPD has been developed by Tharp and Gallimore (1988) and Wertsch (1985). Common to both is the notion of different stages within the ZPD. Both postulate an initial stage in which the child has limited understanding of both the task and the nature of the goal. At this stage, the role of the teacher is to model the process, or to give directions so that the goal can be achieved and the learner can gain an understanding of what they are setting out to do. When they have gained this, then the child can be assisted in performing the same task by questioning, feedback or other parallel strategies, such as written directions.

Wertsch's model makes the additional contribution that communication between teacher and learner is difficult at the early stage as there is a lack of shared language and understanding. According to Wertsch's insight, at this stage, particular attention would need to be given to ensuring that sufficient shared meanings are established to enable the teacher and child to work together within the ZPD. In relation to this thesis, this raises questions about whether these shared meanings could be established for a whole class during whole class teaching.

During the second stage of the model, the child is not yet fully confident, but is able to support themselves in carrying out the task, by mental reference to the support of the adult, such as the child talking to herself during the task in the same way as the adult did in stage one. In Wertsch's version, at this stage, the intermental plane is still being developed as the child's understanding of the task is still not the same as the adult's.

In Tharp and Gallimore's stage three, adult support is no longer needed as the child has internalized the learning. This is understood by Wertsch as representing almost complete congruence between the intermental and intramental planes and a shared understanding then exists between the teacher and the child.

Scott (1997) suggests that although the concept of the ZPD was developed to describe an individual, there may be some commonality in the ZPDs of a class of children. There was an example of this in my exploratory study in which there was a widely held view amongst the children that seeds needed light to germinate. He suggests that the notion of a 'socially distributed ZPD' might be useful in terms of applying the concept of scaffolding to whole class teaching. Mercer (2000) suggests that an alternative way of conceiving the relationship between the social plane and the individual mind in developing understanding would be to seek insights into the ways in which children come to think collectively through what teachers do:

> ...they have studied 'intermental' activity in order to understand the 'intramental' while I am suggesting that we should also try to explain children's development as *interthinkers*. To do so we need to understand how experienced members of communities act as *discourse guides* guiding children...into ways of using language for thinking collectively. (Mercer, 2000, p. 170)

This is useful in making sense of the relationship between social constructivist and sociocultural perspectives as focussing on different aspects of the processes of creating intermental and intramental planes with social constructivists aiming to understand the formation of the intramental plane and sociocultural studies focussing on how the continuous recreation of an intermental plane enables groups of people to develop ideas together. Mercer and Littleton (2007) develop the view that scaffolding is commonly used to focus on the action of the teacher, and argue that this one-way interpretation does not take into account the two-way process of negotiation of meaning between people that is required to established the shared frame of reference they call an 'Intermental Development Zone' (IDZ). In terms of this study it raises questions about how whole class teaching develop an intermental plane and how an IDZ can be achieved.

3.3.5 Perspective of this Thesis in Relation to Constructivist and Sociocultural theories

As I wish to focus on the role of 'interactive whole class teaching', and postulate it as a means of constructing knowledge on the social plane of the classroom, I shall be taking a sociocultural standpoint in this study. Sociocultural theory offers tools with which to analyse the ways in which meanings are developed by the class as a group rather than focussing on the learning of individuals.

According to both constructivist and sociocultural perspectives, 'knowledge is not a static, given commodity, but is, rather, shaped and created as the result of constructive activity.' (Kumpulainen and Wray, 2002, p. 21). Following the position taken by Wertsch (1991) and Mercer (2000), I am not denying the existence or significance of individuals and their active appropriation of knowledge, but focussing my attention on the construction of intermental rather than intramental planes.

However, I recognise that the current education system in England focuses on the learning of individuals and it is, therefore, impossible to leave this discourse entirely if I am to engage with current models of teaching science. This positions the thesis rather uncomfortably, exploring the contribution that a sociocultural perspective can bring to existing accounts of primary science education dominated by social constructivism. Mortimer and Scott (2003) argue that they are taking a sociocultural perspective, which builds on constructivism, but belongs to a 'post constructivist paradigm' and I intend that this thesis may further explore this position.

Sociocultural perspectives are not homogenous and place different emphases on the role of psychological discourse, cultural/historical discourses and the discourse of the 'irreducible situated moment' or 'mediated action'. The latter is limited in its capacity to inform policy and practice for which a longer-term, more generalisable view is required (Claxton, 2002, p. 29). I therefore take the view that, although every class will be unique and every interaction uniquely positioned in time, there is sufficient commonality between classes of children and their teachers working within a common overarching culture that any insights I generate may have wider applicability.

3.3.6 Insights of Discourse analysis

Studies of classroom discourse, for example, Edwards and Westgate, 1994, have shown that whole class teaching is dominated by what Tharp and Gallimore (1988) termed the 'recitation script'. In interactions following the recitation script the teacher leads a three stage sequence: Initiation, Response, Feedback (IRF) (Sinclair and Coulthard, 1975), also known as triadic dialogue in which the feedback is often evaluative (E) and closes the exchange. This form of discourse supports movement towards correct factual answers, but the authors argued that it does not support pupils in developing more complex and elaborate ideas.

Edwards and Mercer (1987) undertook discourse analysis of talk in classrooms, including during science lessons, and their work is significant in understanding the shared construction of knowledge in whole class teaching. For example, they identified how, through the use of paraphrasing and reconstructive recaps in the 'Feedback' part of IRF sequences, the teacher is frequently reinterpreting pupils ideas in order to maintain control over the developing 'common knowledge' and simultaneously maintaining the authority of the teacher. Torrance and Pryor put a more positive interpretation on this process of paraphrasing:

> When he repeats or rephrases a child's statement, this seems to have the function of seeking clarification of what has been said and assisting them to refine their thought or reach consensus. (Torrance and Pryor, 1998, p. 114)

Edwards and Mercer criticised the idea that teacher questioning stimulates thought and discussion, arguing that generally questioning checks pupil attention and assesses rote understanding. They suggested that questions have a role in controlling the discussion and, so, are a key element in the power relationship between teacher and pupils. They and others suggest that this leads to children developing ideas in which knowledge and authority are intertwined (Hammersley, 1990; Wertsch, 1985).

Torrance and Pryor (1998) make an interesting contribution to this discussion. In their analysis of dialogues between children and teachers they identify occasions when the IRF pattern breaks down and a more 'genuine' form of dialogue occurs: the child begins to 'initiate, elaborate, expand and explain and thus provide the text for a more potentially rounded assessment.' (p. 106). They give examples in which the teacher is asking 'genuine' questions, that she does not know the answer to, such as asking children about work they did with another teacher. Similarly, Lemke (1990) identified the use of 'talk partners' as breaking the triadic pattern.

Mercer (2000) analysed both the structures of exchanges, and the meanings associated with them, and he suggests that through the teacher's use of recaps, elicitations, repetitions, reformulations, exhortations and linking with previous experiences, the 'intermental development zone' can be created. Although this range of strategies is used by most teachers he argues that they are not always used in such a way as to construct and maintain an IDZ and that:

> For a teacher to teach and a learner to learn, they must use talk and joint activity to create a shared communicative space, an 'intermental development zone' (IDZ) on the contextual foundations of their common knowledge and aims. In this intermental zone, which is reconstituted constantly as the dialogue continues, the teacher and learner negotiate their way through the activity in which they are involved. ... If the dialogue fails to keep minds mutually attuned, the IDZ collapses and the scaffolded learning grinds to a halt.
>
> (Mercer, 2000 p. 141)

Mercer uses the term 'exploratory talk', distinguishing this from 'cumulative' and 'disputational' talk, to discuss the different relationships people have between their ideas and those of others. Cumulative talk is mutually supportive, uncritical, and used to build a joint identity with a shared perspective, whereas in disputational talk participants strive for control of the agenda through argument. Exploratory talk involves the participants in being critically constructive and agreement is sought through reasoning. The views of others are listened to and engaged with. This is similar to Wertsch's 'internally persuasive discourse' (Wertsch, 1991). Mercer explains that the locus of control in exploratory talk is a matter of constant negotiation.

The categories are held as idealizations that are useful for the purpose of analysis and actual talk will rarely fit neatly into one category. Mercer gives an example in which the boundary between disputational talk and exploratory talk is not entirely clear – participants may have strongly-held, opposing interests yet still listen to each other and respond to what they have said. Taking into account Alexander's cross-cultural research (Alexander, 2001), the ways in which teachers distinguish exploratory and disputational talk might become important where they feel they present threats to children's self-esteem. Osborne et al. (2005) recommend that science teaching should make use of 'argumentation' as being the basis for belief in science and to help children understand the nature of science better, going beyond naïve empiricism and learning to deal with uncertainty. English primary school teachers might find the term 'exploratory talk' to be less in conflict with their concern to protect children's self-esteem. Although the process of argumentation Osborne et al. describe is similar to exploratory talk in that participants should be seeking consensus as to the best outcome through reference to evidence and logic, the positioning of participants in opposition and the everyday meaning of argument make this problematic.

Another linguistic concept that Mercer (2000) develops is that of communities of discourse. Using his notion of collective thinking and relating this to genre, he describes how different communities develop different discourses, with their own frames of reference. These may include technical vocabulary, and meanings or ways of using words that are only comprehensible to other members of that community. Ways of using language develop within groups to support their particular aims and purposes. Lave and Wenger (1991) provide examples of how newcomers are guided into the discourse by existing members of the community who select from and reformulate their utterances to shape them into an acceptable form. The term 'community of inquiry'

(Wells, 1999) has been used to describe a group who establish a questioning and purposeful stance to developing knowledge as their dominant discourse.

Discourses may also have the effect of excluding others. Lemke (1990) argues that the discourse adopted by the scientific community - what he terms the 'language of science' with its absence of people, avoidance of narrative forms and use of the passive tense - has the effect of making science appear authoritative and objective, but also difficult and remote from everyday experience. He sees science concepts as sets of thematic relationships with defined patterns and argues that it is these relationships that teachers are trying to help children see and use. He simultaneously analyses the talk in science classrooms in relation to developing thematic patterns, and how the talk supports the authority of the teacher and the subject. Ogborn also works on a similar premise that conceptual understanding is 'talked into existence' and that first-hand encounters with phenomena lead to an understanding of scientific explanations when teachers construct explanations that put 'meaning into matter' (Ogborn et al., 1996). Ogborn at al. see explanations as being analogous to stories and argue that the teacher's role in 'constructing entities' of science is similar to developing characters interacting in a sequence of events.

Communication in science uses not only words, but images, diagrams and pictures to convey meanings (Lemke, 1998). Wellington and Osborne (2001) also consider how meanings are developed through animation of physical models, the use of gestures and other body language. This work was developed by a 'multimodal' approach to understanding (Kress et al., 2001) which took as its premise that communication is multimodal, and that the meanings of symbols are created and reconstructed through their use in particular situations. They analysed science lessons in terms of the spoken language, but also for actions, gestures and the use of visual images and how they interact together to support the creation of meaning.

For Kress et al. (2001), the analysis of talk is useful, but they prefer a broader semiotic analysis seeing learning as a 'dynamic process of transformative sign making'. They distinguish between signs as representation – what it is about the thing the person wants to represent, and communication – how this is done in terms of the audience. So they see the representation as not arbitrary, but 'motivated'. This means that the choice of mode is significant and its choice in itself conveys meaning. For example, they describe how a teacher uses gestures on his own body to illustrate the position of the heart and the flow of blood alongside a 3-dimensional model and diagrams, relating these to each other using speech and repetition of the gestures. They also interpret the meaning of the position of the teacher, for example, the teacher sitting down could signal that a more discursive episode was about to take place.

3.4 Dialogic Teaching

Sociocultural perspectives on teaching have led authors to use the term 'dialogic' in different ways, drawing on Vygotsky and Bakhtin to try and capture the dynamic, two-way processes of dialogue and to apply this to the classroom context. These different views are explored here as being of significance to understanding 'interactive whole class teaching'.

3.4.1 Alexander's Conception of Dialogic Teaching

The term 'dialogic' is used by Alexander (2004a) to express a 'genuinely reciprocal' process of communication between teacher and pupil in which ideas are developed cumulatively over sustained sequences of interactions. He suggests that 'dialogic' is a more useful term than 'interactive', which says very little about the quality of the talk. He provides a list of indicators of dialogic teaching; it is:

- *collective:* teachers and children address learning tasks together, whether as a group or class;
- *reciprocal:* teachers and children listen to each other, share ideas and consider alternative viewpoints;
- *supportive:* children articulate their ideas freely, without fear of embarrassment over 'wrong' answers; and they help each other to reach common understandings;
- *cumulative:* teachers and children build on their own and each other's ideas and chain them into coherent lines of thinking and enquiry;
- *purposeful:* teachers plan and steer classroom talk with specific educational goals in view.

Important in this is the idea that dialogue should be sustained such that:

> answers provoke further questions and are seen as the building blocks of dialogue rather than its terminal point (op. cit. p. 31)

and structured as 'coherent lines of enquiry' rather than relying on the recitation script. Other indicators of dialogic talk would be that children, as well as teachers, initiate interactions by asking questions and making suggestions, and that children listen to each other and are actively involved when they are not speaking.

Alexander quotes Bakhtin (1986 p. 168) in claiming that: '… if an answer does not give rise to a new question from itself, it falls out of the dialogue,' noting that this is more akin to a natural conversation, but teaching is often more directive than this. Alexander (2004a) explores whether talk can be considered to be dialogic in terms of teaching with pre-determined objectives:

> There are many situations when teachers, too, will use dialogue to steer children in a particular direction, and in this sense dialogic teaching may not conform strictly to Bakhtin's idea of the unending conversation. But the term dialogue remains legitimate, because instead of simply telling children what they want them to know, teachers are using dialogic means to probe the children's understanding, discover the most appropriate springboard for taking this understanding forwards and...the most suitable bridge (or of course scaffolding) by which that further understanding might be secured. (ibid., p. 25)

To resolve the tension between supporting open-ended development of ideas and introducing children to an existing body of knowledge, Alexander makes a distinction between dialogic talk that is 'discussion', which involves shared problem-solving and dialogic talk that is 'scaffolded dialogue':

> …structured, cumulative questioning and discussion which guide and prompt, reduce choices, minimise risk and error, and expedite 'handover' of concepts and principles (Alexander, 2004a, p. 23.)

Evidence for Vygotsky's idea that children can appropriate language and thinking on the intermental plane to the intramental plane comes from the outcomes of the Thinking Together project (Wegerif et al., 1999; Mercer and Littleton, 2007) in which individual children perform better on non-verbal reasoning tests after engaging in group work that developed 'exploratory talk' .

Although not related specifically to teaching science, the government document, Excellence and Enjoyment' (DfES, 2004) provided guidance on the teaching of all primary subjects. It emphasises developing a classroom ethos of valuing children's own ideas and providing a safe environment for exploring them. It includes a section on questioning that emphasises how to move away from triadic dialogue, and advice on how to respond to children's contributions that would lead to more dialogic talk, drawing on the work of Alexander. It also devotes a section to whole class teaching and lists purposes for whole class teaching as follows:

> Whole class teaching is often used when:
>
> - New topics, content or ideas are to be introduced.
> - The teacher or practitioner has 'expert' information not readily available to the learners and wants to make sure all children have access to this.
> - Learning objectives and outcomes need to be made explicit.
> - The teacher or practitioner wishes to model a particular skill.
> - Learning needs to be drawn together, summarised or synthesized in order to move learners on after group or individual work.
> - It offers an efficient use of time. (DfES, 2004, p. 30)

The first four points on this list emphasise whole class teaching as a location for the introduction of authoritative knowledge and it is only the fourth point, in which whole class teaching is seen as a location for drawing together different elements, that has any sense of dialogicality. The document rejects critiques of whole class teaching as passive, using the term 'interactive whole class teaching' to refute this and recommending strategies to encourage 'active listening' and ways of involving children such as paired talk and inviting children to come up to the board or undertaking short individual tasks such as writing on a mini whiteboard. Alexander provides a critique of Excellence and Enjoyment, arguing that it:

> ...ignored one of the central contentions of the government's own flagship Literacy and Numeracy strategies, that treating learning as a *collective* process,

> notably through interactive whole class teaching, actually benefits individuals. (Alexander, 2004b, p. 19).

3.4.2 The Mortimer and Scott 'Flow of Discourse' Analytical Framework

Scott (1998) characterises dialogic discourse by contrasting it with authoritative talk and lists features of each comparatively, so that where authoritative talk is focussed principally on the 'information transmitting voice' and is closed to new voices, dialogic discourse involves several voices and is open to their contributions in generating new acts of meaning (pp. 66-67). Mortimer and Scott (2000, 2003) draw together this work with that of Mortimer (1998) in an analytic framework, distinguishing between teaching that is 'interactive' and teaching that is 'dialogic'. In their definition, the interactivity refers to pupils' participation, and the extent to which it can be characterised as 'dialogic' or 'authoritative' depends on whether the pupils' ideas are also part of the discussion or whether the teachers' ideas or scientific ideas are dominating:

> ...either the teacher hears what the student has to say from the student's point of view, or the teacher hears what the student has to say only from the science point of view. (Mortimer and Scott, 2003, p. 33)

In their research they characterise the 'communicative approach' of episodes within science lessons on two dimensions: interactive – non-interactive and dialogic – authoritative. They propose four classes of communicative approach (Figure 3.1):

> **Interactive/dialogic (ID)** - teacher and students consider a range of ideas and viewpoints.
> **Interactive/authoritative (IA)** – the teacher focuses on the scientific point of view and leads students through a series of questions and answers aimed at reaching it.
> **Non- interactive/dialogic, (ND)** – the teacher presents and considers different points of view.
> **Non-interactive/authoritative (NA)** the teacher presents one specific point of view – that of school science.

Figure 3.1 The Four Classes of Communicative Approach

	INTERACTIVE	NON-INTERACTIVE
DIALOGIC	**A** Interactive/ dialogic	**B** Non-interactive/ dialogic
AUTHORITATIVE	**C** Interactive/ authoritative	**D** Non-interactive/ authoritative

(Mortimer and Scott, 2003, p. 35)

Although Mortimer and Scott see the interactive-non-interactive and dialogic-authoritative dimensions as continuous, these categories of communicative approach are set up as discrete, which could limit their descriptive power, but makes them more manageable as research tools. This perspective on dialogic interactions is developed from Bakhtin's argument that understanding the point of view of another is about being able to provide a corresponding set of internal 'words' in our own minds. As any utterance will provoke some kind of meaning-making in the listener, that will be more or less similar to the meaning of the speaker, but always with some new shade of meaning, all interactions could be said to be dialogic. The particular meaning ascribed to the term dialogic by Mortimer and Scott here refers to the teacher being open to the different points of view held by the student and by 'school science'. This builds on the distinction between internally persuasive and authoritative discourses (Wertsch, 1991), setting a communicative approach in which the teacher attends to the dialogic nature of meaning-making in opposition to when they do not. It also addresses both the Bakhtinian questions: 'who is talking?' and 'who owns meaning?' better than Alexander by the explicit reference to who is participating and whose ideas are given value. However, in the case studies developed by Mortimer and Scott, the interactive – non-interactive dimension is not developed to discuss which children are taking part.

The communicative approach is the central element of the framework developed by Mortimer and Scott to analyse sequences of science lessons in secondary classrooms, and aims to:

> ...characterise emerging *patterns in the flow of discourse* in science lessons, in terms of both teacher and student utterances. The analysis is made over a *continuous timeline*.... The analysis is concerned with the ways in which *conceptual themes or content* are made available and developed on the intermental plane of the classroom. (Mortimer and Scott, 2000, p. 129)

The strength of this model is that it enables the analysis to move between specific episodes within a lesson and to relate it to the lesson as a whole, and to previous and subsequent lessons.

Their framework has five elements (Figure 3.2):

1. Teaching Purposes
2. Content
3. Communicative Approach
4. Patterns of Discourse
5. Teacher Interventions

Figure 3.2 Mortimer and Scott's Analytical framework 'a tool for analysing and planning science teaching interactions

	ASPECT OF ANALYSIS	
FOCUS	1. Teaching Purposes	2 Content
APPROACH	3 Communicative Approach	
ACTION	4. Patterns of Discourse	5. Teacher Interventions

(Mortimer and Scott, 2003, p. 25)

The first element in the framework is Teaching Purposes. They consider the purpose in relation only to conceptual development, identifying six teaching purposes in relation to the science being taught:

- opening up the problem,
- exploring and working on students' views,
- introducing and developing the scientific story,
- guiding students to work with scientific ideas and supporting internalization, and

- guiding students to apply and expand on the use of the scientific view and handing over responsibility for its use,
- maintaining the development of the scientific story.

The second element is the content which analyses the nature of the knowledge being talked about, referring to the extent to which it is 'everyday' or 'scientific', based on Vygotsky's distinction between the informal ideas or 'alternative ideas' that are formed in everyday life and those held by the scientific community and linked to the research into children's 'alternative ideas' in science. The content is characterised as a description of phenomena, an explanation, or a generalisation which goes beyond a single phenomenon to a broader scientific story. The content can be either empirical or theoretical in nature, depending on whether it is concerned with the observable nature of phenomena or theoretical entities that have been created to account for it.

The way in which they developed case studies using this analytical framework emphasised the development of conceptual understanding over understanding of the processes or procedures of science. Mortimer and Scott see this as being a necessary redress to an approach in which practical activity in itself is given priority over what is to be learned from it.

The third element, the communicative approach, which has been discussed above, refers to the interactive-non interactive and dialogic-authoritative spectra and the resulting four categories.

The fourth element, patterns of discourse, describes the patterns of interaction, such as whether the sequences of exchanges of utterances follow the pattern of triadic dialogue (IRE).

The fifth element, teacher interventions, identifies different verbal actions that the teacher might take to develop or maintain the scientific story:

- shaping ideas, for example, by rephrasing a student's utterance,
- selecting ideas, for example, by choosing the ideas of one student to develop,
- making key ideas, for example, by repetition or special enunciation,
- sharing ideas, for example, by inviting a student to repeat an idea to the class,

- checking student understanding, for example, by asking for clarification or a written explanation,
- reviewing, for example, by recapping a previous lesson or summarizing findings from practical work.

The first part of the analysis is to take each teaching episode within a lesson in turn and consider it in terms of each of the elements. The framework is then applied to a sequence of lessons, considering each element of the framework in turn for a sequence of several lessons.

By way of example, in one case study with an empirical rather than theoretical content (exploring factors affecting the rusting of nails), they describe a rhythm in which first children's ideas were 'explored' through an interactive/dialogic approach, then 'worked on' using an interactive/authoritative approach to develop the scientific view, and then 'reviewed' in a non-interactive/authoritative approach, a cycle which is repeated across the sequence of three science lessons. In a different case study, in which the content was more theoretical (gases and particle theory of matter), children's ideas were explored, again through an interactive/dialogic approach, but then a non-interactive/authoritative approach was used to introduce the scientific view as the difference between everyday ideas and scientific ideas in this case would not emerge from the practical activities.

Mortimer and Scott (2003) suggest there are three phases to the learning of a scientific concept and develop a three phase model for learning and teaching based on this: firstly, that the scientific ideas must be 'made available on the social plane of the classroom', then the teacher needs to support the pupils in making sense of and internalizing the ideas and, finally, support the pupils in applying their ideas while handing over ownership of their use. This idea has been developed into a recommendation that teachers maintain cycles of dialogic episodes for 'opening up' and authoritative episodes for 'closing down' the dialogue and 'maintaining the scientific story' (Scott and Ametller, 2007).

The exploratory case study in Chapter Two can be reconsidered in the light of this: first children's ideas about the function of petals were explored through interactive dialogic talk, then an authoritative account of insect pollen transfer took place through a (mainly) non-interactive/authoritative episode, before the children then asked questions about the process in another interactive/dialogic episode, taking ownership, or beginning to appropriate the ideas. In the extract discussing seed germination test results, children's ideas are 'worked on' in an interactive/authoritative episode before the children take the initiative and through interactive/dialogic exchanges make links between growing the seeds in their experiment and growing them underground in everyday life, again beginning to appropriate the ideas.

In Mortimer and Scott's argument there is a place for using an authoritative communicative approach at points within sequences of lessons in order to make the 'scientific story' clearly available on the social plane. There is common ground here with Alexander's more holistic notion of 'dialogic teaching' which refers to the overall nature of the teacher's discourse in relation to knowledge and its characterization as purposeful – teachers plan and steer classroom talk with specific educational goals in view. The advantage of Mortimer and Scott's focus on episodes is that it enables a detailed analysis of how the processes of teaching can maintain the aim of helping children to understand the authoritative viewpoint by starting with their own ideas.

Alexander's (2004a) list of indicators of dialogic teaching expands notions of dialogic teaching as being reciprocal and cumulative and of children's contributions chaining together. Taking a slightly different perspective on this, Mortimer and Scott's conception of 'dialogic' was developed by comparing talk in which ideas are collected together – a low level of 'interanimation' and in which the ideas are considered in relation to each other, they are discussed, or mutually generative – a high level of interanimation (Scott et al., 2006). Alexander (ibid.) places more emphasis on the need for children to be mutually supportive without fear of expressing 'wrong answers' while Mortimer and Scott (2003) acknowledge the importance of the affective dimension but place it beyond the scope of their framework.

Mortimer (1998) develops Wertsch's ideas of 'dialogicality and multivoicedness'. If text and 'reader' share the same codes, the interaction is closer to being univocal, and is the best means of conveying meanings adequately, but the dialogic function – to generate new meanings, is best achieved if there is a difference in the meanings understood by each. This is important because it helps to explain how different forms of interaction may have different purposes and effects and begin to develop a model for teachers to select one communicative mode over another. Mortimer suggests that the movement from multi- to univocal characterises construction of meaning in science classrooms.

3.5 Summary of Literature Review Chapter

The term 'interactive whole class teaching' emerged from a concern, largely based in international comparative research, that talk in whole class teaching is an undervalued teaching strategy in primary classrooms in the UK. There is evidence that whole class teaching is dominated by teacher talk and triadic dialogue, that is not sufficiently challenged by notions of 'interactive whole class teaching' which focus on pupil engagement through interactive pace and broad participation. The alternative conceptions of 'dialogic' talk and teaching offer a means of considering the quality of children's role in the dialogue and this is underpinned by a sociocultural view of learning in which the social plane of the class is conceived of as an 'intermental development zone' under continual construction by both children and teacher. While retaining the need for individual meaning-making, learning is seen as the appropriation of the jointly constructed social plane, offering a means of understanding the role of 'interactive whole class teaching'.

I have raised the issue of how science teaching has been dominated by social constructivist accounts of learning, but their emphasis on learning through the processes of science is questioned by some of those taking a sociocultural perspective. In the next chapter I will examine the role of whole class teaching in models of teaching science at Key Stage 2 that are evident in the literature and consider these in relation to social constructivist and sociocultural perspectives.

Chapter 4: What is the Role of Whole Class Teaching in Models of Teaching Primary Science in the Literature?

4.1 Introduction to Chapter Four

In Chapter Two I raised the suggestion that from the perspective of the teacher there is little guidance in the models of teaching science on how to use whole class teaching, and that, as Galton et al. (1999) suggested, whole class teaching seemed to go against the dominant constructivist models. Chapter Three developed a discussion of the role of talk in learning science from a social-constructivist perspective in which talk is seen as part of the external evidence for individual meaning-making and then a more sociocultural perspective which focuses on creating an intermental development zone through dialogic talk. In this chapter, I will use the insights of the literature review to analyse models of teaching science that are available to teachers and address my sub-research question:

> What is the role of 'interactive whole class teaching' in models of teaching science in the literature?

This chapter also informs the development of the analytic framework discussed in Chapter 5 and contextualises the case studies by providing the reader with a overview of the particular models of teaching science that situated the cases. The data for the case studies was collected in 2004 so literature prior to that date may have influenced the approach of the teachers. Literature after that date is relevant in terms of how the cases can continue to illuminate and develop the shifting models of practice.

4.2 Defining Models of Teaching

The concept of a 'model of teaching science' is important to this thesis in that it seeks to address the teacher's question - 'How should I go about teaching science to my class?'. I am not conceiving model here as 'perfect', but more as a 'template', a general approach to be modified in the course of action, that is underpinned by theory and supported by research. I am taking the term 'models of teaching' to mean ideas about 'how teachers should teach' and the underlying theories, values and beliefs.

Alexander (1995) provides a means of analysing conceptions of 'good practice' in terms of the underpinning values and beliefs, ideas based on empirical studies, the influence of politics and also of pragmatism, acknowledging the complex interactions between them. This is useful in trying to define what a model of teaching science would consist of and, to be consistent with exploring a sociocultural perspective, I will locate the models within the government policies and pragmatic constraints of the historical period. Whilst a full account of the history of primary science education is not required here, I will situate my interpretation of the models of teaching that exist at the time of this study within a broader account of influences on primary education, with a focus on Key Stage 2.

I have taken the term 'model of teaching' to include:

- underpinning assumptions about the nature of science,
- views on the purposes of science education,
- views on the content of the curriculum
- underpinning assumptions about learning in science,
- views on how teaching can bring about the aims.

I will examine the extent to which these are explicit or implicit in the literature and how they lead to views on what should take place in science lessons:

- What the children should be doing
- What the teacher should be doing
- The lesson structure – timing, types of activities, organisation and grouping of children,
- The nature of interactions.

Together these approach a conception of pedagogy as defined by Alexander (2004a); 'the act of teaching and its attendant discourses' (p.7).

4.3 Scope of this Review

There is a distinction between 'espoused theory' and 'theory in use' (Argyris and Schon, 1974) and the research design reflects this. Here I will examine the 'espoused theory' not of individual teachers, but as is evident in the discourse of the primary science education community, with a range of differences of opinion and also areas of consensus. I am attaching particular importance to what I refer to as 'professional literature'; books written by academics and researchers for whom the audience is teachers and trainee teachers as well as each other. These books attempt to combine theory with 'know how' (Claxton, 1997) to provide guidance for the practice of teaching science. This excludes a review of all the resources available to teachers, such as commercial 'schemes' that might be purchased by a school. However, some 'schemes' have been included where they have been developed as a direct outcome of research, and/or where I judge the authors to be particularly influential in determining a view of good practice in science teaching.

Texts recommended by the Association for Science Education (ASE) have been identified as important since they are representative of national esteem. Since Bath Spa University is a significant provider of Continued Professional Development (CPD) in primary science in the South West of England and provided in-service training for the case study teachers, I have taken the texts used by my colleagues and myself as relevant for consideration.

I decided to look at publications not only in the immediate period before the case studies and the most recent available to date, but to take examples of earlier texts that were significant in shaping a view of primary science, in order to make sense of how Bakhtinian echoes of previous voices influenced the interpretation of later texts (section 3.3.3).

4.4 Models of Teaching Science

For the purposes of this review I have categorised the many influences upon primary science pedagogy into five main models, which I have labelled as follows:

- Piagetian constructivist
- Social constructivist – concept-led
- Social constructivist - activity-led
- Social constructivist – procedure-led
- Emerging sociocultural

These are listed in an approximate chronology of their emergence in the literature and do not form clearly distinct and discrete categories, but provide a useful means of grouping the themes that emerged. Rather than discuss each text in turn, I shall consider these groups of models, exploring the main themes and any differences within each.

4.4.1 Piagetian Constructivist

The book Primary Science: Taking the Plunge edited by Wynne Harlen (1985) provides a good overview of ideas at that time, including some differences between the authors. The notion of a Plowden influenced, child-centred approach is evident in many chapters, for example:

> From all around comes the invitation, from all around comes the challenge. The question is there, the answer lies hidden and the child has the key. (Elstgeest, 1985, p. 10)

An anti-'transmission' view of 'children as scientists' also comes through strongly in some chapters:

> We are inclined to think we ought to present the children with the truth and that is where the basic mistake is made. Scientific activity, and also that of the children, is directed towards detecting the truth as it reveals itself in the reality of the things we study. (Elstgeest, 1985, p. 14)

The above quote also reveals an epistemological belief that knowledge emerges from the material world, a belief which underpins the argument of many authors in the book that:

> Our reasons for emphasising the use of science process skills is not, then just for their own sake...this is the only way in which they will build up useful ideas or concepts. (Elstgeest, 1985, p. 40)

However, in a similar way to Leach and Scott's later conception of learning demand (Leach and Scott, 2002), Harlen and Jelly (1989) describe concepts as low or high order, with low order concepts being more concrete and high order concepts being more abstract and able to generalise to a wider range of situations. They argue that the concepts children should learn in primary schools should be restricted to those that can be generalised from a range of experiences (p. 55).

This is not, however, an entirely heuristic model. Although experience before generalisation is the key theme, the role of the teacher is not only to provide the experience, but also to draw attention to particular features and to support the making of generalisations. Later in the book, Elstgeest, Harlen and Symington, (1985) explore the value of a whole class discussion, suggesting it should be called a class conversation: 'a form of communication where the most generous sharing of ideas is made possible.' (p. 93). The teacher is seen as an equal in this, not as an authority, though they do have the role of 'chairing the discussion':

> this gives the teacher a chance to make unobtrusive corrections, to give further encouragement, to point out relationships, to highlight what is relevant and to obscure what is trivial.' (ibid. p. 93).

The sense of reciprocity is an element of dialogic talk (Alexander, 2004a; Mortimer and Scott, 2003) considered in the previous chapter. Drawing on the linguistic insights of Lemke (1990) and Mercer (2000), the suggested teacher interventions could be seen as rephrasing, selecting and marking.

Not all authors at that time shared the view that concepts should be restricted to those that could be derived from empirical evidence. Osborne (1985) focuses on conceptual change, placing an emphasis on children coming to understand scientific ideas as 'intelligible, plausible and useful' (p. 82) and suggests a role for whole class discussion; different ideas about the same thing can be brought together and the scientific ideas should be introduced as a possible option:

> Offer them a scientific view as one worth trying as well as others; don't insist that it is 'right', but let children explore its value for themselves. (ibid. p. 87)

Harlen (1985) discusses the 'process/content debate', concluding that both are important and generalised conceptual content could be specified. She also recommended, for children towards the end of primary school (now upper Key Stage 2), the use of more abstract concepts such as 'plants use the sun's energy to produce food they can use and store', that could not be attained through generalisation. The introduction of the National Curriculum (1990) for science in primary schools provided a model of progression in terms of 'levels of attainment' in both processes and content of science. This led to a version of science that separates the processes of science and other conceptual content, but all versions of the National Curriculum have included in some form the notion that teaching should bring them together (see for example, DfEE/QCA (1999, p. 83).

The constructivist models argued that the role of teachers was to provide experiences and support children in developing the process skills that would enable them to make generalisations from concrete experiences. Discussion was seen as having an important role in the development of process skills, such as in focussing attention on relevant variables, and in comparing results and drawing conclusions. Concepts that could not be attained in this way were seen by most authors as inappropriate aims for learning in the primary school.

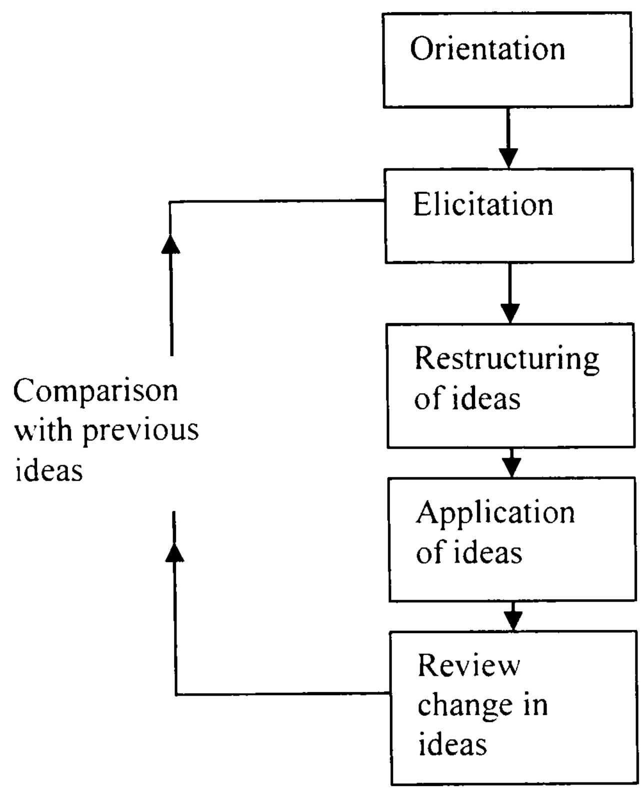
4.4.2 Social Constructivist: Concept-led

In common with the Piagetian constructivist models, the centrality of individual children's ideas as the starting point for conceptual change is the dominant feature of social constructivist concept-led models. Influenced by Bruner and Vygotsky, the Piagetian idea that children could not grasp more abstract constructs until the age of 11 that underpinned the constructivist models had been challenged and the role of the teacher in helping children to understand these ideas shifted accordingly.

Models of teaching primary science were influenced by development of a defined approach to teaching based on social constructivist theories of learning that was an outcome of the secondary Children Learning in Science (CLIS) project (Scott, 1987) shown in Figure 4.1 and so this approach will be explained briefly.

In this sequence, after a period of orientation to engage interest, comes the *elicitation* of children's existing ideas, based on the belief that individuals construct their own meaning and that 'What is already in the learner's mind matters' (p. 7). The focus was on the development of children's conceptual understanding. In the proposed teaching sequence this is followed by *restructuring*, in which the role of the teacher is to provide experiences that may challenge existing ideas that are not in line with those of the scientific community.

Figure 4.1 A Generalised Model for a Constructivist Teaching Sequence



(Scott 1987, p. 9)

In this sequence, after a period of orientation to engage interest, comes the *elicitation* of children's existing ideas, based on the belief that individuals construct their own meaning and that 'What is already in the learner's mind matters' (p. 7). The focus was on the development of children's conceptual understanding. In the proposed teaching sequence this is followed by *restructuring*, in which the role of the teacher is to provide experiences that may challenge existing ideas that are not in line with those of the scientific community.

One means of restructuring suggested by CLIS may be pupils listening to the ideas of other pupils and so having their own ideas challenged. Scott (ibid) also suggests that a teacher demonstration may be used to promote cognitive conflict. In this social-constructivist view, interaction with others is seen as similar with interaction with objects – as a source of cognitive conflict in the external environment. Pupils testing their own ideas through practical investigations is seen as one of a range of experiences that may support restructuring, but the model does not focus on this.

After restructuring comes *application* in which children are to be provided opportunities to use their newly constructed ideas by applying them in different situations, perhaps in problem solving tasks. The final stage is *review* in which the children are invited to compare their new ideas with their initial ones.

The CLIS project led on to the similar primary Science Processes and Concept Exploration (SPACE) project (e.g. Russell and Watt, 1990; Osborne et al.,1991; Osborne et al., 1992) and resulting Nuffield Primary Science SPACE books for teachers (e.g. Bell, 1996) and the teaching sequence was also directly developed by Harlen (1992, 1993) and Ollerenshaw and Ritchie (1993) into differing models of teaching that are considered below.

Harlen makes explicit reference to Bruner and Vygotsky in her discussion of the importance of talk in children's learning. In a change from her previous work she recommends the introduction of scientific ideas, but maintains the importance of empirical evidence for these by recommending that this should be as:

> ...alternatives worth considering *and* that these are tested in terms of the evidence available so that everyone can judge the extent to which they work in practice.
>
> (Harlen, 1993, pp. 118-9)

She goes on to suggest that:

> As children progress they can be encouraged to consider alternatives, by argument and information from secondary sources and not only from what they experience directly.
>
> (ibid., p. 119)

This view of progression is important in defining the curriculum content of the later years of primary school which, in Vygotskian terms, makes a transition between 'everyday' concepts and 'scientific' concepts (Vygotsky, 1987). In a more recent publication, Harlen (2006) recommends different activities and expectations for children in middle (8-10 years) and later (10-12 years) primary years, still grounded in a Piagetian view of development when she writes that for 10-12 year olds:

> The things that can be manipulated mentally are restricted to those that have a concrete reality for the child. (ibid. p. 57)

This raises questions about how and whether decisions about age-appropriate science content can be made from a Vygotskian perspective that also takes into account the realities of maturation.

Teacher books in The Nuffield Primary Science SPACE series provide suggestions firstly for 'Finding Out Children's Ideas', and then for 'Developing Children's Ideas'. They advocate planning activities for individual children based on their initial ideas and an implicit assumption is that different children may be undertaking different activities because teachers need to respond to their personal starting points. The Nuffield/SPACE books suggest whole class discussion as one of a range of strategies for finding out children's ideas, suggesting that teachers should choose their remarks so that the children know the discussion is genuinely open and feel secure in expressing their ideas, have sufficient time to express ideas, value the ideas of others and are prepared to offer and receive comments in a constructive way. This characterisation of discussion could be seen as dialogic in its emphasis on reciprocity, genuine open ended questions and supportive environment. What it lacks in terms of Alexander's (2004a) definition of dialogic talk is an explicit expression of being cumulative.

The Nuffield/SPACE materials maintain a privileged place for experience with objects but also see social interactions as an important means of changing children's ideas:

> While direct experience is the touchstone for learning in the primary school, it is also true that many ideas are acquired, modified and developed during social interactions.
>
> (Bell, 1996, p. 52).

Throughout the Nuffield/SPACE teachers' books, questions that teachers could ask children to elicit and develop their ideas are shown in enlarged type, indicating their significance. They comment that whole class discussions can be useful for sharing ideas but they do not always give all children a chance to speak.

Ollerenshaw and Ritchie (1993, 1997) developed the CLIS teaching sequence for primary schools, drawing parallels with stages of the sequence and processes of science so that Orientation and Elicitation, are related to 'Exploration' and Intervention and Review are linked to 'Investigation'. They focus on the individual:

> The focal point of the whole learning environment is each, separate, individual, child – albeit in group contexts.
>
> (Ollerenshaw and Ritchie, 1997, p. 6)

However, while discussing case studies of groups of children working with a teacher, they examine the ways in which teacher interventions and interactions support learning through the processes of science. They make some specific suggestions about where the whole class could be an appropriate choice of organisation. They suggest it could be used in the Orientation phase, through whole class visits, visitors, story or role play and in Elicitation by having a whole class record of ideas as a floor book or having class discussions, but they prefer small groups with the teacher joining as an equal partner. In the Restructuring and Review phases, they see teachers leading a discussion of ideas as important and note that it can take place with individuals, groups or whole class. The importance of this discussion is explained by citing Barnes who says that learning from group activities:

> ...may never progress beyond manual skills accompanied by slippery intuitions unless the learners themselves have an opportunity to go back over such experiences and represent them to themselves. There seems every reason for group practical work, in science for example, normally to be followed by discussion of the implications of what has been done and observed, since without this what has been half understood may soon slip away. (Barnes, 1976, pp. 30-1)

The last stage of Ollerenshaw and Ritchie's sequence is Application as in the CLIS teaching sequence. By drawing on Tharp and Gallimore's (1988) interpretation of Vygotsky's work - that teaching is assisted performance - they present the role of the teacher as starting out as unobtrusive, while children's ideas are being explored, becoming more interventionist, to restructure these ideas, before becoming unobtrusive again and, finally, acting as a consultant for children to approach if they choose as they apply these ideas. This sense of progressive 'handover' (Bruner, 1983) is more explicit in Ollerenshaw and Ritchie than in the other publications. It can be related to the cycles of 'opening up' and 'closing down' classroom talk in Scott and Ametller's analysis (Scott and Ametller, 2007).

Harlen (2000) moves away from her earlier Piagetian constructivist stance towards a social constructivist emphasis as underpinning the view of learning:

> ...through becoming aware of others' ideas and sharing their own, children negotiate meaning for their experiences and the words used to communicate them....It is central to learning in science that children have access to the views of others and to the scientific view, but at the same time retain ownership of their developing understanding. (p. 24).

Harlen (2000) advocates that children should be given the freedom of discussion in small groups without the teacher to formulate ideas before reporting them back to the whole class. She provides no explicit theoretical underpinning for her recommendation that class discussion should take place at the beginning and end and sometimes during the lesson. She suggests that the function of the discussion at the beginning is to motivate, to make sure children know what they have to do and what is expected of them, and that 'at intervals in the work children should meet together as a class to listen to reports of each other's progress and share ideas' (p. 69). She recommends that teachers should 'organise small and whole-class discussion of what has been learned both from the findings and from the procedures used' (p. 85). She argues that this provides the opportunity for children to reflect on the procedures and learn from any mistakes and that holding a whole class discussion at the end 'should be the normal practice' (p. 115) drawing on the same quote from Barnes (1976) as did Ollerenshaw and Ritchie to support this.

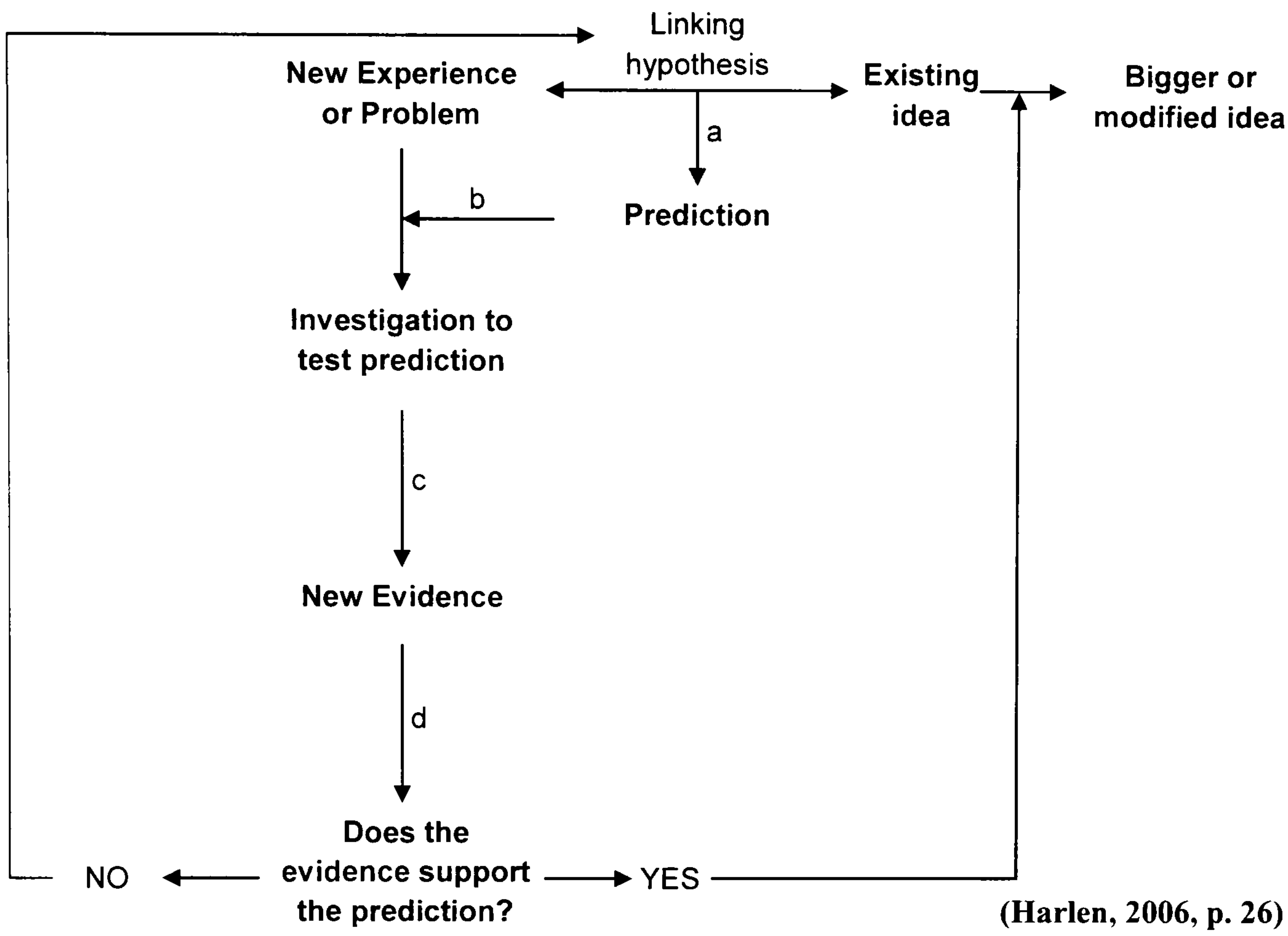
Harlen (2000) notes that a 'supportive classroom climate is needed for productive discussion. Ollerenshaw and Ritchie (1997) take this social consideration further towards a cultural view and, for example, discuss how mutual lack of understanding between teacher and child can lead to barriers to learning. They cite Wells (1996), saying that 'the desire to communicate promotes in children the art of formulating thoughts and feelings which itself becomes the strongest spur to trying actively to understand them' (Ollerenshaw and Ritchie, 1997, p. 19), pre-empting what has since been defined as a sociocultural perspective.

In the social constructivist-based models described above, the role of the teacher in discussions is being part of a group rather than dominating it. Harlen (2000) recommends listening and encouraging, asking children to explain their thinking, valuing children's ideas, and avoiding giving the impression that only one right answer is acceptable and should be guessed, ideas which are also present in Ollerenshaw and Ritchie (1997). These recommendations form a version of classroom interaction in line with the 'deep features' of interactive teaching listed by Moyles et al. (2003), (section 3.2). The authors do not distinguish between the kind of teacher talk to be used in whole class discussions and that to be used in small group discussions or with individuals.

Case studies in the professional literature that present extracts of transcripts of discussions between teachers and children to exemplify dialogues that support learning (for example, Harlen, 2000; Ollerenshaw and Ritchie, 1997), are mostly taken from small group interactions rather than whole class discussions. The implication seems to be that small groups are the preferred location for this kind of interaction. However, Harlen (2000) also discusses two case studies, which involve the discussion of ideas as a whole class. In these the sharing of ideas was emphasised, with reference to Barnes (1978) and 'co-constructing' knowledge. Barnes (1976) views what he terms 'exploratory talk' in Piagetian terms as 'the means by which assimilation and accommodation of new knowledge to the old is carried out.' (p. 39). In this model, the emphasis remains on what happens within the mind of the individual, rather than considering how what happens between minds contributes to this as emphasised by sociocultural approaches.

It is only in Harlen (2000) that she refers to the CLIS based teaching sequence as a model of teaching and instead she develops a model for children setting up and carrying out investigations to support conceptual change. This has developed over time and the most recent available (Harlen, 2006) is presented in Figure 4.2. In this model the Piagetian notions of accommodation and assimilation are evident in the way that new evidence is seen as confirming or rejecting a hypothesis/child's idea. Also in the category of professional literature Ward et al. (2005) follow Harlen in focussing on the role of process skills in developing children's conceptual understanding. The concept of child as scientist is still strong here in spite of critiques such as that of Driver et al. (1994).

Figure 4.2 The Last Stage in Harlen's 'Model for the Development of Understanding'



(Harlen, 2006, p. 26)

4.4.3 Social Constructivist: Activity-led

With the exception of identifying children's abilities to contribute to both whole class and small group discussions as a key skill, the National Curriculum (DfEE, 1999a) does not make any reference to whole class teaching. It avoids any discussion of how to teach, leaving a role for professional literature in doing that. The introduction of the NNS and NLS changed this, providing explicit models of practice in terms of lesson structure, groupings and even guidance on pedagogical techniques and details of the kinds of interactions that should take place. This was non-statutory, but Ofsted expected to see it and so there was considerable pressure on schools to adopt the strategies (Cambridge Primary Review, 2009a). There was no equivalent strategy for science, there was, however, a non-statutory 'scheme of work' for science that was published by the Qualifications and Curriculum Authority (DfEE/QCA, 1998).

The schemes of work take the Programmes of Study from the National Curriculum to provide a map of topics, or 'Units of work', for each year group based on the conceptual content, and integrate this with a view of progression in scientific enquiry so that each unit of work also has a focus on aspects of the processes of scientific enquiry. A unit of work consists of a sequence of activities. Specific vocabulary associated with the unit is listed and, occasionally, there is also a reference to the kind of talk that children would have the opportunity to use, for example, 'expressions of reasons using because', 'expressions for making and justifying predictions, generalising and summarising' (DfEE/QCA, 1998, Unit 3B), each of which are associated with an aim and learning outcomes.

An interesting example to consider is an activity from Unit 5C Gases around us. It states that through this activity children should learn:

- that powders and sponges are solid materials with air in the 'gaps' in between particles
- to make careful observations of materials and to explain these using scientific knowledge and understanding

(DfEE/QCA, 1998, *Unit 5C Gases around us, p. 1)*

This model states defined conceptual and procedural aims. These are linked by the idea that observations can be explained using scientific concepts. Activities, such as squeezing a sponge under water to make bubbles are recommended. The wording of the associated learning outcomes: that children should be able to 'describe how the bubbles appear' and 'identify the bubbles as coming from the spaces between the particles and with help suggest they are air' makes a clear link between the empirical experience and the explanation, seeming to suggest that the explanation should be developed somehow by the teacher through discussion. There is no guidance here, however, on the form the 'help' should take.

Similarly, Unit 3B recommends that children should grow plants in different conditions and that teachers should:

- Talk with children about what the results show
- Extend their knowledge from *e.g. the roots need more room*, to *e.g. the roots need more room so they can take in more water*
- Help children to decide what evidence to collect
- Ask what else beside water and light is necessary for growth. If necessary prompt them to think about warmth.

(DfEE/QCA, 1998, *Unit 3B Helping plants to grow well, p. 1)*

This emphasis on the development of ideas through a combination of practical experiences and talk is very much in line with a social constructivist approach. There seems to be an attempt to avoid any language that could be seen as being within a 'transmission' view of teaching, and reluctance to position the teacher as a source of knowledge. Words like 'help' and phrases like 'extend their knowledge' imply a teacher intervention, but terms such as 'tell' are not present. There are occasional recommendations for narrowly focussed interventions:

> Ask children to suggest why using lots of seeds rather than one or two might be better.
>
> (DfEE/QCA, 1998, *UNIT 3B Helping plants to grow well, p.1)*

But these are rare. We can imagine how a teacher using this model would find themselves engaged in the 'dishonest' dialogues described by Driver (1983) as they attempt to reach specified learning outcomes while avoiding any sense of 'transmission'.

Unlike in the 'concept-led' models of social constructivist teaching, there is no link between the elicitation of the ideas of individual children and the planned activities. In the QCA model, the assumption is that the entire class will undertake the same or similar activities and so the implicit message is that much of the discussion will occur in whole class contexts.

The commercial scheme *New Star Science,* published by Ginn, will be discussed here as it is an example of an activity-based model that influenced the teachers in the case studies and also because its authors are leading figures in the ASE. In this scheme, a sequence of activities is suggested and these are linked with the aims and content of units in the QCA scheme of work. These are often practical, but frequently advocate teaching abstracted procedural knowledge through discussion activities. They provide specific questions that the teacher could pose to develop either conceptual or procedural understanding, for example, 'Do you think a solid disappears in the water when it dissolves?' and 'What can Gina [a fictional character] say from her results?' (Feasey et al., 2001, p. 6 and p. 12 respectively). The *Teachers Guide*, (Feasey et al., 2000) explains that these can be used for individual, group or whole class interactions and stresses the need for teachers to take a flexible approach to their use. This scheme has the advantage of providing domain-specific questions that link what children might experience with common alternative ideas and scientific knowledge, but again avoids any notion that the teacher may need to introduce the scientific view in the resulting discussion.

4.4.4 Social Constructivist: Procedure-led

Anne Goldsworthy has been a leading author in a number of different publications with a common theme of atomising different aspects of the process of scientific enquiry, and what might be involved when children carry out investigations. In the ASE Guide to Primary Science, Goldsworthy suggests improvements that can be made to investigative work including:

- Identify which decisions will be taken by the teacher and which by the pupils. Do not expect pupils to take all planning decisions in every investigation.
- Teach pupils the skills and procedures of investigations, clarify how pupils can learn scientific procedures through doing an investigation and make them aware that this is the purpose of the lesson. (Goldsworthy, 1998, p. 69)

Goldsworthy's (1999) recommendation that specific skills be taught to children prior to carrying out investigations that will need those skills is in opposition to the recommendation of Ollerenshaw and Ritchie (1997) that any teaching about the processes of science is best done in context as the need arises during investigations. An assumption of the Goldsworthy model is that the main focus of an investigation has usually already been decided by the teacher but children may, for example, identify variables or make decisions about measurements to be taken.

Models of practice encouraged in the NNS and NLS and promoted by Black and Wiliam (1998) in 'Assessment for Learning' emphasise making learning intentions explicit for children. This has been related to science teaching in Key Stages 2 and 3 by the AKSIS project (Goldsworthy et al., 1999, 2000, 2001) which identified that children were frequently unaware of the teacher's purpose when they were carrying out investigations, i.e. that they were to be learning process skills as well as whatever was the conceptual focus. They argued that if pupils had a clear understanding of what constituted 'good' process skills, they would be much better able to learn them and put them into practice. The AKSIS project published teaching materials that included, for example, whole class teaching activities on how to phrase a scientific generalisation.

Children are asked to compare statements about a set of data such as 'The higher your breathing rate, the greater your pulse rate' and 'Jenny had the most breaths and she also had the highest pulse rate' (Goldsworthy et al., 2000, p. 82). These comparisons present the language of science as part of the children's understanding of what constitutes 'good process skills'.

The resources (overhead transparencies) and detailed instructions for the teacher are in line with conceptions of 'interactive whole class teaching': the class is usually specified as the organisational group and strategies, such as children coming to the front of the class to point out features, move cards or draw on the transparencies, or short discussion in pairs before feeding back to the class, are similar to those recommended by the NNS and NLS.

The approach adopted in these publications was supported by developments in testing at the end of Key Stage 2 to include questions that focussed on aspects of the process of scientific enquiry. In this model, the separation and atomisation of processes and content is justified as it supports clear communication of success criteria to children but is also conveniently accessible to summative assessment and the associated external accountability which may drive a teacher's implementation of the model. I have found that teachers are pleased to have a simplified solution that relieves them of the demands of supporting around thirty children in planning and carrying out practical investigations (McMahon and Davies, 2003). In her review of teachers' and educationalists' views of the aims of science education, Eady concludes that:

> while science educationalists perceive this [the role of processes] in terms of capitalising on the interrelationship between skills and concepts, by eliciting and developing pupils' preconceived ideas and turning them into a form that can be tested, schools are more likely to focus mainly on developing process skills...and teaching scientific knowledge as a separate entity and specifically for tests. (Eady, 2008, p. 17)

In the procedure-led model process skills become a body of knowledge in their own right, a model in line with their presentation, in National Curriculum terms, as elements that can be assessed distinctly. This cannot be considered as a complete model in that it only addresses the process element, but in taking that element as a distinct body of knowledge to be taught to the class as a whole it is different from the concept-led models and follow the recommendation of Gott et al. (1995) that procedural knowledge should be seen as an end in itself.

4.4.4.1 Summary of Social Constructivist Models

In the concept-led models examined here, (Harlen, 2000; Ollerenshaw and Ritchie, 1997), 'elicitation' of children's existing ideas is understood as being in line with developing the hypothesis of a scientist. Although Ollerenshaw and Ritchie (1997) stress that the time scales between elicitation and intervention can vary, with elicitation sometimes informing the next verbal exchange, the dominant approach has been a focus on the longer time scales and how teachers can use elicitation to inform their planning of activities. The activity-led models tend to see it as a means of assessing children's progress towards predetermined goals.

For many authors who relate their models of teaching to social constructivist theories of learning (Harlen, 2000; Harlen and Qualter, 2004; Ollerenshaw and Ritchie, 1997; Howe et al., 2005), knowledge about the nature of science will be an outcome of children undertaking enquiries into questions of their own, or being encouraged to test their own ideas. There is broad agreement that acting like scientists can help children to understand the relationship between ideas and evidence. The procedure-led models recommend explicit teaching to help children understand these relationships rather than a more contextualised approach.

Harlen (1993, 2000) and Ollerenshaw and Ritchie (1997) emphasise the centrality of children testing their own ideas, with support from the teacher in planning, managing and making sense of their investigations. This is not a naive empirical view of the role of practical work (Millar, 1998), but the models in the professional literature have not yet produced clearly accessible guidance for the teacher on how to talk about the relationship between children's ideas, the outcomes of their investigative work and scientific knowledge. The activity-led models place more emphasis on practical work and enquiry that is teacher-led, and use a repertoire of investigative activities that are believed to support learning of particular concepts.

4.4.5 Emerging Sociocultural

Harlen and Qualter (2004) recognise some challenges to the social constructivist model. Chapter 7, entitled 'A Framework for Learning in Science' focuses on the role of scientific processes in conceptual learning as in Harlen's earlier publications. However, much later in Chapter 19, 'The role and organisation of practical activities', literature is cited that challenges this: Miller and Luben (1996) found that children did not change their ideas through practical work and recommended it should be used mainly to develop procedural understanding. Cited alongside this are Murphy et al. (2000) who reported that practitioners who promoted interaction were the most successful and that classroom talk was central to learning.

Going still further in this direction of sociocultural approaches, Harlen (2006) reemphasises the centrality of scientific processes in children's learning of science, but also includes a section on the importance of 'dialogic talk' and notes that the emergence of what she terms 'sociocultural constructivism' places greater emphasis than before on communication through language, on the influences of cultural factors and on linking to a 'community of learners', but this is not integrated into her model In using the term 'sociocultural constructivism', Harlen locates sociocultural approaches within constructivism rather than suggesting this is a post-constructivist paradigm as proposed by Mortimer and Scott (2003).

Harlen acknowledges that:

> It is possible that by following the ideas of Piaget, mediated by educators who have translated his views of learning into classroom experiences, there has been an overemphasis in primary classrooms on activity at the expense of discussion....Children need not only to have direct experience but to develop their understanding of it through negotiation – exchanging views with others. It is important, therefore, to plan time for discussion into practical work. It also helps to structure that time so that ideas are shared and used to take the understanding of all beyond what each could achieve individually.
>
> (Harlen, 2006, p. 163)

The last sentence is of particular significance to a consideration of whole class teaching and suggests a possible role for it in structuring lessons and time that will be considered through the case studies.

There remains a sense of separation between hands-on experiences with objects and the role of interaction with other people, as is evident in these sentences;

> However, we may still think of the individual as taking from this shared understanding what helps them make sense of their own experience. Thus we consider learning being developed through interaction with objects as well as people. (ibid., p. 8)

Whereas Kress et al. (2001) argue that when using any objects within a science lesson, their meaning and the way in which children relate to them is always mediated by the culture through the teacher and other children.

The model proposed by Howe et al. (2005) is based on the authors' version of the CLIS teaching sequence and influenced by Ollerenshaw and Ritchie and so is rooted in social constructivism. They maintain the central importance of children using the processes of science to develop their ideas, but alongside this introduce a repertoire of other strategies, such as explanation through analogy. They identify different procedural knowledge for different domains of science and teaching strategies for particular concepts within those domains. The emergence of sociocultural approaches in research into science education is noted by the authors but not well integrated into their approach. They make some comments about the role of whole class teaching (based on early emergent ideas from this thesis): that sharing ideas supports a culture of collaboration, that children can learn from each other's ideas and that teachers can signal particularly significant ideas. The second edition, (Howe et al., 2009) draws on research for this thesis to begin to develop ideas about the implications of a sociocultural approach for their interpretation of the CLIS teaching sequence.

There is further evidence that more recent publications are shifting towards a greater consideration of the role of talk in teaching science from a sociocultural perspective. The ASE Guide to Primary Science Education, edited by Wynne Harlen (2006), which provides a good overview of contemporary dominant ideas in the primary science community, contains a chapter written by Phil Scott and Hilary Asoko in which they explain, for a primary science audience, the concept of communicative approach developed by Scott with Mortimer (2003) and Mercer's ideas about exploratory talk (Mercer, 1995) as explained in section 3.4. This is underpinned by a sociocultural view of learning and the centrality of talk in meaning-making. In the same book, Dabell et al. (2006), note the importance of the role of discussion between children and others:

> ...children need to discuss ideas, build on each other's expertise, use each other as sounding boards and work creatively in a community of learners. They need to interact with others to plan, explore and discuss and direct their activities; in doing so they try out and modify their ideas. (Dabell et al., 2006, p. 140)

This explicit reference to a community of learners relates to work such as that of Wells (1999) locating it within a sociocultural approach.

In more recent publications, there is increasing emphasis on the role of talk, including whole class discussion, but still little guidance for teachers on how to use talk for different purposes. In particular, guidance needs to be developed for ways in which talk related to hands-on experience with objects can help children to learn established scientific concepts. Leach and Scott (2003) argue that practical work 'should be conducted in such a way that the main purpose is for students to interact with ideas, as much as the phenomena itself.' (p. 104) and see this as a challenge for developing the existing models of teaching science. There is also a need for guidance on how talk can be used in different classroom organisation contexts, including whole class teaching.

4.4.6 Summary of the Role of Interactive Whole Class Teaching in the Models

In the professional literature, the importance of talk and other interactions is mostly understood in social constructivist terms – how, through questioning, teachers can help children to use their existing ideas to make sense of the evidence. What it does not always acknowledge are the insights of linguistic analyses: that, through interactions, teachers are selecting, shaping and providing messages about which ideas are 'correct'; talking entities into existence (Ogborn et al., 1996); and developing semiotic relationships (Lemke, 1990). In their concern to avoid advocating 'transmission teaching', the role of the teacher in introducing the ideas of the scientific community and in providing children with access to these ideas, is presented in the models as subtle, perhaps too subtle for teachers to implement with confidence. Conceptions of dialogic teaching are beginning to influence these models, however, and Table 4.1 provides a summary of the guidance available on the role of whole class teaching and talk addressing my sub-research question:

> *What is the role of 'interactive whole class teaching' in models of teaching science in the literature?*

Table 4.1 Summary of the Role of Interactive Whole Class Teaching within each model

Model	**Role of Interactive Whole Class Teaching within each model**
Piagetian Constructivist	Focus on individual and small groups, not whole class. Explicit examples and advice on types of teacher questions to support process skills. Whole class discussions can be used to make children aware of the ideas of others and stimulate personal ideas for more exploration/testing. Limited by a view of the knowledge to be constructed – only that which can be generalised from direct experience

Model	**Role of Interactive Whole Class Teaching within each model**
Social constructivist **Concept-led**	**Harlen:** Whole class teaching is important at the start of lessons to: • Motivate • Clarify goals • Set up group work And at the end of lessons: • Children reporting to each other • Children questioning each other • Increasing emerging understanding It can also be used at intervals to share ideas and report progress. **Ollerenshaw and Ritchie:** Orientation - through whole class visits, visitors, story or role play. Elicitation - whole class record of children's ideas, class discussions, (small groups preferred). Restructuring - discussion of ideas as whole class, (individual and small group preferred.) Review - helping children to understand the significance of the results of investigation, refer to previous ideas. Regular whole class discussion is important at the beginning and end of activities.
Social constructivist **Activity-led**	Whole class activities are assumed. Discussion is recommended to review ideas and to discuss the outcomes of experiments in order to help children reach particular concepts
Social constructivist **Procedure-led**	Whole class organisation is assumed Interactive - verbally and physically - use of talk partners. Focus on establishing scientific conventions and language relating to process skills.
Emerging sociocultural	Dialogic talk is explicitly introduced, but not well integrated. More emphasis on collaborative learning resulting in better outcomes than individuals could achieve alone.

4.5 Summary of Chapter Four

Five models of teaching science have been identified and discussed with particular reference to 'interactive whole class teaching' at Key Stage 2:

- Piagetian Constructivist
- Social constructivist – conceptual-led
- Social constructivist – activity-led
- Social constructivist – procedural-led
- Emerging sociocultural

The dominant models of teaching science at Key Stage 2, which is espoused in academic literature and theory-driven publications for teachers, are underpinned by social constructivist principles and focuses the learning on individual children, privileging the role of hands-on experience and learning through exploration and experiment. Although these do not oversimplify the complexity of the connection between children carrying out scientific investigations and learning scientific ideas, and note the importance of talk, the ways in which the two are linked is not clear for teachers. A discussion is emerging about the potential for sociocultural perspectives and, in particular, for the role of dialogic talk that validates the focus of this thesis. Aspects of the models identified in this chapter inform the analytic framework developed in the methodology chapter.

Chapter 5: Methodology

5.1 Introduction

In Chapter Five, I will provide a rationale for the case study methodology adopted to address the research questions and discuss the associated ethical issues. I will then explain how conducting a pilot study led to refinements in the data collection and development of the analytic framework. The analytic framework will be explained and related to the research procedures, raising issues of validation and reliability, which will be considered.

5.2 Developing a Methodology Consistent with a Sociocultural Perspective

Making the ontological assumption that the reality of social interaction is constructed through the negotiated meanings of those involved, I began my search for an appropriate methodology with a consideration of ethnographic approaches. Woods (1996, pp. 37-41) takes symbolic interactionism as the theoretical framework for his consideration of an ethnographic view of educational research, noting the layered complexities of meaning that are developed by individuals and by individuals' responses to each other, and how these develop within a particular social framework. This interpretative approach offered a way of addressing my main research question:

> *How can an understanding of 'interactive whole class teaching' make a contribution to the development of models of science teaching at Key Stage Two?*

by exploring classroom talk in terms of what it meant to the participants and to me in my role as a lecturer in science education, and by emphasizing the need for trusting relationships and explaining the role of researcher reflexivity. However, although the ethnographic approach generates rich descriptions that provide a critical perspective, it doesn't seek to provide direct recommendations for practice whereas the approaches adopted by educational researchers using a sociocultural perspective aim to generate guidance for practitioners (Mercer, 2008), and this is in line with my aim; to develop models of science teaching at Key Stage 2. As discussed in chapter 3, sociocultural theory provides a way of understanding the relationship of knowledge construction between the individual and others in terms of interaction between intramental and intermental planes (Vygotsky, 1978; Wertsch, 1991; Mercer and Littleton, 2007), offering a way of making sense of 'interactive whole class teaching' in terms of the development of an intermental plane.

Bruner (1996, pp. 13-42) provides a set of nine tenets which seek to encapsulate the sociocultural perspective in relation to understanding education and these provided a useful frame of reference for developing my methodology and relating the research questions generated through the exploratory case study in chapter 2 more specifically to a sociocultural approach.

Perspectival Tenet - The meaning of any fact, proposition or encounter is relative to the perspective or frame of reference in which it is construed.

In chapter 2 I introduced the reader to my perspective and in chapter 4 I sought to understand 'interactive whole class teaching' in terms of existing perspectives in primary science education. The perspectival tenet raised questions about what different perspectives were relevant to my study and therefore which different participants I should seek to access. As it was the role of teachers I was most concerned with, their viewpoints would be central and I needed an approach that would access these. Thus the perspectival tenet underpins the question:

> What are teachers' understandings of how 'interactive whole class teaching' contributes to their teaching of science?

Constraints tenet - Meaning making is constrained by 'natural predispositions' shaped by the cultural 'tool kit of ways of thinking'

Individual predispositions of children were not a focus for my study; rather I wanted to explore the role of 'interactive whole class teaching' in developing a 'cultural tool kit' around scientific ways of thinking. My analysis would need to enable me to consider what versions of scientific thinking were informing this tool kit so it was important to access teacher's views of the nature of science.

Constructivist Tenet - Reality is constructed

My assumptions are that the participants in classroom interactions; the teacher and children are constructing reality both in terms of the versions of scientific knowledge and of their understanding of the social meanings of interactions. As a researcher located in the classroom I myself would be constructing reality in the field, and then reconstructing it through later analysis of data.

Interactional tenet - Passing on knowledge and skill involves a sub community in interaction. In many cultures one subcommunity often takes the form of a teacher and class of children with the specific purpose of bringing about learning.

The interactionist tenet is central to my research question as it is the nature of the interaction between teacher and children in passing on the knowledge and skills of science that is my main focus hence the research questions:

> What is the nature of interactions within whole class interactive teaching in science? and
>
> How does 'interactive whole class teaching' contribute to teaching about the nature of science and scientific processes and scientific knowledge and understanding?

I decided to use video as a method that would capture both the utterances and actions that make up the interactions.

Externalization tenet - Externalization enables the development of shared and negotiated ways of thinking in a group. It also enables reflection and metacognition.

I wanted to minimise the impact my presence as researcher had on the shared and negotiated ways of thinking in the class being studied so I could access the normal patterns of 'how we do things here'. Being a non-participant observer was a natural consequence of this. I also sought to externalise ways of thinking held by the teacher and this informed the research method: asking the teacher to reflect on video footage of 'interactive whole class teaching'.

My focus on 'models of teaching' is a form of externalization in which approaches considered to be of value within the science education community are theorised and made explicit. This relates to my question:

> To what extent are strategies within whole class interactive teaching evident in classrooms supported by the models of teaching science identified in the literature?

Instrumentalism tenet - Education has purposes and consequences for individuals and for cultures. These may be explicit through a curriculum, but are also outcomes of cultural values and expressions of power through an 'underground curriculum'.

In my analysis I wanted to recognise that both explicit and hidden purposes would be shaping events and so consider interactions during whole class teaching both in terms of the curriculum and deeper ideas about the purposes of science education and how children were being positioned in relation to science.

Institutional tenet - As institutions schools are distinctive, but may compete with other institutions to which children belong, such as family, or church, for power and privilege.

The culture of the school in which the classes to be studied were situated needed some consideration as part of the contextualisation. A consideration of the ways in which the identities of individual children related to the classroom context was beyond the scope of my study, but it was important to acknowledge that the children in a class did not form a homogenous group, and give some indication of the nature of the diversity as part of contextualising the class.

Tenet of identity and self-esteem - Humans recognise a self with agency and self evaluation and this leads to (culturally situated) versions of self-esteem.

Children's self-esteem could clearly have consequences on their engagement in whole class interaction and teacher's constructions of self-esteem have an impact on their approach (Alexander, 2000). While not placing it as a central focus I intended to be alert to self-esteem as an issue.

Narrative tenet - Humans seem to organise their experience as either logico-scientific thinking or as narrative. Narrative helps individuals to find their place within a culture.

Bruner argues that the role of narrative is undervalued, particularly in disciplines such as science. Scott (1997) has suggested a role for whole class teaching 'maintaining the scientific narrative' and I intended to pursue this sense of narrative over the sequence of lessons that form a unit of work. A case study methodology lends itself to this and also provides a narrative for readers to relate to in terms of their own experience (Stake, 1995). Kumpulainen and Wray (2002) consider that a challenge for sociocultural research is how to describe and analyse the dynamic nature of interactions and the meanings that are generated. Following Bakhtin, they suggest that rather than focussing on single utterances, chains of utterances and longer episodes should be analysed in order to understand the meanings developed through them over a period of time. By looking not at single lessons or even short sequences of lessons, but a whole linked sequence within a 'topic' I aimed to explore meanings developed over a longer time frame that was meaningful to the teaching context.

5.3 Reasons for Choosing Case Study Methodology

An analysis of models of teaching in the literature alone would not develop an understanding of how these models of teaching science were being applied in real classrooms with their conflicting demands and tensions, and how they are developed and modified by teachers as a result of their own ideas and the contexts in which they are working. I decided to adopt a case study methodology as this has the advantage of providing a rich account of the complexities of teaching. By developing case studies of teaching in action I hoped to develop knowledge of how 'interactive whole class teaching' is being used in science lessons and understand this in relation to both the teachers' interpretations and theoretical frameworks.

I decided to look at the existing practice of teachers based on the view that practice and theory are inextricably linked. Bruner (1996, p. 152) uses two terms to discuss this; firstly conventionalization – the notion that we do something, and then think about why later, and secondly: distribution – the view that intelligence doesn't exist in a single head, but in the particular environment of practices, of recorded knowledge and other people, so that intelligence is seen as located in a community. From this perspective seeking to understand how teachers use 'interactive whole class teaching', and then helping them to explain why they did what they did is a means of accessing their tacit knowledge (Claxton, 2002) in order to reflect on the relationship between theory and practice, but also in order to consider how make it available to other teachers (Bishop and Denley, 2007).

Similarly, Stake (1995) makes epistemological assumptions that there are different forms of knowledge; tacit knowledge and propositional knowledge. Tacit knowledge is the unconscious knowledge we have based on 'experiences and rumination' that we do not formulate explicitly, will have an have impact on the process of teaching, as teaching involves interactions that are too fast for considered reflection at every point. Propositional knowledge is 'interpersonally sharable' knowledge that can be made explicit. Case study provides an opportunity to access both the propositional and the tacit knowledge of teachers, and by relating these to the models of teaching identified in the literature I intend to develop that propositional knowledge.

5.3.1 What Kind of Case Study?

Yin (1993) categorised case studies as being exploratory, descriptive or explanatory. He saw the value of exploratory cases as being to generate research questions or as pilot studies. Yin presents descriptive cases studies as being of less value than explanatory case studies, and notes that it is the depth and detail that can lead to understandings of cause and effect type relationships that are not possible in larger scale studies. Taking a different position on the value of descriptive case study from Yin, Stake (1995) argues that the epistemological strength of case study lies in its ability to develop tacit knowledge, and 'naturalistic understanding'. In his account, Stake suggests that by providing a rich case study researchers are contributing to the experience base on which the reader will construct generalisations. Stake (1995) suggests that case studies are valuable as they communicate the findings to readers in a way that engages with their tacit knowledge and leads to learning on a deeper level. He sees this as strength of the narrative form and gives this as a prime reason for choosing case study methodology.

Taking a slightly different emphasis, Bassey (1999) argues that there are at least 3 categories of case study:

- Theory testing and theory seeking
- Storytelling and picture drawing
- Evaluative

and proposes that the first kind can lead to what he terms 'fuzzy generalisation' in the form 'it is sometimes true that...'. He argues that this form of generalisation is legitimate in that it is contextualised for readers by the evidence in the case study.

Some aspects of teacher practice are more open to propositional formulations than others, for example, the finding that teacher 'wait time' after asking a question is usually seconds (Rowe, 1972) is easy for teachers to contextualise and reflect on without the need for a case study. However, more complex linguistic analyses, of how subtle classroom messages are conveyed may require a fuller and more extended account such as a 'story telling' type of case study for them to be meaningfully translated, or appropriated into tacit knowledge. Because my aim is to develop models of teaching science, I wanted the outcomes of my research need be in a form that is ultimately accessible to teachers. Black (2000) stresses the importance of considering at the design stage of research how 'research knowledge can be transformed into 'classroom knowledge'.

However, by formalising aspects of tacit knowledge as 'propositional knowledge' we are able to examine it in different ways – to try and understand the context in which it has developed, the values and assumptions on which it is based, and to make judgments about it. This, of course, involves the researcher and reader's existing ideas, and so if this process is to be more than recycling and reconfirming existing ideas and their prejudices reflexivity is required. It is the job of the researcher then to bring this reflexivity to the telling of the story of the case, and through this, to support the reader in considering different interpretations and understandings of taken for granted actions and understandings of the classroom.

In order to address my research question, and be in a position to make recommendations about practice I needed to take a theory seeking approach, however, in order for those recommendations to be understood and to support reader relatability (Bassey, 1981, p. 85)

I wanted to maintain the strengths of a 'story telling' case study and aimed to make the most of both of these aspects of case study.

5.3.2 Reasons for Multiple Case Studies

A sociocultural perspective leads to an emphasis on research that in some way links the analysis of action to the specific, cultural, historical or institutional settings. However, Wertsch makes the point that;

> And even in the case of sociocultural studies that involve no explicit comparison, the comparative method lurks just beneath the surface, since the notion of *situatedness* implies a contrast with other possibilities. (Wertsch, 1991 p. 19)

Yin (2003) considers that a single case study is appropriate when it is a unique or extreme case that could illuminate particular aspects. This kind of case is not available for my research question. He also sees some value in the use of a single case that can be claimed as 'typical'. Yin (2003) advocates the use of multiple case studies to increase the 'external validity' – the extent to which theories can be generalised. Yin suggests that 'replication logic' means that findings replicated in several cases would be more robust that those based on a single case study. However he argues that the choice of case is important – rather than seeing the cases as a large sample in a statistical way, cases should be chosen because they predict the same or contrasting results from previous cases and used to test propositions and in this way support the development of theory. Hammersley (1990) similarly considers that the selection of cases is very important, in order to provide some control of extraneous variables. Another advantage of multiple cases is that it enables comparisons between the cases that make 'taken for granted' features of a case more apparent and supports reflexivity.

5.3.3 Selection of Cases

I have developed four case studies, each making a different contribution to the research (summarised in Table 5.1). I conducted an exploratory study with my own Year 5 class which raised questions and explained my start points as discussed in chapter 2. I conducted a pilot study with a Year 4 class which enabled me to rehearse and refine aspects of the data collection and analysis. I then developed two case studies in Year 6 and Year 3.

The cases I chose could be said to be typical in that there are no outstanding social advantages or disadvantages and children's achievement is broadly consistent with national norms. This has the disadvantage of making the cases less varied with reduced opportunity for teachers in a range of situations to relate to them. The pilot study was chosen on the basis of convenience.

However, the teachers were not 'typical' in that they had all developed primary science teaching as an area of expertise; all were science subject leaders in their schools and, in cases 1 and 2, had undertaken a professional development course that I had led. This had several advantages for the research: the teachers were familiar with the existing models of 'good practice' in science teaching espoused on the course, and were intending to explore how these models could be realised in the classroom. It also meant that the teachers were better placed to engage in reflective dialogues about teaching science. The teachers were also relatively confident with their subject knowledge in science, an aspect of science teaching that can prove limiting (Harlen and Holroyd, 1997). This confidence may have contributed to their willingness to allow themselves to be videoed and had a positive contribution to the research ethics in that it may have enabled them to have more control over the discussions with me. As the teachers felt themselves to have some expertise in this area, they were both interested in the outcomes of the research for its own sake, and hoped that the process of the research would be an opportunity for professional development within their area of expertise and so were willing to take part. However, my previous relationship with them as course leader also meant that these teachers may be more concerned with 'doing it right'. This offered reflexive potential for examining tensions between what they imagine 'doing it right' to be and what they felt worked in practice.

Having different year groups within Key Stage 2 enables this dimension to be considered and having different topics being taught also provided another difference to explore, but I left the choice of topic to the teacher as it seemed more important that they were teaching a subject area they felt confident with.

Table 5.1 Summary of Cases

Case	**date**	**Year Group**	**Content area**	**Special features**
Exploratory	June1999	5 (9-10 years	Plants	My own class, exploratory study
Pilot	Jan-June 2001	4 (8-9 years)	Forces, Habitats	Pilot study
CS1	January-March 2004	6 (10-11 years)	Materials Dissolving	Leading Science Teacher, with Science degree,
CS2	April-May 2004	3 (7-8 years)	Plants	Advanced Skills Teacher, Arts degree

5.3.4 Case Boundaries

A case can be considered a being a 'bounded system' (Stake, 1995). I defined the boundary of each case as being one 'class' – one teacher and the group of children usually taught by that teacher, and focussed only on the science lessons. I defined the content as being all science lessons taught within a given 'topic' which effectively also set the case within a particular time frame of 6-8 weeks.

In line with my focus on 'interactive whole class teaching' I also decided to gather detailed data only on episodes of whole class teaching and record only brief information on episodes of non-whole class teaching in relation to these.

5.4 Ethical Issues

The biggest ethical challenges have been concerned with the class teachers in relation to the research. The issues are not only of how to conduct the research in an ethical way, but of the implications my relationship with the teachers has for my interpretations. There were tensions between maintaining 'respect for persons' and respect for truth' Bassey (1999). Bassey identifies four aspects to consider in terms of respect for persons:

1. permission to conduct research
2. arrangements for transferring ownership to the researcher
3. identifying or concealing identify
4. permissions to publish case report

In arranging access to the teachers I sought to ensure that they had a good understanding of what the research process would involve and clarified issues of anonymity and ownership. This was summarised in the letter of permission that was signed by both the teacher and the headteacher. Parental permission was sought by the school and parents signed a letter of consent that the schools held. I made it clear that the teachers could withdraw from the research at any time, or ask me to leave the room during a lesson. I never asked to leave the room, though in Case Study 2 the teacher asked me to switch off the camera for a period of time when a child from a different class was brought to her as part of a disciplinary procedure.

A particular ethical concern was ownership, as I initiated the research and would be writing about it, yet it depends on the work and personal reflection of teachers. I decided to ensure that teachers' contributions are valued and made explicit in publications. All children, teachers and schools will be anonomised in reports. Where there was a tension between acknowledgement and protecting anonymity, I planned to discuss this issue with the teachers and reach an agreement. Electronic and physical data have been stored separately from any identifying material. These decisions were in line with The British Educational Research Association (BERA) ethical guidance (BERA, 2004).

Oakley (1981) argues that the quality of data is better if person feels they are participating in a real conversation and treated as having equal status with 'interviewer'. She argues that morally it is not acceptable for feminist researchers to objectify the experience of other women and the creation of this personal relationship for the purposes of research can be seen as exploitative. Through this research the teachers' practice is exposed; the use of video to record teaching increases their vulnerability, but their perspectives and skills are also valued. However I had concerns about exploiting trusting relationships developed between researcher and the 'subject' (Oakley, 1981, Hammersely, 1999) and I discussed with the teachers that having too personal a relationship might make them feel exposed later, and that I would, for example, avoid asking them personal questions not directly related to the research.

Woods (1996) suggested that a way forward to ethical research with teachers is to focus on 'good practice' and I decided to choose video clips for teacher reflection that were often examples of what I judged to be successful teaching episodes. This was helpful to my purpose of identifying successful teaching in order to develop new guidance, but, to do this entirely would have skewed the case and reduced validity. To have focussed overly on the positive aspects of the teaching would have created a false impression about the stance I would be taking in my writing, and could lead to the teachers feeling betrayed later, so I also decided to include episodes that illustrated any concerns I had about the teaching. This elicited some useful data on the constraints teachers felt they were working within, and their ways of balancing the different tensions in the classroom.

It was my intention that the teachers involved in the research should gain personally and professionally from their experience rather than be exploited as objects of study. Involving teachers in reflective dialogues would both increase the validity of the data and analysis and provide those teachers with an opportunity for professional development.

5.5 Research Methods Adopted for the Pilot Study

The pilot study raised a number of issues for the development of the methodology. In this section I will explain the approach I adopted in the pilot study briefly, acknowledging that it had weaknesses, before going onto explain how the issues that emerged form identifying these weaknesses informed and strengthened the approach adopted in developing the main case studies explained in the rest of this chapter.

I decided not to follow the approach to researching classroom interactions based on systematic observation (Galton et al., 1980, 1999; Moyles et al., 2003). This approach enabled researchers to attempt to make comparisons across a wide range of cases and across time, but systematic observation imposes a predefined set of possible interpretations on the data that does not take into account how the meanings of apparently similar interactions may be different in a different time and context (Edwards and Mercer, 1987; Hammersely and Atkinson, 1983) and is not consistent with a sociocultural approach which understands the situatedness of utterances. As I wished to understand how 'interactive whole class teaching' was being used over a sequence of lessons this consideration was important. The approach I developed for the pilot study was to record utterances and the associated action during whole class teaching using video recording and make field notes to contextualise and start to interpret these.

In order to provide a rich base of data from different sources to explore different interpretations of the situation I decided to interview the teacher and a sample of six children. My intention was to take a very loosely structured interview approach in order to impose minimal preconceptions on the data. In order to provide triangulation I sought the teacher's views on the transcripts with my initial analysis. I also trialled watching the videos of the lessons with the teachers as a means of stimulating discussion on what had taken place from the teachers' perspective.

5.6 Outcomes of the Pilot Case Study

The pilot study raised methodological issues around use of field notes and my relationships with the children and the teacher. It also raised issues of how to manage the meaningful analysis of large amounts of video data. The issues are summarised in the list below.

- My relationship with teacher became too close, making it difficult to for me to be critical as described by Oakley (1981) and producing a tension between research ethics and validity.

- My concerns about the value of the teacher's time during breaks and after school meant that I was not asking her for her views, before and after the lesson and she spent less time in reflecting on the data than was needed for rigorous triangulation. I decided to pay the case study teachers for their time before and after lessons and for reflection on the video.

- The loose structure of the interviews with the teacher enabled me to access biographical information well and to explore her views about teaching science, but was not successful in accessing a deeper understanding of the teacher's view of the nature of science.

- My interviews with pupils about their contributions to 'interactive whole class teaching' had an impact on their subsequent interactions. Having asked one child about his lack of participation, in subsequent lessons he frequently looked over at me, trying to catch my eye and smiled at me when he put his hand up to contribute, which he did much more often. I decided not to interview children and remain aloof as a non-participant.

- Using video was a powerful way of stimulating discussion with the teacher about the lessons. However the approach I adopted in the pilot of attempting to look at the entire whole class interactions within a lesson was too time consuming. I had also focussed on validating the accuracy of transcript (Bassey, 1999), which was not the best use of this time. A more structured approach with a sharper analytic purpose was required.

- I found that my field notes were descriptive, but not sufficiently focussed to offer insights into my research question. Again, a more clearly defined analytical framework was required.

Overall, from conducting the pilot study I found that in order to address my research question I needed to shift away from a more open-ended approach influenced by ethnography and establish a clear framework for analysis derived from literature that I could apply both in the field and in post-field data interpretation.

5.7 Developing the Analytic Framework

In seeking to examine the ways in which teachers use 'interactive whole class teaching' I needed to characterise the nature of 'interactive whole class teaching' and its pedagogical purpose. Consequently there are 2 main strands to the analytical framework, firstly:

The Communicative Approach, based on Mortimer and Scott (2003), to capture the nature of the interactions between the teacher and children in the class using their distinction between interactive and non-interactive, and authoritative and dialogic.

And secondly;

The Purposes, including both more immediate pedagogic purposes and deeper purposes about the aims of teaching science and nature of science, the relationships that are established between people.

These are discussed further in the next sections.

5.7.1 The Communicative Approach

As discussed in the literature review (section 3.5.2), Mortimer and Scott (2003) developed four categories for the communicative approach adopted in teaching as:

interactive/authoritative (IA)
non-interactive/ authoritative (NA)
interactive/dialogic (ID)
non-interactive/dialogic (ND)

Defining the 'interactivity' of teaching is clearly central to my research question and this is captured within the interactive-non interactive dimension. As the categories were developed in the context of science teaching they also address a central issue that is evident in the models of teaching science - the relationship between children's ideas and scientific ideas - expressed in the dialogic-authoritative spectrum.

As I began field work for Case Study 1, Alexander (2004a) published his version of dialogic teaching and I extended the detailed descriptions of interactive - non interactive and dialogic - authoritative based on Scott (1997, 1998) with additional elements from Alexander's list of indicators of dialogic teaching (Appendix 1).

5.7.2 The Purposes

The second layer of my analytical framework is my interpretations of the purposes of the teaching. As noted above, I am using the term purposes in two ways: firstly to reflect on the 'pedagogical purposes', for example, that the teacher wanted to find out children's ideas about a concept, or demonstrate the correct use of some equipment, and secondly the 'deep purposes', which include reflection on the constructions of the nature of science that are taking place.

5.7.2.1 Pedagogic Purposes

In order to support making judgements of purpose whilst making observations in classrooms, a list of possible pedagogic purposes was generated based on Moyles et al. (2003) (section 3.2) and is shown in Appendix 3. The categories from Moyles et al.(ibid) emerged from discussion with primary teachers about their views on the role of 'interactive whole class teaching' in general, but I identified some aspects of these purposes that related to models of teaching science and these are noted on the table in

Appendix 3. This was not to be used as a restrictive coding device, but a start point for making links between interactive whole class teaching and the models of teaching science identified in the literature through the development of the case studies.

5.7.2.2 Deep Purposes

Following Bruner's Instrumentalism tenet (Bruner, 1996) and notion of an 'underground curriculum' there are different kinds of 'deep purposes' in relation to science education I will be considering in my analysis:

- The learning of science 'content'
- Constructions of the nature of science
- The positioning of the children in relation to science

5.7.2.2.1 The learning of scientific 'content'

Rather than focus on either conceptual understanding or procedural understanding, I decided to address both together because the dominant social constructivist models of teaching emphasise this as the way to approach the teaching of science.

Instead of trying to make a direct assessment of the development of children's understanding during the topic, for example by interviews or some form of test, I decided to rely mainly on the evidence available through children's utterances as they participated in whole class teaching. This was justified by evidence supporting Vygotskian assumptions that the intramental plane of individuals is related to the development of the intermental plane (Wegerif et al., 1999), and because it was the contribution of interactive whole class teaching to this plane that I was interested in examining. I did however collect copies of assessments that the teacher had planned as part of the unit of work.

5.7.2.2.2 Constructions of the nature of science

Examining the ways in which the relationship between the processes and concepts of science are constructed in whole class teaching, along with any explicit teaching about the nature of science, or the work of scientists, or the status of science and scientific knowledge will help me to form judgements about the ways in which science is being constructed as an entity in each case.

5.7.2.2.3 The positioning of the children relative to science

I will examine the way in which children are being situated in relation to science – are they seen as scientists themselves? Are they seen as recipients of scientific knowledge? Are they able to question science, and to ask questions themselves? Is science made relevant to them?

I have introduced no specific tools for tracking these deep purposes, relying on my interpretation of events. (This is reviewed later in section 8.2.1.) I was seeking to make links between the communicative approach and the purposes of different parts of the teaching. For example, by asking questions such as, how the use of a communicative approach for particular pedagogic purposes affects the outcome in terms of the deeper purposes of learning science. As Lemke (1990) notes, most teaching has several purposes operating simultaneously.

5.8 Three Layered Analysis

Wertsch (1991) explains how Vygotsky argues that the 'sense' of a word is dependent on the context in which it is used. This includes how it is used within sentences. This had implications for the choice of 'unit of analysis' I needed to make; word, sentence, or group of sentences, a whole lesson, or an entire sequence of lessons? I am taking a Bakhtinian perspective in that I am not looking for words or phrases in isolation, but am considering the way in which utterances are contextualised and given meaning by what happens before and after, and also during. In order to achieve this the analysis within each case study is layered (Kumpulainen and Wray, 2002): episodes of interaction within a lesson are analysed for a more detailed understanding of how these contribute to the development of understanding over longer periods of time – both within a lesson, and over a series of lessons. The analytic framework is developed at three levels:

- sequence of lessons,
- lesson, and
- episode.

The relationship between these levels of analysis was not conceived of as occurring in one direction but as an ongoing process of 'zooming in' and 'zooming out' (Roth, 2001) to explore ways in which the parts contributed to the whole and are located in it and are mutually constraining (Lemke, 2001). Details of how this was managed and of the selection process are contained in Appendix 8.

5.8.1 Analysis at the Level of Episodes

For each episode I recorded a brief description of what had taken place, coding the 'communicative approach' episode (ID, ND, IA, NA) after Mortimer and Scott (2003) and a list of my teaching purposes of the lesson, as I judged them at the time.
Each episode was first viewed in its entirety, then a rough transcript was made of the talk, and any teacher gestures, actions and movements judged to be significant. Repeated viewing of the episodes refined my interpretations. This is the iterative process described by Stake (1985) as leading to rigour in case studies and offer a form of triangulation. My reading of certain literature at the time had an impact on factors I saw as being significant, and these episodes were repeatedly reworked as the analytic framework was developed. These influences on my interpretation are described by Stake (1985) as 'emic' - issues belonging to the case, and 'etic' – those brought in from outside, from the research community.

Detailed analysis of transcripts at the level of episodes draws on some of the concepts developed in discourse analysis to characterise classroom talk as discussed in the literature review. This enabled me to do three things: firstly, to understand better how the different communicative approaches are constructed, secondly, to relate the communicative approach to pedagogic purpose, and thirdly, to reflect on how 'hidden purposes' may be being revealed through the meanings that are being constructed. A summary of the terms adopted from discourse analysis and a brief explanation is provided in Appendix 2.

5.8.2 Analysis at the Level of Lessons

For each lesson I produced an overview of the time spent in whole class teaching and within that of the use of communicative approaches. This quantitative representation, in combination with my field notes was used to produce a description of the lesson as a whole. I then watched selected lessons again, amending my description and analysing the lesson according to the analytical framework.

The analysis of lesson structure draws on Alexander (2000) discussed in the literature review (section 3.2.1) using the terms 'fixed' or 'elastic' to describe the flexibility of lesson length and internal structures and 'unitary' or 'episodic' to describe the pattern of tasks within a lesson.

5.8.3 Analysis at the Level of the Sequence of Lessons

Drawing together quantitative data on the amount of time spent in episodes classified by communicative approach provided one means of providing an overview of the case for comparison. Examining the sequence of lessons as a whole was a key point for considering how the practice observed related to the models of teaching science identified in the literature.

There is a lack of existing frameworks for interpretative analysis of long sequences of lessons in the literature, other than a broad ethnographic approach. However, Mortimer and Scott's 'flow of discourse' analytic framework (Mortimer and Scott, 2003) discussed in the literature review (section 3.3.2) does address this and they apply it to sequences of three lessons. I decided that using the five elements to characterise each episode its application to sequences of 8-12 lessons would generate such a complexity of strands to track through that for this level of analysis I would rely on the emergent story of the cases.

This multi level analysis is situated by an exploration of the teachers' ideas about science, and teaching science and their professional biography.

5.8.4 Interviews with Teachers

In order to understand the teacher's perspective I aimed to gain:

- biographical information related to teaching science,
- their views on teaching and learning science;
- their views on the role of interactive whole class teaching; and
- their views on the nature of science

through semi - structured interviews outside of normal teaching time (Appendix 4, Appendix 5). I also sought the teacher's views on each lesson immediately before and as soon after each lesson as was possible. This was recorded as part of the field notes.

In order to overcome the difficulties I experienced in the pilot case and probe teachers' understanding of the nature of science I drew on the categories (detailed in Appendix 7) developed by Lunn (2002) of:

Scientism
Naive empiricism
New-age-ism
Constructivism
Pragmatism
Scepticism

I explored the extent to which teacher agreed or disagreed with prompt statements (Appendix 7) based on these categories to develop an understanding of their views of the nature of science.

5.8.5 Video Stimulated Reflective Dialogue (VSRD)

The teacher reflection on video used in the pilot study was formalised into a version of Video Stimulated Reflective Dialogue (VSRD) (Moyles et al., 2003). It consisted of the teacher and myself watching video clips of selected episodes as a prompt for reflective discussion. The VSRD took place either during the sequence of lessons, or within 2 weeks of the end of the sequence of lessons. The VSRD itself was recorded on audiotape and a transcription made.

During the VSRD my role was to question, listen actively and make links between the episode being viewed and more general issues identified in the case. For each clip I had a focus, but this was not framed as question. The protocol was not tight – but loosely based on Moyles et al.(2003) in having two parts. First there was reflection on the action and situation from the day to day perspective of the teacher 'in action'. This focussed on the teacher' interpretation of events in the clip – prompted by questions such as 'What was happening there?'. It explored how the teacher felt about the episode and whether she felt it achieved her purpose at the time. This enabled validation of my interpretation of the purposes of the episode. Second, there was a joint reflection on how it related to educational goals, theories and political and cultural issues. For this I asked the teacher to move into 'researcher' mode, and respond to questions such as 'What was gained and lost by doing that as a whole class rather than as a group'?

Rather than adopt the position of 'neutral interviewer', I sometimes presented my own views and interpretations, though in a tentative manner to develop a discussion.

5.9 Validity and Generalisation

Qualitative case studies are subjective, but this should be seen as an essential element of understanding not as a failing (Stake, 1995, p. 45) as they strive to enable the reader to empathise and understand the motivations and interpretations, the meanings of the participants. Classrooms are complex systems and understanding the interrelationship between different elements is not open to simple accounts of cause and effect. Although no predictive forms of generalisation are possible, the insights gained may have some generalisability to other similar contexts and stimulate a deeper understanding of the issues (Stake, 1995). As well as being unique, Key Stage Two classrooms also have many common features and readers will recognise the basic organisational form of a single teacher with 20 – 35 pupils. A sociocultural viewpoint brings both the assumption of unique individual interpretations, but also of a shared set of meanings and understandings and interpreting case studies is congruent with this: each case is seen as uniquely situated, but within an overarching culture. Each reader will make a unique interpretation, but through some shared perspectives too. By adopting a multiple case approach and acknowledging what is particular about each case I will provide the reader with the opportunity to decide if the insights generalise to the cases they are interested in.

Different elements of the research design have contributed to its validity and these are summarised in the list below:

- Presenting original data in the form of transcripts alongside my interpreting contributes to reader validation and is a form of triangulation.

- Perspectives of teachers through VSRD and interviews before and after each lesson.

- Offering the entire case to the teacher for their views on it before publication.

- Selecting episodes for detailed discussion of transcripts and making the process of this selection transparent.

- Although in adopting a situated, case study methodology I am not seeking reliability, readers can examine the extent to which my interpretation of the coding of classes of communicative approach compares with that of other researchers (Scott, 1998; Mortimer and Scott, 2003; Mercer, 2007; Scott and Ametller, 2007).

Having undertaken this process of data analysis, which will produce a 'case record', there is a further stage of selection as I attempt to draw each case together as coherent pictures. At this stage it will be important that I do not introduce distortions through over simplifications and reduction and it will be important to demonstrate in the thesis the relationships between the case data, the case record and the case study (Wellington, 2000).

In presenting the case studies to an audience, further decisions about selection of material had to be made. The case studies will take the approach of telling the story of the sequence of lessons, and selecting lessons and episodes in order to illuminate issues that emerged whilst maintaining the integrity of the whole. As this final selection necessarily came after the processes of analysis, the means by which the case record relates to the selection for the case studies is summarised in Appendix 8.

Woods (1996) notes that researchers do have a different role from the teachers and must avoid over empathising such that distortions occur. Reflexivity is an essential component of interpretative research (Woods, 1996), and I needed to continue to consider and question how my own ideas, values and assumptions contributed to the situation and the impact they have on my perceptions and interpretations.

5.10 How the Research Questions will be answered

A summary of the data sources that will be drawn on to answer each research question and an indication of how they will be interpreted is provided in Table 5.2.

Table 5.2 How I will answer the research questions

Research question	Data sources	How the question will be answered
What are teachers' understandings of how interactive whole class teaching contributes to their teaching of science?	Interview 2 VSRD Discussions with teacher pre and post lesson	Teachers' views on their beliefs about the nature of science and views of interactive whole class teaching as espoused in semi-structured interview and in reflections on their practice will be presented in the case studies.
What is the nature of interactions within whole class interactive teaching in science?	Field notes Video recording of whole class episodes. VSRD	Episodes of lessons will be characterised by the dominant communicative approach and other linguistic features. Quantitative representation of communicative approaches across lessons and sequences of lessons will be used to seek patterns. Communicative approach will be considered in relation to interpretations of the purposes of selected episodes.
To what extent are strategies within whole class interactive teaching evident in classrooms supported by the models of teaching science identified in the literature?	Field notes Video recording of whole class episodes. VSRD	The interactive whole class teaching in each case will be related to the models of teaching science identified in the literature. This comparison will provide both a means of making judgements about the value of the interactive whole class teaching in the cases, and begin to identify aspects of the models to be developed.
How does interactive whole class teaching contribute to teaching about the nature of science and scientific processes (Sc1) and scientific knowledge and understanding (Sc2, 3, and 4)?	Video recording of whole class episodes Transcription of selected episodes Teacher planning documentation Children's responses in end of unit assessments.	This question will be addressed within the development of the cases as a whole and how particular episodes contributed to the construction of dominant meanings on the social plane of the classroom. Emergent themes will be identified.
What is the role of 'interactive whole class teaching' in models of teaching science in the literature?	See Ch. 4	

How can an understanding of the role of interactive whole class teaching develop the existing models of teaching science at Key Stage Two?	All the above	Drawing on the outcomes of the sub-questions I will make judgments about how different approaches to whole class teaching can contribute to different outcomes and make some tentative recommendations for practice and developing models of teaching in the literature.

5.11 Summary of Chapter Five

In this chapter I have explained the reasons for my choice of multiple case study methodology with an emphasis on combining a narrative and theory seeking approach. Teachers for the case studies were selected as practitioners with an awareness of the models of teaching science in the literature supporting the aim of examining and developing the models through exploring practice. I have discussed ethical issues centred on my relationship with the teachers and the associated concerns for validity. I have introduced the analytical framework based on 'communicative approach' (Mortimer and Scott, 2003), pedagogic purposes (derived from Moyles et al., 2003) and deep purposes of science education. I discussed further issues of validity related to data collection and analysis.

Chapter 6: Case Study 1

6.1 Introduction

This chapter is Case Study 1. It begins by introducing the school and the class and then proceeds to explore the teacher's ideas about the nature of science and teaching science. The main body of this chapter goes on to construct the story of the lessons that took place, first considering the sequence of lessons as a whole and then selecting lessons and episodes for more detailed analysis. Finally, emerging themes are summarised and developments of the analytic framework that resulted from the case are explained.

6.2 The School

The case studies took place in a primary school situated in a large village in South Gloucestershire, not far from Bristol. According to the report of an Ofsted inspection, the socio-economic status of the pupils was average and the population was mostly white British. The school had a record of end of Key Stage 2 test results for English and maths that that were in line with the national average and that of similar schools and the attainment in science was judged by Ofsted as being 'well above' the national average and the average for similar schools.

6.3 The Class

The Year 6 class (10-11 years) of 32 children (18 boys and 11 girls) were considered by the teacher, Clare, to be a more challenging class than others she had taught, in that their behaviour was somewhat difficult to manage and their range of attainment was broad. The headteacher expressed his view that it was a 'tricky class' and Ofsted had identified 'low level, wearing' misbehaviour as a concern. The teacher described their attainment in science in National Curriculum terms, as spanning from Level 5 to below Level 3.

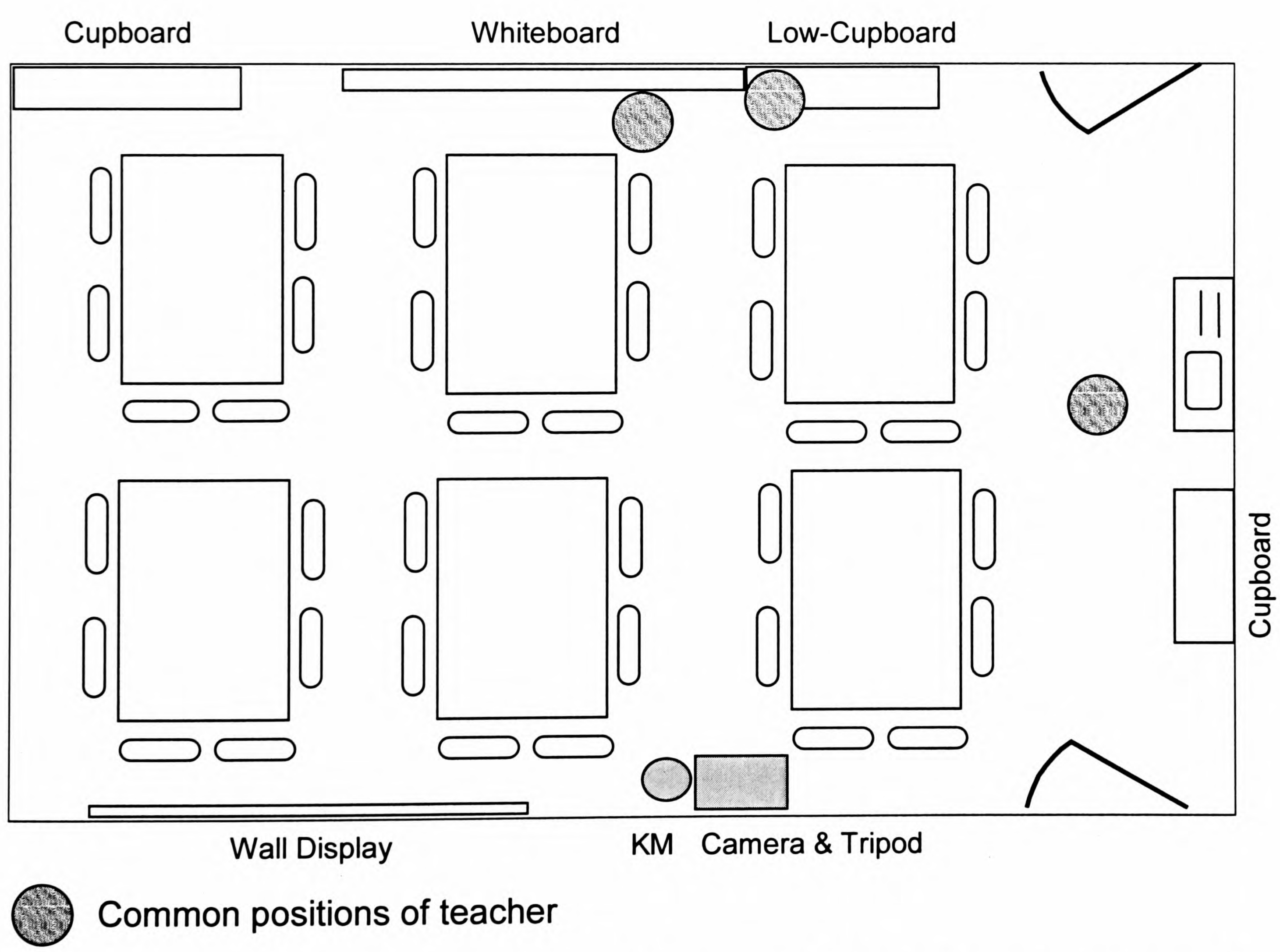
The lessons observed took place in January 2004, with end of Key Stage tests ('SATs') approaching in May. Clare clearly felt the pressure to get good results, but was concerned that this should not become the reason for doing science lessons.

> Because that's another thing I really think is important to get across to children [the importance of practical work], especially now we are more results driven, more test driven than we ever were in primary school really, is that why are we

doing it, are we just doing it so we can get our SATs? Cos Year 6s particularly have got that so fixed in their heads, it's a travesty really... (interview 24.1.04)

The science topic for this case study was 'Dissolving'. This included ideas about solubility, separating mixtures of soluble and insoluble materials, evaporation and condensation. The previous term, the class had studied 'Liquids and Gases' and so they had already been introduced to ideas about changes of state. The topic has a significant 'learning demand' (Leach and Scott, 2002) for the age group in that some of the processes are 'invisible' and there is also specific scientific vocabulary with words such as 'solution', that the children are unlikely to use in everyday life. However, a particle model is not part of the National Curriculum for Key Stage 2 (DfEE, 1999a) and the explanations required are empirical rather than theoretical.

Figure 6.1 Classroom Layout #1



The classroom was arranged so that the children were sitting at tables in groups of six (Figure 6.1). These were arranged so that some children were directly facing the front of the class, defined by the whiteboard, and some children were sitting sideways-on to the front. There was no 'carpet area'. A large display board occupying half of the back wall of the classroom was devoted to science and this display was added to during the course of the study.

6.4 The Teacher

Clare had studied science subjects at A' level and had a science degree in Pharmacology; her subject knowledge in science was stronger and more confident than that of most primary teachers (Harlen and Holroyd, 1997). She had been teaching for eight years and had been the school's science subject leader for four years. She was a 'Leading Science Teacher' for the then Local Education Authority (LEA).

She had attended a course for primary science subject leaders that I had led and so she was aware of the pedagogy I espoused at that time and this may have influenced what she told me about her teaching and the approach she took to teaching the topic, however, she put forward her own views confidently. When asked about the impact of my presence in the room on her teaching she said she had not changed anything, but had 'tightened up', and was trying to ensure that her teaching was in line with her ideas about what constituted good practice, as the following extract from the interview transcript shows:

> T: It also made me realise how, it made me tighten up – that all the things I think are important I actually am doing.
>
> KM: Like...
>
> T: Doing plenty of practical work, questioning things, and.... It also makes you realise, if somebody is coming in and you tighten up, then actually that shouldn't be the case really.
>
> (Interview transcript 24.1.04)

Clare's background in science and her route into primary teaching were similar to my own and I was keen that my identification with her should not influence our relationship and that I would be able to maintain a critical stance to the case study. Woods (1996) notes how researchers can over-empathise with teachers leading to distortions. This concern was shared with Clare and she seemed comfortable with the idea of maintaining a 'professional distance', saying that it would make it easier for her, too. I wrote in my field notes after the first meeting in school:

> We have similar educational backgrounds and this means I tend to empathise with her. Felt I somewhat overcompensated by being less friendly and chatty than might have helped her to relax.
>
> (field notes 15.12.03)

This tension between being warm and supportive, while remaining critical, was one I was aware of throughout the development of the case study.

6.4.1 The Teacher's Ideas about Science

Based on Lunn's (2002) categorisation of teachers' beliefs about science, Clare's characterisations of the nature of science displayed aspects of constructivism and empiricism. She placed a strong emphasis on the importance of data and also saw science as the steady accumulation of facts – in line with more empiricist views of science. Of the statement: 'Science proceeds by trying things out to 'see what happens', and is driven by data derived from such observations.' she said:

> I don't see how you argue with that really, because at the end of the day it is experimentation, you do want to see what happens, and then you get your data and do more and...there we go.
>
> (interview 24.1.04)

However, her views cannot be described as naïve empiricism as she also believed that science is rooted in attempts to construct explanations of phenomena, which originate in discursive speculation and imagination, placing this highest in the group of statements she agreed with. This is more in line with constructivist views of science.

> I like the idea of imagination. I strongly agree with that ...
>
> (interview 24.1.04)

Whilst agreeing with the statement that all scientific knowledge is tentative, she qualified this with her view that if there is a body of knowledge with sufficient evidence to support it that, then it can be generally accepted.

> Well nothing's ever proved a hundred percent is it, it's all sort of more and more proved, ... because at the end of the day no-one really disputes theories that have got enough evidence to support them...
>
> (interview 24.1.04)

The value she placed on established scientific knowledge and procedural knowledge and skills was evident in her teaching as will be shown in later sections of this chapter.

6.4.2 The Teacher's Ideas about Teaching and Learning Science

This section directly addresses the research sub question:

> *What are teachers' understandings of how 'interactive whole class teaching' contributes to their teaching of science?,*

by presenting the views that this teacher espoused about the teaching and learning of science and the role of interactive whole class teaching within this. This is discussed in relation to the models of science teaching identified in the professional literature in Chapter 4. However, a more contextualised account of the teacher's understanding of the role of interactive whole class teaching is embedded within the case study itself as they reflect on their lessons and on the episodes presented for VSRD.

Clare explained that she would begin a sequence of lessons with an elicitation activity, suggesting that she was taking a concept-led social constructivist approach (section 4.4.2), though she was unsure about whether elicitation was actually used to support teaching and learning:

> We do try *(to begin with eliciting the children's ideas)*, but how much we use it to move forwards… *(tailing off)*
>
> (field notes 15.12.03)

She saw elicitation as being mainly a means of fine tuning existing plans and interactions with children, more indicative of an activity-led version of social constructivism (section 4.4.3):

> I tend to still do the same activities that I probably would have done anyway, but I do know then is more a feel for what individuals might know and so ideally directing questions a bit more there, for what they don't know or where they are, it stops me making assumptions, …
>
> (interview 24.1.04)

She also expressed the need for some form of structure in supporting her teaching.

> In theory moving from the children's ideas is great, but I think not...there are only a few people, and I'm not one of them, who really has a clear idea of exactly how to do that without some kind of structure of what you might be aiming for.
>
> (interview 24.1.04)

When asked about the role of whole class discussions, she explained that she would target the level of the discussion to the class as a whole, tending to pitch it 'too high', but would also target questions to particular groups of children or individuals based on what she knew about them. She saw whole class discussions as an opportunity to differentiate to meet the needs of the higher attaining children as, during group work time, most of her time and support was directed towards the lower attaining children. She also saw this 'pitching it high' as a means of expressing her high expectations of all children.

Clare explained that the general structure of her lessons was 'talk – do – talk' showing that she valued the role of talk in learning. She explained that she would generally begin a lesson by reviewing previous learning, often doing this through whole class discussion. Other purposes she gave for whole class teaching, particularly before practical work, were to give information, to give examples of what she wanted from the children, or to teach specific skills. The procedure-led model was evident here.

She felt that whole class discussion at the end of a lesson was very important to share the outcomes of tasks and, in particular, to relate the outcome of the practical tasks to scientific knowledge and understanding, either relating it to the children's existing ideas or developing new ideas. She noted that this was particularly important if the outcomes of the practical work were not as anticipated and that she might then discuss issues such as precision of measurement and careful use of the equipment. This use of class discussion is as advocated in the concept-led social constructivist models of teaching.

She had views on what 'interactive' might mean in science teaching:

> I take it to mean...rather than the children being passive... 'I talk you listen'... I might ask questions, but not expect too much.
>
> (field notes 15.12.03)

This view of 'interactive' is resonant of the brisk-paced whole class teaching recommended within the National Numeracy Strategy. She explained that she made use of strategies developed through the National Numeracy Strategy and National Literacy Strategy such as asking children to discuss an answer in pairs before sharing it with the whole class, and sometimes expecting a 'chorus' response from the whole class. She noted that the chorus strategy was 'not very interactive'.

It was important to her that the children undertake practical activities:

> You know this whole thing about what a scientist is and what a scientist does is very important to me, ... science is practical isn't it? You don't have, there aren't people really who are paid to learn facts, that isn't what science is, really is it? ... if they get the idea of what a scientist is, and what a scientist does, and how scientific discoveries are arrived at then hopefully, cos really what they need to be able to do is deal with science in the media...
>
> (VSRD 13.3.04)

This opinion of the purpose of science education is very much in line with the notion of education for scientific literacy (Millar and Osborne, 1998).

6.5 Analysis at the Level of Sequence of Lessons

The twelve lessons in the sequence took place over a period of six weeks during the spring term and the timing of these was regular – they took place after lunch on Tuesdays and Wednesdays. Each lesson lasted for an hour so they could be described as being fixed rather than elastic (Alexander, 2001). Clare's medium term plan was not written down, but was based on a combination of the QCA Scheme of Work Unit on Dissolving (QCA 1998) and the Ginn New Star Science Teacher book *Dissolving* (Feasey et al., 2001). She drew on ideas from both sources and also added activities she had devised herself as the topic went on. Table 6.1 shows a summary of the content of these lessons.

6.5.1 Analysis in Relation to the Models of Teaching Science

The sequence begins with a review of existing ideas and an exploration of the children's understanding and use of specific scientific vocabulary and in this way is influenced by the concept-led social constructivist model's recommendation to begin with an elicitation of children's ideas (Ollerenshaw and Ritchie, 1997). The majority of lessons included a practical activity: either an illustrative activity or a structured investigation. The illustrative activities were used to support the development of conceptual understanding. The children's ideas or questions were not used as a start point for the planning of investigations, but a procedure-led approach was adopted in which different aspects of the investigative process were focussed on in different lessons. Towards the end of the sequence of lessons, problem-solving activities required the children to apply the concepts developed in earlier lessons to new contexts, in accordance with the 'Application' phase of some concept-led social constructivist models of teaching. There were frequent recaps of scientific vocabulary during and at the end of the sequence of lessons, but children were not invited to reflect on how their ideas had changed so this was not a 'Review' phase as in the concept-led social constructivist models of teaching.

Table 6.1 Summary of Lessons in Case Study 1

No	Description of Lesson
1 Wednesday pm	Reviewing existing ideas about dissolving. Practical activity: observation of what happens when you add substances (jelly, sand, salt, instant coffee) to warm water. Working in pairs to finish the sentence: 'When a material dissolves it…' and record it on their mini-whiteboards.
2 Thursday pm	Reaching a class definition of 'dissolving'. Practical activity – observation of mixing substances (Oxo cube, salt, flour, sugar, lentils) with different liquids (water, vinegar, cooking oil and lemonade). Feedback on activities using the terms: soluble, insoluble, solution.
3 Wednesday pm	Reviewing meanings of terms (solids, liquid, soluble, dissolve, insoluble, solution) by making sentences with them. Practical activity separating mixtures using filters and sieves.
4 Thursday pm	Oral recap using key words to make sentences. Problem solving activity – how to identify the 'mystery solutions' by evaporation and looking at the resulting crystals. Worksheet-based data interpretation task on water evaporating from salt solution

5 Wednesday pm	Observation and interpretation of outcomes of evaporation of mystery solutions. Introduction of post-it planning boards to identify and control variables. Planning an investigation into how sugar could be dissolved quickly into a cup of coffee.
6 Thursday pm	Discussion on the meaning of 'fair testing'. Practical activity - carry out tests into dissolving sugar. Making generalisations from results.
7 Wednesday pm	Use of AKSIS table to graph teaching strategy. Using data provided in worksheet to draw a bar chart and then a line graph.
8 Thursday pm	Thought experiment - evaporating cabbage cooking water – how would the condensed water in the saucepan lid taste? Theoretical problem solving – how to get a drink in the desert using certain equipment.
9 Wednesday pm	Discussion of the meanings of words including soluble and dissolve. Challenged to make 'instant coffee granules' from filter coffee using the equipment available. Pairs of children plan and then summarise the general approach to filtration, followed by evaporation, of the filter coffee.
10 Thursday pm	Practical activity: carrying out plans to make coffee granules by putting filter coffee solution onto Petri dishes to evaporate. Reports on the activity are recorded in science notebooks.
11 Wednesday pm	Not observed. Pencil and paper assessment from Ginn New STAR Science.
12 Thursday pm	Review of key vocabulary and ideas. Observing outcomes of coffee granule making process. Writing draft letters to the instant coffee manufacturers explaining their process using scientific vocabulary.

6.5.2 Communicative Approaches Adopted Over the Sequence of Lessons

An indication of how the communicative approach (Mortimer and Scott, 2003) during whole class teaching varied across the sequence of lessons has been calculated by multiplying the length of the episode by the dominant communicative approach used during that episode, as shown in Table 6.2. Although this oversimplifies both the complexity of what actually happens within episodes and the subtle shifts along the interactive - non-interactive, dialogic - authoritative spectra, it does present some sense of the scale of differences between lessons in terms of the time spent in whole class teaching and in the different communicative approaches. This was used to signal possible patterns that were further explored through the qualitative analysis and for cross-case comparison.

Table 6.2 Percentage of Lesson Time Spent in Whole Class Teaching Subdivided by Communicative Approach

Lesson	**Percentage of lesson time spent in whole class teaching in each communicative approach**				
	ID	**IA**	**ND**	**NA**	**Percentage of lesson time spent in WCT**
1	31	15	8	17	71
2	34	24	0	18	76
3	19	39	6	4	68
4	20	32	6	18	76
5	18	39	7	19	83
6	12	20	14	13	59
7	0	54	0	4	58
8	17	24	0	16	57
9	24	25	0	11	60
10	6	9	1	11	27
11	No data	No data	No data	No data	No data
12	4	42	0	10	56

Key:
WCT whole class teaching
ID Interactive/dialogic
IA Interactive/authoritative
ND Non-interactive/dialogic
NA Non-interactive/authoritative

The findings from this quantitative treatment of the data are listed below.

1. There was a high proportion of whole class teaching in most lessons. In 10 of the 12 lessons 57-83% was spent in whole class teaching. Of that, about two thirds were defined as 'interactive'.

2. The dominant communicative approach was interactive/authoritative. Interactive/authoritative episodes dominated in lessons 5 and 7 in which procedural knowledge was being taught.

3. The most time spent in interactive/dialogic talk was during the first two lessons which explored children's ideas about the conceptual content.

4. There was a tendency for the percentage of the lesson spent in whole class teaching to decrease over the sequence of lessons.

6.6 Analysis at the Level of Lessons and Episodes

6.7 Lesson 1

The lesson began with Clare explaining the aims of the lesson to the class.

6.7.1 CS1 Lesson 1 Episode 1-Thinking about what we already know about dissolving

At the start of this episode, the children were sitting facing the front of the classroom where the lesson objective was written on a whiteboard: To review what we understand about dissolving. A list of phrases was written on the right-hand side of the board: dissolves, doesn't dissolve, not sure, our group thinks... Clare asked the class what the word 'review' meant. One child, Sarah, suggested 'remembering'.

> T: We are going to be learning about dissolving this term. So it doesn't matter, if you think, eurgh, I don't know what that word dissolving means, or, I know what it means at home, everyday life, but I don't know what it means in science lessons, if there's any difference, and that doesn't matter, cos we're thinking about what we know already, so we know what to do next. So that's what we're doing today, but Sarah, you had the spot on word when you said remembering, so reviewing, revising, thinking about what we know already about dissolving. OK...

This short introductory episode had limited interaction since only Sarah had contributed orally to the dialogue. It was coded as dialogic because, although they hadn't expressed their own ideas yet, Clare acknowledged that they would have ideas and also that those ideas might be based on knowledge from home and not school. She felt it was important to talk about this aspect of the episode.

> And one thing I am quite keen on is that they don't think the stuff they know from everyday experience is less valuable than the scientific words, names, they are equally valid, but different, because if you don't notice things in everyday

> life you can't do the science bit – it's that thing of where do you get your ideas from…
>
> (VSRD 31.1.04)

In the process of valuing both 'everyday ideas' and 'scientific ideas' Clare also set up the notion of a distinction between them, developing multivoicedness (Mortimer, 1998).

Clare wanted to set up an environment in which the children felt safe to express their current understanding, whilst also conveying the message that their ideas may need to change.

> … because I don't want them to feel insecure if they haven't got the answers, but I don't want them to feel that they necessarily have and they are not going to explore them any further…because otherwise they could be quite confident that dissolving is disappearing …
>
> (VSRD 31.1.04)

In the second episode, Clare began the process of reviewing previous ideas about dissolving by asking pairs of children to finish a sentence starting 'Dissolving means...', recording their ideas on a mini whiteboard. She was explicit that they might 'change these ideas' later. In this short episode, only the teacher spoke so it was 'non-interactive' but it has been classified as dialogic in that it is about the children's ideas, rather than focussing on the 'scientific ideas'. Clare saw the purpose of the episode as 'setting up, introducing the objectives' (VSRD 31.1.04), which has some congruence with 'Orientation' in concept-led social constructivist models of learning.

When asked why she didn't keep all the children's writing on the whiteboards she explained that:

> I didn't keep what they wrote right at the beginning, I kept what they had written at the end of that lesson... Finding out where they were. It didn't really matter that I didn't have what they wrote at the beginning because all that that one was for was to open up the discussion and open up the whole thing. They are very much like I am in that you don't want to be

> committed to your ideas – you don't know what you think until you've thought it!
>
> (VSRD 31.1.04)

The emphasis was on seeking to provide emotional safety by creating an environment in which children could explore their own ideas with little teacher assessment. Clare was explicit that having an understanding of the children's ideas was an outcome of the lesson, but saw this more as establishing the understanding of the class as a whole, rather than seeing it as a means of eliciting the ideas of individual children:

> I've got a feeling about what the class knows. (field notes 6.1.04)

Episode 3 was problematic to classify. As the children were working with 'talk partners' at their tables, it could be seen as 'not whole class'. However, I decided to classify it as 'whole class' because the short amount of time spent on it (165 seconds) meant that it became an episode within a whole class phase of the lesson. This is also in line with the ways in which interactive whole class teaching was defined by the NNS and NLS; such activities are seen as what makes whole class teaching 'interactive'. My view is different from Clare's:

> That's not really whole class teaching, that's more independent working.
> (VSRD 31.1.04)

A group of five boys were sitting at a table near the camera and their conversation could be heard. It was not possible to distinguish individuals.

> C: Dissolving, that's when a solid turns into a liquid
> C: No dissolving is if you've got salt look and (inaudible)
> C….and you drop it into a liquid and
> C: solid, break up, into liquid
> C: It's like, to melt
> C: vanishing
> C: I think it means a solid, breaks up into little bits

Within this group of children, some common alternative frameworks were evident. They were confusing melting with dissolving and thinking of dissolving as materials disappearing. One child had an understanding of dissolving as 'breaking into little bits'. Clare had set up this short (2 ½ minutes) focussed discussion, but did not ask them to share the outcomes with the class.

The next episode, Episode 4, exemplifies the classification non-interactive/dialogic. The children do not talk, so in that way it is not interactive, but Clare is referring to the children's ideas and accepting them as valid start points. She restated that they may want to change their ideas during the course of the lesson.

6.7.2 CS1 Lesson 1 Episode 4-You might even change your ideas today

T: What I want you to do with those ideas is keep them. Keep them on your table, and tell me… (inaudible) because that's your ideas of what dissolving means before we do anything. You might even change your ideas today, so I'm not going to ask anybody to read them out just yet. We might do that at the end. And you might say, 'well exactly what I thought it was is what I think now, or you might change your mind a little bit, you might be able to give me some examples of dissolving.

In this sequence of four episodes, the whole class teaching provided a structure within which children were invited to think about their existing ideas and discuss these with their peers. There was a clear message that these ideas were to be seen as provisional and open to change and the transient recording medium of the mini whiteboards reinforced this. There is no reflection in a whole class forum on the specific ideas that the children hold and nor is there any challenge made by the teacher to individuals who hold alternative frameworks. It had the effect of creating a safe social environment in which the children could explore their ideas. By keeping these ideas in the personal, rather than public domain, perhaps they were being labelled as 'likely to be wrong' and, therefore, not appropriate for inclusion in the social plane of the classroom.

In the second phase of the lesson (Episodes 5 to 21) the children undertook a practical activity; mixing different materials (salt, filter coffee, sugar, instant coffee granules, jelly) with water, and recorded their observations on a pre-prepared sheet, again working in pairs. Whole class episodes were used mainly to ensure the task was being carried out as Clare wanted; to organise resources and manage pace and noise level. They were all authoritative, sometimes interactive, but mainly non-interactive. During the 29 minutes of the practical activity, the teacher stopped the class and drew them together as a whole class six times so there were very short periods when the teacher was not intervening in some way. It may also be that my presence in the room contributed to this – Clare had described this class as being quite difficult and she may have felt under extra pressure to maintain what she saw as a good standard of behaviour for me and the camera.

By circulating the room, Clare realised that a number of the children were focussed on deciding whether the solid does/doesn't dissolve and she stopped the class for what she called a 'check point' for feedback on what the children had been recording. At this point, she decided to refocus them on recording their observations rather than their 'conclusions'. This interactive/authoritative episode (Episode 13) has been selected as significant in that its purpose was concerned with promoting an aspect of scientific enquiry; observation, and developing a relationship between evidence and ideas. She didn't want the children to move directly to an interpretation – 'it did or didn't dissolve', without making careful observations on which to base this decision.

6.7.3 CS1 Lesson 1 Episode 13-'what happens' and 'what you see'

T: So stop stirring, stop writing, 30 second checkpoint, this way please... If I have to say names it takes longer doesn't it, and I know you all want to get on...

Lots of you have written exactly what happens on their sheets... They've written what they saw. I think probably by saying what happened its leading you to say 'dissolved' and 'not dissolved' OK? What I would like is for you to make sure as well you are saying what you see. So perhaps I should have written 'what happens' and 'what you see' rather than 'what happens'. So I do want you to write what you see. Even if you are at the stage where you are using the words dissolves and not dissolves, that's fine, I want you to say what you see, not just what you think has happened. OK. Do you see the difference?

Um for example, put your hand up if you have looked at sand so far.

(several children put their hands up.)

Right. What did you see...Sam!

Sam: It just goes to the bottom and stays there *(T nods)*

T: Right the sand just goes to the bottom and stays there. That's what you saw, yeah?
What did you think had happened?

Sam: Um.. Nothing

T: Right, so that's what's happened. Can you see there's a bit of a difference between what you see and what has actually happened. And the what you see, is probably more important for the minute, though if you have an idea about what happened as well that would be good. So put your hand up if you are going to change what you write for the next thing you will have written? *(Only a few hands go up.)* The hands I'd expected haven't gone up, because they hadn't written what they'd seen. So make sure you write down what you <u>see</u> in your container. OK, *(looking at the clock)* A quarter to – on you go

Teacher talk dominates this episode; interaction is limited. Clare repeats the key message that the children are to write down what they see four times and then exemplifies this through the interaction with Sam. His short responses are characteristic of an interactive/authoritative communicative approach in two IRE cycles. As the children start working she reinforces her message yet again by writing on the board 'What you <u>SEE</u>'.

This short episode of whole class teaching in the middle of the practical activity is used to direct and refocus the way in which the children are working. It was a response to the teacher's observations of a group that she felt were taking an over-simplistic view of dissolving, and decided to encourage the whole class to focus on what they had actually seen as a means of challenging this.

> I don't know that I actually had the idea at the beginning that that lesson was going to be about seeing what actually happens, I think that came out of it … mainly because I wanted them to get the idea of what dissolving *meant* rather than just saying it happens… I really wanted to do that observing what's happened rather than telling me… I wanted it to be bit more than 'yes/no'.
>
> (VSRD 31.1.04)

This emphasis on empirical evidence to develop conceptual understanding is in line with concept-led social constructivist models of teaching, as is taking an emergent opportunity to develop the relationship between ideas and evidence in science. Here, however, Clare made the assumption that the group was likely to represent more children in the class and decided to address it as a collective issue rather than as something to discuss with individuals. The importance of the idea was emphasised by placing it clearly in the public domain. It is perhaps also an example of using whole class teaching for efficiency – she was able to quickly raise the issue with the whole class, and do so in time for them to modify the way in which they were interpreting and recording their observations.

In the third part of the lesson, the observations made by the children were discussed as a whole class and this is exemplified in Episodes 22 and 23 below.

6.7.4 CS1 Lesson 1 Episode 22-Would you say it dissolved or not?

The distinction created earlier in the lesson between 'what you see' and 'what happens' was drawn on as the children were asked to report back their observations one at a time.

On the board behind the teacher is written 'What do you SEE?' (underlined twice)

T *(Standing up with arms folded. Unfolds arms.)*
We'll talk about what we've seen now. And also what happened. I shall know for next time that I need to write down that 'what you see' bit as well as 'what happened' because I think that's been quite important really. Right, let's look at what we had in to mix. *(Sits down, perching on desk indicating discussion is about to take place)*

Unfolding her arms seemed to be a visual cue that Clare was moving from an authoritative stance to a more conversational mode, reinforced by her then perching on the edge of a desk in an informal manner.

The response of the class to Clare's opening question 'Were there any surprises for anyone?' was very limited; they did not seem to be comfortable or prepared to take up the discussion in their own directions. The episode continued with Clare indicating a structure for the discussion; they would consider each material in turn. The children described their observations, suggesting that they had understood the distinction between observing and interpreting that was made earlier.

T: Now let's just go through the materials one by one. Sand. What did you see when you mixed sand with water? *(Several hands go up)* Keiran.

Keiran: The sand went right to the bottom.

T: Right – the sand fell to the bottom... Anyone see anything different to that? Anything else they want to add to that? *(Several hands go up)*. Mark?

Mark: The water goes all murky.

T: The water goes all murky? That's fair. Sometimes it does, sometimes it doesn't. The water went all murky. *(nods head at child to indicate he can talk)*

C: Most of it sank, but some of it floated.

T: Most of it sank, but some of it floated. I've seen that as well, its, how would you describe when it's sort of on the surface, what did it look like? (*several children put their hands up) (T indicates by pointing to a child that they can answer)*

Edwin: Looked like a thin layer of skin

T: Looked like a thin layer of skin, *(making horizontal gesture with hand)* good. I like that way of describing it, you often see that don't you. Thinking, if I'd asked you what you'd expected, you might have expected the sand to fall down to the bottom.

Here the discussion is opened up and more children became willing to offer comments so that a much richer range of observations is drawn on. Clare used a combination of repetition and evaluation in her responses. This seemed to serve to value the child's idea as worth considering, while maintaining her own authority as the absolute judge of any observations. Repeating the child's words also drew the everyday language used by the children into the scientific discussion supporting 'multivoicedness' (Mortimer, 1998). The discussion is opened up to the class more widely, and the possibility of different acceptable answers is indicated in her use of the 'invitations to participate': 'Anyone see anything different to that? Anything else they want to add to that?'

The episode was concluded with the establishment of a shared view across the class that the sand had not dissolved.

T:	Right. So. Sand. Would you say it dissolved, or not?...Put your hand up if you thought sand had dissolved. *(no child moves))* Whether you think you know what dissolving is at all. ... Put your hand up if you thought sand had dissolved. *No hands go up)...* Put your hand up if you thought it hadn't dissolved. *(most hands go up*). Right, OK, Interesting.

Clare didn't conclude it by providing an authoritative decision on whether sand had dissolved or not, she left the authority of that decision with the children. An opportunity to make explicit the link between the evidence, and its problematic nature was not explored at this point. How could the 'murky' water be interpreted?

The next material to be discussed was the salt. After a discussion with the child who had said that when she put the salt into the water it 'went all cloudy', Luke put his hand up unprompted and was asked to speak. Clare made use of the distinction that had been made earlier between what is 'seen' and 'what happens' to respond to Luke's comment that the salt had disappeared.

Luke:	It disappeared
T:	*(tiny pause as she registered this 'alternative framework')* It disappeared. Is what you <u>saw?</u>, yeh. *(turning back to whole class)* So what had happened? Do you think... *(a few hands go up)* What had happened? John
John:	Dissolved?
T:	Yes, cos what you see and what happens are not always the same. Cos what you see is that it does disappear *(tiny nod towards Luke)* but had it, how would you know, if that salt was still in the water or not?... *(two hands up)* Again it's something you couldn't do today... Edwin.
Edwin:	You could have drunk it
T:	You could have drunk it...cause then you'd have got in trouble...but what you'd have known then was that the salt hadn't disappeared, but what you <u>see</u> is that it seems to disappear doesn't it...

This short sequence provides an example of Clare publicly addressing the conceptual understanding of a child by involving other members of the class. She is careful to try to maintain his self-esteem by acknowledging that his observation was accurate. It is not possible to judge from this episode whether this has helped Luke in developing his understanding of dissolving, but the alternative idea of dissolving as disappearing has been challenged on the social plane of the class as she used cued elicitation (Edwards and Mercer, 1987) to establish the scientific view.

Clare also challenges a simple 'primary science' view of solubility as a binary property (soluble/insoluble) which she believed most children held by drawing attention to evidence from their observations of the 'murky' sand and water mixture. Here she drew on the child's own language, however, there is little chaining or connecting of the different ideas. The teacher's authoritative voice was dominant, and the IRE structure is evident throughout. This episode was classified as interactive/authoritative.

This episode fulfilled at least two teaching purposes. Firstly, the empirical evidence of first-hand observations was highly valued. Secondly, an element of 'cognitive conflict' was introduced – simple ideas the children might have developed about materials as soluble or insoluble have been challenged and this raised questions about dissolving that were developed in the next episode.

6.7.5 CS1 Lesson 1 Episode 23-You can't really be sure

This episode began with Clare drawing attention to the distinction between the instant coffee and the filter coffee that the children were testing. In the extract presented here the teacher focussed attention on the children's observations of the filter coffee in water; that the water had changed colour and that some bits were left on the bottom – two ideas that Clare wanted to establish as being important in deciding whether or not the material had dissolved.

T: So what did we think with ground coffee?....*(some hands going up)* Dissolved, not dissolved, or not sure? *(Puzzled expression on her face)* I won't ask you to put your hands up this time. Phillip?

Phillip: Dissolved *(T listens with head on one side)*

T: You thought it had dissolved. Right. *(brief thumbs up towards him)* Anyone think it hadn't dissolved? And maybe give a reason why? Peter?

Peter: Because you could still see a load of bits at the top.

T: Cos you could still see those bits at the top

Peter: Yes

T: and you think if it had dissolved you would have expected not to, *(nodding, circular rolling hand gesture)* Good. Well done. Anyone not sure? *(several hands go up)* Not sure, Ryan, *(open palm gesture to Ryan)* why weren't you sure?

Ryan: Because it just looked..too murky

T: It looked too murky, so you couldn't see, good point, Angie? *(gestures to Angie)*

Angie: Because the water went brown

T: Mmm

Angie: But like there's still…the granules

T: *(thumbs up)* Right, so the water went brown *(raises one finger to indicate this is point one,)* , but there were still granules *(raises another finger to indicate that there is a second point)* Good, so you can't really be sure can you?*(making 'weighing up' alternate up and down movement with hands)* Its difficult to be sure.

A definition of dissolving as 'not having bits left' and 'changing the colour of the water' was developed, with this being articulated by the teacher in a summary at the end. Peter adopted the word 'murky' used by Mark earlier, suggesting that a shared vocabulary is being developed. Clare's use of the counting gesture with her fingers, emphasised that there were two parts to the evidence that were being considered, and then the 'weighing up' gesture signalled that these two pieces of evidence were in conflict and that a simple conclusion couldn't be drawn.

It is an example of a dialogic discussion in that the children's ideas were being drawn on to move the discussion on, but it was not open ended, again being directed by the teacher towards to develop uncertainty about whether the materials had dissolved or not. This is an example of what Alexander (2004a) referred to as a 'scaffolded dialogue'; attention was being focussed on specific features of the phenomenon in order to help the children follow the sequence of the discussion and reach the same conclusion.

Clare saw classifying materials as soluble and insoluble as simplistic and was drawing on her scientific knowledge that went beyond the content defined by the primary curriculum:

> When you actually do it, its not as straightforward because you have to go into, you almost have to go into suspensions don't you, because some insoluble solids make suspensions and some don't, ... it was one where I thought they wouldn't be sure, and I think that whole idea of not being sure *(tailed off)*...
>
> (VSRD 31.01.04)

The lesson concluded with the children working in pairs to verbally complete the sentence 'When a material dissolves it…' and record it on their whiteboards under what they had written at the start of the lesson . These were then shared with the class in episode 28, with the teacher accepting all the responses. Clare asked for the boards to be left for her to have a look at.

6.7.6 CS1 Lesson 1 Episode 28-When a material dissolves it…

T: Very, very quickly *(sits and perches on ledge at the front)* I'm going to ask one pair on each table to tell us the ending to the sentence 'when a material dissolves ...' and we'll talk some more about that tomorrow. It isn't necessary for you to have a big answer, or, you know, the right answer, when you're ready, shh, I shall wait until everyone is ready. ……… (*standing up*) Right, somebody from table four, in fact Sam, when a material dissolves.

Sam: Um it disappears.

T: OK, *(gestures to another table)* Table 5, Katy.

Katy: Um, when a material dissolves, the water changes colour.

T: When a material dissolves, the water changes colour *(open palm gesture towards Katy)* Ralph? *(Open palm gesture to Ralph)* Go on then.

Ralph: When a material dissolves, you can't really see it, but it's still there... down at the bottom, sort of

T: Good, Well done, Daisy

Daisy: When a material dissolves it turns into a liquid

T: It turns into a liquid *(Open palm gesture to Daisy),* Sam

Sam: When a material dissolves it fades

T: It fades. OK *(Open palm gesture to Sam),* and ... Phillip

Phillip: When a material dissolves it looks like it has dissolved [sic] but it hasn't

T: Right, thank you very much, lots to talk about, well done.

This interactive/dialogic episode served the function of acknowledging and valuing the range of different ideas that exist amongst the members of the class. It contributes to a 'structured heap' of ideas (Sprod, 1997) and enabled children to see that different ideas are possible. What it doesn't do, at this point, is to challenge any of the ideas. There is a low level of interanimation (Scott et al., 2006), though the teacher's closing phrase 'lots to talk about' sets up the notion that some ideas may be open to challenge later.

In a discussion after the lesson, Clare said that she had intended that all children would share their ideas in the plenary, but that they had run out of time. She read the whiteboards at the end of the lesson and noted that some children were confusing melting and dissolving, but that there had been some changes when she compared the ideas at the beginning and those at the end of the lesson, with fewer children using the term melting. The word 'melting' was absent from the whole class discussion, and its exclusion from the social plane may have contributed to this. She also identified that the majority of children saw dissolving as mixing with water rather than any liquid.

6.7.7 Summary of Lesson 1

The transitions between episodes were clearly marked by signals such as 'OK' and 'Now' with Clare waiting for complete silence before beginning a discussion. There was a sense of Clare keeping a close grip on the actions of the class and controlling the direction of the lesson tightly. The lesson was characterised by frequent changes between whole class and paired work which seemed to reinforce the distinction between the children's ideas and the teacher's scientific ideas.

In terms of the social constructivist concept-led models, this lesson could be understood as orientation to the new topic with the children structuring their existing ideas and the teacher eliciting these ideas. However, the class is treated as a group rather than a collection of individuals.

An interesting feature of this lesson is that it is tightly teacher directed, but the main audience for the children's ideas is apparently themselves. It seems that the purpose of this process was very much about making the children aware of their own ideas. An alternative interpretation, that Clare was 'going through the motions' of a concept-led constructivist approach without really being interested in the detail of the children's ideas is possible. My interpretation is that she was looking for general patterns of understanding within the class as a whole and was 'sampling' children's ideas. She was interested in whether the response of the class indicated that their understanding was broadly in line with her expectations, and was open to any evidence of particular alternative frameworks.

A difference has been created between what the children may think dissolving is, and what the teacher and the authority of science understand by dissolving. So, a range of voices have been heard – it is a 'multivocal' discourse (Wertsch, 1991). This lesson can be understood as 'opening up the problem' (Mortimer and Scott, 2003).

6.8 Lesson 2

In Lesson 2, the alternative ideas held by some children in the class about dissolving being disappearing or melting were addressed through episodes of whole class discussion.

The ideas about disappearing were related to ideas about magic, and the cultural assumption was made that logical cause and effect were required for a scientific explanation. Then evidence for an alternative idea was drawn out by closed questioning; that you could taste salt or sugar, even if you couldn't see it, and that sometimes things dissolved making a coloured solution. Clare accepted ideas about dissolving as melting as more plausible, as they related to the work the class had been doing previously on changing state.

6.8.1 CS1 Lesson 2 Episode 2-I can see why you would think that

T: Some of you applied what we learned last term about changing states, so melting, freezing, and evaporating, all those sorts of things and you said that dissolving was when a solid changed to a liquid. Now I can see why you would think that. Why do you think some people thought that dissolving was when a solid changed to a liquid? Think about my brown sugar *(holds up water and brown sugar solution)* why do you think someone might have thought that? Andrew?

Andrew: *inaudible*

T: Andrew can you think about the question I asked

C: Cos it was a solid, and when it went into the water, and the water changed colour and it...

T: Brilliant, spot on, We started off with a solid, we put it into the water, and all you can see at the end of it is a liquid. OK, so that's a fair enough thing to think. Um, do you, I have to tell you, it's not what happens, its not the same as melting, dissolving isn't like melting. It's more like the solid spreading out through the liquid OK, so if you think about that brown sugar having spread out through the liquid that's probably a better way of thinking about it because its not, what do we not do. Did we heat the sugar at all yesterday? Have I heated the sugar?

C: No

T: No, and we know that we have to put heat in to a solid to melt it don't we, so it can't be melted, but its spread out.

At the start of this episode, Clare validated the logic that might be behind the confusion between melting and dissolving. Although Clare referred back to the practical work of the previous lesson, the way she developed the distinction between melting and dissolving was by introducing the scientific view, or at least a primary science version of the idea, that the solid had spread out in the water. The way that she prefaces the introduction of this idea with 'I have to tell you' is almost apologetic. She also contrasted this new idea with melting, noting that no heat is needed for dissolving. None of the children challenge this logic, which they might well have done, as they used warm water to dissolve salt and sugar the previous day. Perhaps this is because of the persuasive authority of the view - it has been presented as 'probably a better way of thinking about it'. In this episode the teacher exposition of the scientific story is the dominant feature, and so it is classified as non-interactive/authoritative.

Clare then asked the children to come up with 'a class definition' for dissolving, asking the children to work in pairs to come up with a definition and write it on their mini-whiteboards, asking them to 'think, talk and write'. These were not fed back to the class, they were asked to compare them with the definition that she then read out, leaving the responsibility for the evaluation of their ideas with the children. This can be seen as a planned opportunity for the children to appropriate the ideas constructed on the intermental plane; beginning to take more ownership of them.

Definitions of soluble and insoluble were also discussed in pairs and followed by whole class discussion. Then the children carried out a practical activity – mixing substances (Oxo cube, salt, flour, sugar, lentils) with different liquids (water, vinegar, cooking oil and lemonade). As in Lesson 1, Clare stopped the class during the practical activity on several occasions to clarify aspects of the task and set her expectations of pace through non-interactive/authoritative episodes of whole class teaching.

The lesson finished with the class being invited to tell the teacher a word they had learned or thought about today and to explain what it meant. Three children did so, demonstrating different degrees of success in appropriating the scientific ideas.

Sam:	Soluble - it means when the solid dissolves into the liquid.
Andrew:	Insoluble - it means um, a solid that didn't change to a liquid.
Kirsty:	A solution - is what's made when a solid dissolves into a liquid

This lesson follows the social constructivist concept-led model by aiming to restructure children's alternative ideas, but that it does this in a collective way, rather than focussing on ideas held by individual children. It has the apparent advantages of 'efficiency' – the teacher can address the ideas of a significant proportion of the class at once, and of doing this in an anonymous and therefore 'safe' way. The idea of dissolving as 'melting' was taken seriously and this consideration of children's alternative ideas and thinking about where they come from was modelled for the class and valued. The 'non-scientific', magic idea of 'disappearing' was given less status.

Possible disadvantages of this collective approach might be that, to benefit from this discussion, children had to maintain their concentration when listening to other children and the teacher, and had limited opportunity to express their ideas out loud. These were mitigated by the short episodes, and the frequent paired discussion that gave children the opportunity to talk through their own ideas. However, some children may have had difficulty in following unfamiliar vocabulary and meanings, and there was no way of feeding this back to the teacher and working through ideas at their own pace.

6.9 Lesson 3

In Lesson 3, the meanings of the terms solids, liquid, soluble, dissolve, insoluble and solution were reviewed again, this time by pairs of children being asked to think of sentences that used the words and record them on a mini-whiteboard.

The following sentences were selected later for display on the classroom wall:

> Salt is soluble in water.
>
> Insoluble means it doesn't dissolve in a liquid.
>
> When you put a solid in a liquid, the solid might be soluble or insoluble, if the solid is soluble, it will dissolve to form a solution.
>
> Insoluble is the opposite of soluble.
>
> When salt is placed in water it will dissolve.
>
> Sand is soluble, whereas instant coffee is soluble (sic).
>
> Salt is a solid which dissolves in water.
>
> Some solids are insoluble in liquids, this means they don't dissolve.
>
> If solids dissolve in water they make a solution.
>
> Salt is soluble.

Children were invited to share these with the class. Most of the responses were accepted by Clare as correct, showing the shift in ownership of the vocabulary and meanings from the teacher to a shared language that is understood by those children. Some led to a follow up question to probe the child's thinking and to clarify their use of language and, in one case, this led to an extended dialogue.

6.9.1 CS1 Lesson 3 Episode 4 - Solid and a ..?

Lily: When you mix two things together it's called a solution.

T: What two things would you need to mix together to make a solution?

Lily: Um

T: Which two words might you pick from that list

Lily: ...solid and

T: Solid and a ..? *(indicating the card on the board that says liquid)*

Lily Liquid

T: Liquid good well done. Which particular solid might you mix with water Lily?

Lily: Jelly?

T: You could do, couldn't you, well done

This is an example of an interactive/authoritative communicative approach used for the purpose of 'working on children's ideas' as described by Mortimer and Scott (2003).

This was followed by a practical activity involving separating mixtures using filters and sieves. As in Lessons 1 and 2, this activity was punctuated by frequent authoritative whole class episodes relating to organisation and clarification of the tasks.

In a whole class discussion, the children were then asked to apply ideas developed through experience to separating a mixture of sugar and lentils, and then brown sugar and granulated sugar grains. Again the technique of having time to talk to your partner first was used in these interactive/dialogic episodes.

6.10 Lesson 4

Lesson 4 began with a brief episode in which children were again being asked to use key words (soluble, insoluble, solution) to make sentences, this time orally and without discussion with a partner, rehearsing the use of the scientific language on the social plane of the class before applying them in the next activity.

Clare then introduced a problem solving activity in which the class were challenged to identity the 'mystery solutions' – by evaporation and looking at the resulting crystals. A whole class discussion took place in which children made suggestions and a child talked about his knowledge of how to get salt from seawater. This was classified as dialogic overall, but there was a clear 'story' that the teacher was maintaining. The children set up samples of the solutions in Petri dishes and left them to evaporate until the lesson the following week. Having done this, they were given a worksheet-based data interpretation task on water evaporating from a salt solution.

The first four lessons in this sequence focused on the development of conceptual understanding and on the use of the associated vocabulary. Over the sequence of lessons, children were given opportunities to further appropriate the concepts by rehearsing their use and applying them in different contexts. Practical work took place in every lesson; this took the form of 'illustrative activities' rather than 'investigations' (Howe et al., 2005).

6.11 Lesson 5

This lesson was selected to exemplify the teaching of specific processes in science, using the procedure-led social constructivist model. Within this case study, this lesson was recorded as having the highest proportion (83%) of the lesson spent in whole class teaching, of which 57% was coded as interactive.

The first, shorter, part of the lesson (episodes 1-8) was concerned with looking at the outcomes of the practical activity in Lesson 4 and matching the crystals left by 'mystery solutions' with those of 'known solutions'. It is not discussed here.

The second, main part of the lesson, which is considered in more depth, was concerned with planning an investigation into factors affecting how sugar dissolves. Using aspects of the procedure-led social constructivist model; the teacher introduced planning boards with post-it notes to identify the different possible variables and then to choose which will be changed, controlled and measured in order to plan a fair test (Goldsworthy and Feasey, 1998).

The teacher set up a context for this activity by telling the class a story about a day when she was feeling ill and had little energy. She wanted to dissolve four spoonfuls of sugar in a cup of coffee as quickly as possible so that she could drink it before she began teaching. The children were taken through a step-by-step planning process, alternating between short episodes of whole class discussion and talk in pairs beginning in Episode 12.

6.11.1 CS1 Lesson 5 Episode 12-What affects how fast sugar dissolves?

T: *(Walks to the centre front and picks up a board pen)* Now.
(Writes 'What') We're going to tie this down to a bit more of a scientific question later, but for now *(writes 'affects how fast sugar dissolves?')*
What affects how fast sugar dissolves?
We're going to think, a minute, *(quietly)* you are going to write on the whiteboards in minute, I wouldn't be so mean as to give them out if you weren't going to write on them, If we're going to think about what

affects how fast sugar dissolves *(picks up glass mug of coffee from a tray on ledge in front of board).* I'd like you to think, I've got my cup of coffee here, (*sits down and reaches for a beaker of sugar, that is also on the tray)* I'm going to give you a few clues, *(lifts up transparent plastic cup of castor sugar, shakes it and puts it down again)* I've got castor sugar in this tray, and I've got granulated sugar there, right*?(Lifts up transparent plastic cup of granulated sugar, shakes it and puts it down again).* Does anybody know the difference between granulated sugar and castor sugar? *(Several children put their hands up)*

T: *(looks at child to indicate they can answer)*

C: Castor sugar has got smaller grains than granulated sugar

T: Castor sugar has got smaller grains, right. I've got (inaudible) types of sugar here.

In this section, Clare indicated to the children that there were a number of answers that she had in mind, and that the children were to work out what they were from the 'clues' she gave them, a visual version of a 'cued response' (Edwards and Mercer, 1987). This set an authoritative tone for the episode. In the exchange above, the teacher marked the significance of the difference between granulated and castor sugar by repeating this theme verbally, and also visually, by holding up each type of sugar in turn.

Having explored a range of possible variables through the visual and language clues, Clare then handed over to the children the responsibility for drawing them together into a list.

T: Right, so you're, just to start off with, with your neighbour, I want you to think about...things about making this cup of coffee that I could change, to try to make how fast the sugar dissolves, change as well. Right, so what could I change about this cup of coffee *(holds up mug, using repeated open hand gestures towards the class with the other hand)* to make how fast the sugar dissolves change as well? Right I want you to write down as many as you possibly can. That you think will be relevant, cos after all, we're trying to help me, we're trying to help me with my cup of coffee and making the sugar dissolve quicker, alright? So try and think of as many factors, as many things that you could

> change, about the cup of coffee, or maybe the sugar, those sorts of things, that will change how fast the sugar dissolves. Off you go. *(Puts mug down and makes hand gesture towards the class. Picks up stop watch from tray and waves it as she stands up and moves off to the right)* Four minutes times on the clock

Clare's choice of vocabulary here had been influenced by the Goldsworthy and Feasey approach (1998), which uses variations on the phrase 'things that could change' to express 'independent variables'. She is modelling the use of scientific language through the linking of the independent and dependent variables in phrases such as 'What could I change about this cup of coffee to make how fast the sugar dissolves change as well', and emphasizing this pattern by repeating it four times, each time in a slightly different way. This 'glossing' (Lemke, 1990) links the meaning of 'factor' and 'thing you could change'.

The episode also narrowed the possible outcomes - the range of variables that the children would identify - providing Clare with some means of controlling the activity that was being planned. Given that time is limited in the fixed lesson structure of the class, it is understandable that the teacher wanted to make it as 'productive' as possible, in terms of being manageable in resources and time and relating to the conceptual understanding that she wished to develop. In the VSRD Clare saw this start point as a more open ended alternative to setting a question that already had the independent and dependent variable embedded in it.

> I didn't want to frame the question too specifically ...because... if I framed the question too specifically then you know the investigation would have been set up...
>
> (VSRD 13.03.04)

The children spent Episode 13 in pairs listing on mini-whiteboards different 'things that could be changed'. Then in Episode 14 these ideas were shared as a whole class.

6.11.2 CS1 Lesson 5 Episode 14-What can we change?

> *(The teacher is perched on the ledge in front of the whiteboard). On the whiteboard is a card with 'What could we change? (variables)' written at the top of it.)*

T: OK let's see. So what can we change about my cup of coffee then, and the sugar, the whole scenario? *(points at a child)* Sarah

Sarah: How small the grains are?

T: Ah, so we could change how small the grains are*)* How small the grains are, a good suggestion *(writes it on a post-it note)* Well done *(sticks the post-it onto the card) (two thirds of the class have their hands up)* Ryan?

Ryan: (inaudible)

T: Pardon, the amount of coffee? *(Writes this on a post –it)* OK *(sticks the post-it onto the card)*

Most of the class was engaged with this process; approximately two thirds of the class had their hands up bidding to offer suggestions. Sarah and Ryan made suggestions that were acceptable to Clare both in content and in the form in which they had been expressed. Later suggestions of the time the sugar is put in and the temperature of the sugar, visibly surprised the teacher, but she wrote them on a post-it, so they were accepted, with reservations.

In this next section, Katy's suggestion was transformed from a pragmatic, everyday idea to a scientific variable.

T: Katy

Katy: You could hold your hands round the cup to... like you're sort of heating it

T: What do you think... *(Nodding, and puts pen to mouth)*...Is there? I see what you're saying you're saying sort of insulate it, with your hands

Katy: Yeah

T: What do you think that might be almost the same as? *(Indicating card)* What would I be, what would I be trying to keep the same...?

Katy: The temperature of the coffee?

T: Right. So it's a really good idea, I think its probably covered by changing the temperature of the coffee, cos what you're really saying is keep the coffee hot aren't you?... *(lots of children's hands are up)*

Clare has quickly understood Katy's idea that the cup could be insulated and has also quickly seen that this can be understood as a variation on 'temperature'. She creates a shared intermental space by moving into the child's understanding. She stopped herself making her point too quickly, and instead checked her understanding with Katy, using the scientific term 'insulate', and this seems to be understood by the child, shifting the shared idea from Katy's context-specific meaning of putting your hands around the cup, towards a more general idea held by the teacher. The question 'What would I be trying to keep the same?' was effective in helping to relate Katy's idea to the more generalised list of variables that they are creating together and Katy was able to make this link. This process constructed the entity of a scientific variable on the social plane – illustrating how it is the abstraction of a key concept from a more complex and contextualised situation.

This process of constructing variables continued in the next part of the episode:

T: Sasha? *(Indicates to another child they can speak)*

Sasha: Making it hotter

T: Making it hotter, *(poises with pen over post-it then hesitates)* What would you be changing if you made it hotter? What would you be changing about the coffee? *(Leans towards Sasha.)*

Cs: *(two boys near camera whisper)* temperature, temperature

Sasha: It's getting hotter.

T: Its getting hotter, can anyone help Sasha out?

Sasha: The warmth?

T: *(circling open hand gesture to the rest of the class)*

C: the temperature

T: the temperature, Well done *(writes 'temperature' on a post –it)* the word for that is temperature. OK Good.

Sasha understood that making the coffee hotter may affect the speed at which the sugar dissolves, but had not understood the particular form of words and technical vocabulary that was required by the teacher here. She is not using the 'language of science' (Lemke, 1990). The key question the teacher uses to help Sasha phrase her suggestion in the form of a variable is: 'What would you be changing if you made it hotter?'. The form of this question suggests that a singular answer is required and, after initially retaining her own version, Sasha comes up with this: 'the warmth'. This move towards the scientific version is not acknowledged, but the 'correct' scientific term: 'temperature' is supplied by others in the class.

The episode was concluded with one suggestion; 'how you stir'. This was accepted, but adjusted by Clare to the more formal 'type of stirring' which loses the personal pronoun 'you' and consequently the more human element – supporting the construct of science as impersonal (Lemke, 1990). This movement between providing a meaningful context and an abstracted situation is constructing on the social plane a version of the nature of science as generalised rather than personal.

The way in which Clare held an extended series of interactions with individual children in order to develop their ideas and so models this process for the class as a whole, is resonant of what Alexander (2000) described in Russian classrooms and can be seen as scaffolding in that the task was broken down (Tharp and Gallimore, 1988) and the teacher's feedback was contingent on the child's response (Wood et al., 1976).

I was interested in Clare's perspective on the use of the Goldsworthy and Feasey (1994) planning approach with the class as a whole and to find out what she felt had been gained or lost by doing that rather than letting the children plan more independently.

> I suppose you've got more input to more individuals, more of the time, but you haven't focussed your input, quite so tightly, ...I don't think it works if you just do carpet type discussion and that's all there is, I think you've got to give them some sort of paired time or individual time to think and write down their ideas or I think there's a danger you only get five or six main characters contributing and the rest that are being carried along, but if they've all had to think and been expected, and know that you might ask them for an idea, then I think you get possibly the best of both worlds,...
>
> (VSRD 13.03.04)

What emerges from this is how Clare sees the relationship between the whole class teaching and the paired and individual time. Given the structure of the lessons, characterised by short episodes, with frequent changes between whole class and individual work, this was important in understanding her approach. Through the paired and individual work, she was encouraging what could be termed 'active engagement' and 'broad participation' in the lesson (Moyles at al, 2003). She was less clear about the role of the whole class teaching, but suggests that some children with limited ideas benefit from hearing the ideas of other children.

The class were then asked to plan their own investigation in pairs, choosing variables to change, 'keep the same' and measure. They were given a worksheet to support this process. While the pairs were planning, Clare stopped the class several times, for example, to remind the class that in a fair test only one variable is changed, assuming that this was a shared understanding.

6.11.3 CS1 Lesson 5 Episode 22-What are they going to measure?

T: *(moves away from the children she has been sitting near and sits down on the ledge at the front of the classroom)* Its really easy to get confused on when you're planning investigations, and I've seen somebody who needed a bit of help with that, so there's a good chance that there might be somebody else as well. So can you just put your pens down and look this way please…

Clare signalled to the children that she had identified an area that they may be having difficulty with and she is going to help them with it. This assumption that many of them may share the difficulty provided a collective opening to the episode, placing the whole class as a single group. This was not to be a public working through of one child's misunderstanding, as described by Alexander (2000) in Russian and French schools, but was to be owned by the class. The teacher's tone was not critical, there seemed to be an acceptance that misunderstanding is to be expected.

The misunderstanding that she had noticed was confusion between the need to measure some of the variables in order to control them, and measuring the dependent variable. This has arisen partly out of the terminology. In this system (Goldsworthy and Feasey, 1998) the dependent variable is named 'what I will observe or measure', often just 'what I will measure'. The episode is largely concerned with her efforts to explain the difference between this specific use of 'what I will measure' and the more general use of measurement to control variables.

T: Where it says, 'What you're going to measure'...Right...Somebody said to me *(reaches for a measuring cylinder)* 'I'm going to put I'm going to measure how much coffee there is' *(holding up the measuring cylinder).* Right. That's true (*tapping the cylinder with the other hand).* Why are they going to measure how much coffee there is? *(makes repeated gesture of pouring out from the measuring cylinder)* (indicates Ryan)

Ryan: Because if they put too much in it won't dissolve.

T: Because if they put too much in it...well lets talk about the the, the water, *(miming repeated pouring out of the measuring cylinder)* pouring so if you put, why would you want to measure how much water you use? Why might you want to measure how much water you were using?. *(One girl's hand has gone up)* Kieran?

Kieran: To make it a fair test?

T: Right, to make it a fair test, because if we, used a different amount of water, good, it might change how fa...um! *(looks severely at a child...)* It might change how fast the sugar dissolved, and we don't want that to happen if we've chosen something else to change. ...But it's not really that that we're talking about when we say 'What we're measuring'. *(moving cylinder up and down)* We want to know, what we're going to measure to find out *(stands up and turns to whiteboard)* whether there's any difference in how fast the sugar dissolves *(indicates the question that is written on the board – 'What affects how fast sugar dissolves).* So you might have to measure the amount of water you *(miming repeated pouring out of the measuring cylinder*) used each time, alright. It's a bit of a funny way to write it actually, sometimes I think I ought to change the way that that little bit is written....

She began by establishing the validity of the misunderstanding – noting these other variables will need to be measured - and used Kieran's response to help make the point that, in this case, it is in order to control the variables and so make the test 'fair'. It is not clear how well Kieran really understood this, or whether this was understood by any other members of the class. Clare acknowledges that the terminology is confusing, and by being critical of it, places herself with the children using this imposed system for a moment. This section was followed by a low level disruptive incident by children identified as lower achievers, possibly indicating their lack of understanding of the explanation.

The point about the need to measure the control variables was reinforced in the next section by repetition with different examples, and by the teacher acting out measurement possibilities with equipment.

This episode constructs a version of the processes of science as being rather puzzling and mysterious and in which the teacher is very much the expert. The stimulus for the episode was a child's idea, but it was conducted through an authoritative approach, with little interaction and, hence, little feedback for Clare about the children's understanding.

In our discussion immediately after the lesson, Clare was not happy with how this lesson had gone, she said that there were a number of children who had not understood that only one variable should be changed, and others who were not clear on what to measure. She decided to look at the children's work to see how widespread this difficultly had been across the class and adjust her plans for the following day accordingly. She wondered 'Maybe I had too fixed an expectation', and suggested that 'Maybe that's why some people don't do investigations – it's too messy'. This last comment seemed to refer to the process, rather than to a physical mess.

Afterwards, she reflected on how difficult it was to support children in planning and carrying out investigations, and that, even as a science subject specialist, this was still a challenge for her. She explained that some of the anxiety associated with this is to do with maintaining control of the class and that this is more difficult to maintain during practical work. 'I can see why other staff might not want to do whole class investigations – it's hard to control, all that equipment out...'(field notes 21.01.03). The need for teachers to feel in control of practical work is an issue here – the more diverse the range of activities the children are carrying out, the more challenging the classroom management in terms of equipment and time and similarly, the more freedom the children have to choose their own lines of enquiry, the less the teacher is in control of the direction of the lesson which may feel more threatening to her.

6.11.4 Summary of Lesson 5

In the second part of this lesson, the process of identifying and describing variables is set up as authoritative knowledge – there is a correct scientific way of phrasing variables, using impersonal language and expressing the range of the variable, such as 'the temperature of the water' rather than 'I will make the water hotter'.

An aim of the Goldsworthy and Feasey /AKSIS materials is to help make the processes of science explicit. The intention is that, by creating a shared understanding and vocabulary, the teacher and children will be able to discuss the processes of science as well as the concepts. A positive interpretation of what took place in this lesson is that the children will have a clearer idea about what is acceptable in how to phrase a variable, with the language of science having been made available on the social plane. A possible negative consequence of doing this seems to be that the processes of planning a fair test may become a set of mysterious rules to be learned. This raises questions about defining the processes of science in this way. Does this version of scientific processes being distinct from 'thinking' make dialogic interaction more difficult and construct an authoritative view of the nature of science?

6.12 Lesson 6

In Lesson 6, the children carried out the practical investigation into factors affecting the speed of dissolving sugar that they had planned the previous day. Later in the lesson, the children's findings were reported back to the whole class.

To start the lesson, the children were invited to read the learning objective from the board: 'To plan and carry out a fair test, selecting and using appropriate equipment'. Clare asked questions to ensure that the vocabulary: 'selecting' and 'appropriate' had been understood. Through an interactive/authoritative episode she recapped that fair testing involves changing one variable.

In Episode 3, she asked the children to phrase a question, and make a prediction using the AKSIS 'two part model' that links the independent and dependent variables, for example, 'How does changing the (independent variable, e.g. temperature of the water) affect the (dependent variable, e.g. time the sugar takes to dissolve)?' and 'I predict that the hotter the water the shorter the time it will take to dissolve.' (Goldsworthy et al., 2000).

6.12.1 CS1 Lesson 6 Episode 3-Tighten up that question

During this episode the children had their own plans for the investigation in front of them.

T: Now. It does mean that you're going to have to write just to tighten up that question just a little bit cos, *(takes lid off pen and turns as if to write on whiteboard)* so I'm going to focus on that today, I'm going to show you how to do it. So suppose I was doing that investigations with grains of sugar, right, I want to know what affects how fast sugar dissolves, but cos I planned my investigation now I've got a bit of a better idea what the question I really want to answer is and actually, *(draws on the board 3 'grains' of different sizes while talking)* if I'm using my different sized grains, what I really want to find out is *(writes 'How does changing the' on board as she says it)* How does changing the, What am I changing? How does changing the *(turns back to face class and selects a boy to answer by pointing at him)*

B: The size and the shape?

T: The size...does it… *(turns back to speak to boy)* shall I just put size because the size is the important thing? *(writes on the board 'size of the grains')* How does changing the size of the grains ...change what? affect what? What am I thinking, what am I going to put? *(Turns back to the class and indicates a child with their hand up.)*

C: The time it takes to dissolve?

T: Yeh, the time the sugar *(very slight emphasis)*, the time the sugar takes to dissolve *(writes on the board 'the time the sugar takes to dissolve)…*

The two part pattern of the independent and dependent variables in Lesson 5 is used again here, reinforcing it. Clare selects from this response the part she wants attention to be focussed on – the size of the grain.

Teacher talk dominates this episode, although there are a few opportunities for the children to provide brief answers or feedback by putting their hands up. The communicative approach has been categorized as interactive because of this, but the children's verbal contribution is minimal. It is clearly authoritative in nature with the teacher's view of how to phrase a question correctly being made very explicit. The AKSIS model of supporting children in phrasing questions is very much in evidence. Clare's frequent repetition of the pattern of words reinforces it and her use of the whiteboard, indicating and underlining the two distinct parts of the question – the 'what we will change' and 'what we will measure' - provided a visual means of developing the idea.

While watching this episode on video, Clare became quite frustrated with herself for talking for too long and with her use of repetition (VSRD 31.1.04). In the next episode, the children worked in their pairs to make predictions. Reflecting on this Clare noted how surprised she had been with the difficulty that the children had had in phrasing the question in this way, suggesting that

> ...perhaps it was that whole thing of ... not interactive enough. Cos that was, actually thinking about that section, it was not very interactive is it..?
>
> (VSRD 31.1.04)

Clare then explained to the class that she would be showing them how to carry out the investigation so they could concentrate on doing it and getting the results. In an episode characterised by an interactive/authoritative communicative approach, dominated by triadic dialogue interspersed with teacher exposition, she showed them how to measure out the water and then the sugar, by using level teaspoons, and that using black paper as a background would help them to observe when the sugar has dissolved. The children were clearly getting restless by the end of this demonstration.

The children began the practical activity with enthusiasm, and all the children appeared to be fully engaged with it. There was evidence that a great deal of care was being taken with the measurements – two of the 'lower attaining' children, in particular, were taking a great deal of trouble to use level teaspoons of sugar.

6.12.2 CS1 Lesson 6 Episode 16-The smaller the grain, the faster it dissolves

Episode 16 took place after the practical activity. Its main purpose was to provide a forum in which to discuss the results of the children's investigations. The ways in which different factors affect the speed of dissolving were discussed and there was an emphasis on how to phrase generalisations, again using the two part structure: 'what I changed' and 'what I measured' to support this. There was also an evaluative element to the episode as Clare tried to help the children to reflect on the reliability of their measurements. First, through a series of exchanges with one child she established the way in which she would like results to be presented in the form of a generalisation.

Clare is perched on the ledge in the centre of the whiteboard.

T: Now. Put your hand up if you were thinking about the size of grain, if you changed the size of grain. *(a number of hands go up - 6 in shot)* Mark, what did your, you were lucky weren't you? what did your trio find out?

Mark: uh...

T: can I, can I just, when we're talking about these conclusions, I expect lots of you, *(double open hand gesture)* chose to write your predictions, I think that the bigger the grain, the quicker the, *(following rhythm of speech pattern with a beating hand)* whatever you felt, the bigger the grain the quicker the sugar will dissolve, or whatever you thought. So actually, when we come to say what you found out from the investigation, looking at our results now. You could tell me right, in the same words, rather than, just chop off the 'I think'. Right. Have a go at saying it that way.

Mark: Ur, the castor sugar was dissolved quicker than *(inaudible)*

T: Right, so the castor sugar was the quickest, so thinking about it, was it, was what I said true? Was it the bigger the grains, the quicker the sugar dissolved..?

Mark: *(shook head?)*

T: So how would you say it then?

Mark: Ur, the smaller the grains, the quicker it dissolved.

T: Great, so you found the castor sugar dissolves the quickest.

This section shows an example of how IRE triads have been used to help Mark convert his response, by taking individual cases from his results and comparing them with a generalisation in which the independent variable has been shifted from being the 'type of sugar' to the 'grain size'. By having Mark perform his answer in the acceptable form of a generalisation in the whole class forum, the scientific form of words was given particular value and attention was focussed onto a particular quality of the sugar – the size of the grain.

Clare first modelled the form of the answer she wanted to hear: 'the bigger the grains the quicker the sugar dissolves', and when Mark provides his answer in a different form, that is not a generalisation, she repeats the form of words that she wants, and Mark is able to change one word – bigger, to smaller, in order give the answer in the required form. Clare finishes by affirming Mark's own conclusion by repeating his original form of words back to him. The same meaning has been expressed in two ways: Mark's way and the teacher's way. The 'scientific version' is implicitly favoured as it is the one the teacher has used, and requires the children to rehearse, but Mark's version is also given some value. Later in the episode, the same pattern of phrasing results in a two part generalisation which was again reinforced through repetition. Overall this episode was classified as interactive/authoritative.

Clare then went onto to ask for the results of the investigations that had changed the temperature of the water.

T: Right. Um anybody find something different when they were doing the temperature of water? What did you find out Ralph?

Ralph: that they weren't that far away from each other when the tests were

T: What was

Ralph: The hot was thirty-four point fifty- four, warm was thirty-two point sixty-two, and cold was I minute point fifty-nine

T: Right, so the results were quite close. What was the overall pattern, if you had to say?

Ralph: *(shakes head)*

T: What did you think to start off with? What was your prediction, what did you

Ralph: We thought that the hot water would dissolve it more quickly than the cold

T: and it did, but again, it wasn't, you thought, you thought that there wasn't quite so much difference that you'd want to tell. Part of that is, ideally, what temperature water do you think I'd like to have used as the hot water? Mark?

Mark: Quite hot

T: Quite hot, yeh I needed, can anyone see why I couldn't use really hot water today, why you couldn't use really really hot water? Lily?

Lily: (Inaudible)

T: Yeh, you might hurt yourself. So in actual fact, you might find, if we did this again, and we used really hot water and really cold water then we might have found that the results were a bit different, so we were a bit limited by how much you can do safely in a classroom. Ur, Matt?

Matt: The hotter the water, the quicker it dissolves

T: So you did find the hotter the water, the quicker it dissolved. Well done.

Ralph was keen to talk about the lack of difference in the measurements he had made, and had found no clear pattern. This provided an opportunity to discuss the possibility that his second result was an anomaly, but this was not taken up by the teacher, possibly at this point she was focussed on making sure that the 'right result' was found and so the 'correct scientific view' upheld. This happened when Matt stated his results, in the very acceptable form of a two part structured generalisation, and earned him a 'well done'.

The third section of this episode was spent discussing the results of those who had varied the speed of stirring.

T: Um. Right, stirring speeds, they're the main thing, what did we find out there? *(looks round all the hands that are up)* one two three four five six, I'm going to ask Lily and Daisy cos I didn't talk to them quite so much while they were doing their investigation. What did you find out girls?

Daisy: Um the slow one it was, took the longest, both times, and the medium one, and the fast one was the fastest.

T: Uh huh, so if you had to talk about it, if you had to say, the quicker you stirred it, how would you say, the pattern came out?

Daisy: The quicker you stir it, the quicker the sugar dissolves.

T: The quicker you stir it, the quicker the sugar dissolves. Right. Now

The teacher felt that this episode had been successful in supporting children with how to phrase conclusion, though she qualified this by saying it was the 'more capable' children' who were beginning to do it, and that they were not yet doing it independently.

> ...they hadn't, they quite clearly hadn't got the idea of how to say the conclusions, and they had moved, the later children, they were more capable than the earlier ones, but they had they got it quicker, so I do think they learned.... though they don't necessarily independently do that.
>
> (VSRD 13.3.04)

This episode gradually developed a shared understanding of the scientific form of words on the social plane, by the teacher selecting responses, modelling the desired form of words and supporting the children's appropriation of it.

The lesson was concluded by relating investigation back to the original context of a cup of coffee – what advice would you give someone who wanted their sugar to dissolve quickly? Many children put their hands up to do this, suggesting that the outcomes were understood by the majority of the class. This was conducted through triadic dialogue, and presented an authoritative summary of the results in line with the scientific view, it does appear to have been a summary that the children shared, and was constructed jointly.

In the end of unit test (Appendix 9) the majority were able to interpret a table of results to make some kind of a generalisation about the relationship between the size of a salt grain and the time it took to dissolve. The AKSIS materials say that a 'good' generalisation refers to 'what we changed' and 'what we measured' and comments on the overall general pattern of results (Goldsworthy et al., 2000). Only four of the 33 children produced the 'perfect' responses:

> The smaller the salt piece, the quicker it dissolves (Annie)

However, there was evidence that 23 of the other 28 children were in the process of appropriating this special scientific language. Most children (10) used variations used elements of the 2 part pattern, and some generalisation, such as using the comparative forms, for example;

> If you have bigger pieces of salt, its slower to dissolve, if you have smaller pieces, it is faster' (Matt)

Four children followed the two part structure, but were also providing an explanation rather than a description of the results with reference to the dependent variable, for example;

> The smaller it is, the less it has to break down. (Mark)

Only two children did not give a response and those who did not use the two part structure provided an example at the extreme of the independent variable rather than a generalisation:

> Because if it is big it will have to be stirred longer. (Sam)

Considering the few children who took an oral role in the whole class discussions this widespread confident use of the two part pattern suggests that it is not verbal participation in whole class discussions that is important in learning. Possibly the pair work was important, or perhaps it was repetition of the pattern in different contexts throughout the lesson. Lemke (1990) discusses how it is important for children to practice using the patterns of the language of science orally and in writing, but also that they should be given opportunities to formulate phrases in different ways, in different contexts, in which they are using the meanings and semantic relationships between the words rather than reciting the formula. Alternatively, from a Piagetian constructivist view point it may be that the practical work led directly to this understanding of the relationship.

After the lesson the teacher said:

> I felt it was better, it was tighter. They were organised and good science came out of it as well'. At one point P was stirring the water and asking 'why does this happen?' – that's how it should be.
>
> (CS1 field notes book 1 p. 116).

My impression during the lesson was that both the teacher and children had felt more relaxed (CS1 field notes book1 p. 112.) The tight framing of the lesson in terms of organisation and teacher control of aspects of the investigative work, may have contributed to a working atmosphere that felt safe to everyone in the room.

Children's ability to plan and carry out an enquiry can often limit how useful they are in developing scientific concepts (Harlen and Qualter, 2004). This highly structured approach is more likely to generate data that are in line with the scientific version, but there was no evidence that children were developing their conceptual understanding of factors that affect dissolving through this lesson as there was no evidence of their initial understanding. Rather, the main purpose of the lesson was to explore the relationship between data and making generalisations. The teacher expressed a view that it is preferable have an approach to teaching scientific enquiry that is about teacher 'modelling' aspects of investigative work and children applying this, rather than an alternative model in which the emphasis is on more iterative cycle of children devising their own investigations and evaluating these. Although these models are not necessarily mutually exclusive, in terms of making a decision about how to use the limited time available, a choice has to be made, and the modelling approach may appear to be more time efficient.

> I strongly believe that you can't teach all the skills in an investigation at once.You need to have all those things, some discussed, some given and you must be clear about which parts you want the children to think about. I don't want to go back to the days when you write up the whole thing. An investigation is a big thing, and you can't expect them to do it all at once.
>
> (VSRD 13.3.04)

My concern is that the dominance of an interactive/authoritative communicative approach in association with the processes of science is that it provides a limited model of how science develops knowledge, supporting a naïve empiricist view. It does not support children in developing the more discursive and creative ways of thinking about science that are supported by dialogic talk.

6.12.3 Summary of Lesson 6

Interactive/authoritative episodes appear to have been successful in enabling children to appropriate the procedural language of science. It also led to the opportunity for some children to discuss sophisticated issues of validity. However it also has the effect of constructing an authoritative version of the nature of science that is distanced from a motivating drive to seek answers to interesting questions.

6.13 Lesson 7

Lesson 7 was a worksheet (Feasey et al., 2001, pp. 21-2) based lesson, with the aim of learning how to construct graphs from a table of results, in particular with learning how to decide whether a line graph or bar chart is the more appropriate. The context was that these results had been produced by fictional children, one investigating dissolving different kinds of salt, and the other investigating the effect of changing the volume of water on how fast salt dissolved. So this was very similar to the practical work on sugar the children has carried out in lessons 5 and 6. The lesson was structured in two phases, each beginning with interactive/authoritative episodes in which Clare explained different aspects of the task and checked the children's knowledge and understanding of detail such as how to label axes correctly and choose a scale. There were no dialogic episodes in this lesson.

6.14 Lesson 8

In terms of some of the concept-led constructivist models (Scott et al., 1987; Ollerenshaw and Ritchie, 1997), lesson 8 can be understood as 'application'. Ideas the children has developed in previous lessons about solutions, evaporation and condensation were to be applied to new contexts: in the first half of the lesson (episodes 1-17), to thinking about the water evaporated from a saucepan of boiling water cooking cabbage, and secondly, to a problem solving scenario of explaining how it might be possible to obtain water in a desert using certain equipment (episodes 18-26).

Through an interactive/authoritative episode she was able to gauge that her previous assessment of the children's understanding had been over optimistic – the children had more difficulty in applying their understanding of dissolving, evaporation and condensation that she had anticipated as was evident in their discussion about the 'cabbagy water' in the lid, rather than expecting it to be pure water.

> ...I almost thought we didn't need, once we'd done the crystals investigation, that this was all just so much padding, and that you know, they didn't really need this, but they just hadn't.. I just think still they thought that um ..perhaps some of it was being taken away by the water..(VSRD 13.3.04)

Clare responded to that assessment through interactive/authoritative episodes, drawing on children who had understood the concept to rehearse the explanation on the social plane of the class.

In the second part of the lesson another problem was posed to the children: how to get water in the desert using a rock, a plastic sheet and a bowl. They were shown a using a cross sectional diagram on the whiteboard to show how it could be set up, and asked to try and explain how it might work. Again the strategy of discussion in pairs followed by whole class discussion was used.

6.15 Lesson 9

The purpose of Lesson 9 can be understood in terms of the concept –led social constructivist model as being an 'application' of both conceptual understanding of evaporation/condensation and solubility and filtration and practical knowledge and skills. Clare posed a question that that occurred to her; how might instant coffee granules be manufactured from coffee beans? This question was 'real' in that it is not part of the usual repertoire of primary science investigations and she was very engaged by it.

> It was kind of the assessment really, I think, in so far as you know it was applying, applying things to a different context...Applying two skills really in one wasn't it , yeah, the.. about filtration, and evaporation. So its assessing practical skills in a way, will they all remember how to use their filter and what they use it for ...and seeing whether they can actually relate skills to a different context. (VSRD 13.03.04)

She made it explicit to the children in the opening episode of this lesson, that they had developed all the skills and understanding they would need to tackle this question in the unit of work so far. This seemed to serve the dual function of being both reassuring and challenging.

Before introducing the problem more fully, there were several episodes (2-8) in which the key terminology and definitions of the unit of work were reviewed. These presented challenges in terms of defining the communicative approach as the children seemed to have taken ownership of the ideas, so although they were the scientific ideas, mostly expressed using the level of scientific vocabulary and phrasing the teacher was aiming for, they also belonged to the children. Categorising the episodes as dialogic, or authoritative became more problematic as a shared understanding was constructed and 'handover' (Bruner, 1983) or appropriation (Rogoff, 1990; Mortimer and Scott, 2003) had apparently taken place.

6.15.1 CS1 Lesson 9 Episode 2-We're going to do a dictionary

The episode began with an authoritative voice as Clare implied that she will be assessing the children's understanding of certain terms.

T: *(sitting perched on ledge in front of whiteboard)* Just to, what we're going to do is a dictionary, right, and I'm going to put a word here *(stands, indicating board)* and you're going to talk to the person next to you, and see if you can come up with what it means. There are some words we are going to need, before we even talk about what we're going to do today. OK so the first one.. *(writes 'filter')* is ..'filter'. Right, what is it, what to we do, or what happens when we filter something. *(children begin to talk in pairs, some put their hands up almost immediately)* And why would we do it?

This paired discussion can be compared with lesson 1 in terms of the structure of episode. In lesson 1 there was a very clear distinction made between the whole class time and the paired talk time, in this lesson they blended together more, with the children beginning to talk before the teacher stopped and told them to, and the teacher saying something over the children as they talked. This might be a further outcome of the children's appropriation of the knowledge and the teacher's 'handover' (Bruner, 1983).

T: OK, lets see, who's got an ideas of what filtering is, *(many children are still talking at this point)* if you don't know, it doesn't matter, cos that's part of the reason we're going over this, to check we do. *(all children have now stopped talking)* Jo.

Sam: Um, to stop the dirt going through, into the the filtered stuff you're going to drink.

T: Right. So its to stop dirt going through into the stuff you're going to drink. Edwin

Edwin: To separate a solid from a liquid.

T: Good, *(indicates another child)*

C: Cleans water

T: Cleans water. Yep, good. Ben

Ben: I was going to say the filter on the (inaudible) *it* has like um sort of black charcoal inside it

T: Right

Ben: that cleans the water and some bits come out and it

T: Brilliant. So the filter bit, what does the filter keep in it? Whatever kind of filter you use? *(indicates a child)*

Ben: Er, everything apart from the water

T: Everything apart from the water. *(double open hand gesture)* Everything apart from the liquid hopefully will stay in the filter. OK

Five different children have expressed their conception of filtering, all in slightly different ways, and these ideas, together with the contribution and prompt question from the teacher: 'What does the filter keep in?' established a meaning of filtering on the social plane that would be accessible to most children in the class. The language used moved between the everyday – 'stops dirt going through into stuff' and scientific 'to separate a solid from a liquid' with the teacher using both and children contributing to both.

This episode had dialogic elements in that Clare accepted a range of the children's ideas about filtering, rather than looking for a single definition, and Ben introduced his own experience of filtration, from outside of the classroom and this was welcomed. But Ben's contribution was not pursued, possibly because Clare was keen to abstract the general features of filtration rather than focus on specific examples and so the authoritative view dominated. In spite of the teacher's evaluative responses the tone was of recap of shared knowledge rather than of teacher assessment – although the ideas being expressed were in line with the curriculum aims, this is because they had become shared.

A similar, but shorter process took place for the words 'sieving' soluble and solution. In episode 8 there was a further shift towards the children's ownership of this process of defining words, of claiming them, as the children proposed the words that should be included in the list, though Clare retained the right to affirm this by making evaluative responses to their offers.

6.15.2 CS1 Lesson 9 Episode 8-Are there any other words?

T: Um, ..Well you tell me, are there any other words I might need to put up there? Andrew?

Andrew: Condensation

T: Condensation *(writes this on the board)* and..I'm going to ask Andrew as well to tell me what it means then

Andrew: A gas turns into a liquid?

T: Good, a gas turns into a liquid. Any other words? Luke?

Luke: Dissolve

T: Dissolve *(writes 'dissolve' on the board),* Good. So, what does that mean Luke?

Luke: When a solid dissolves, when a solid mixes with a liquid..

T: nods, yeah it breaks up, and can you ..Sam, anything to add to dissolve

Sam; Oh, Insoluble

T: Oh, you want to add an extra word. I'll let you do that in a minute. Nick?

Nick: I was going to say insoluble.

T: You were going to say insoluble as well. Good, well, lets put that one up. *(writes ' insoluble' on the board)* That kind of goes with ..

C: soluble

T: soluble…this is really great. I really am very pleased with this, so..hand down a minute, Angie cos you've had a turn haven't you? Sam, are you going to tell me what insoluble means?

Sam: Um, ..a solid wont dissolve into a liquid.

T: Right, good, when a solid doesn't dissolve in a liquid its insoluble.

In this episode the children are taking the lead in shaping the direction of the dialogue, although Clare resisted this when she wanted to clarify the meaning of dissolving further. At the time I wrote: 'Hands up unprompted' (field notes 3.2.04) to capture the way in which the class were eager to participate. Although Clare was evaluating the children's ideas with a 'good' and she was sometimes adding to what they have said, this seems to be in the spirit of articulating and recapping shared knowledge rather than testing individual recall. There is evidence of some development of the ideas of one child here: in Lesson 1 Luke explained dissolving as 'disappearing' and now he is saying it is 'when a solid mixes with a liquid'. That the children and the teacher were on a shared intermental plane is supported by the way in which a child finishes the teacher's sentence with the word 'soluble' (Mercer, 2000).

The children's ideas are in line with the scientific view so there is no need for intervention, and in that sense there is a single voice – the authoritative scientific voice - being heard. The episode is still authoritative in that the teacher is evaluating the children's responses. The children and the teacher have produced a summary together through this interaction. The term 'authoritative', is in some ways unhelpful here, as it has overtones of teacher authority rather than the children's authority over the knowledge and thus negative connotations that don't fully capture the shared aspect of the knowledge. It can be seen as stage 2 in Mortimer and Scott's view of the stages of appropriation (Mortimer and Scott, 2003, p.115): the children see the idea as half their own and half belonging to others and the teaching purpose is to support the children in working with the new ideas.

In the next phase of the lesson Clare demonstrated how to make coffee in a cafetiere and introduced the problem to the whole class – how could ground coffee be turned into instant coffee granules? The children worked in pairs to plan how they would go about solving this problem. In brief whole class episodes in which Clare responded to her talk with pairs or individuals as she circulated by sharing the response with the whole class. These related to matters such as the available equipment or how they could present the work as a series of instructions. Towards the end of the lesson, the children were asked to feedback their ideas to the class.

6.15.3 Summary of Lesson 9

There are features of lesson 9 that indicate it fits into the 'review' and 'application' phases of the concept-led social constructivist model. The children's ideas are part of the dialogue, but they have developed from the start of the sequence of lessons and the ideas being expressed are now mostly in line with the scientific version, or at least, with the primary science version. The children have been given more control over the direction of the discussion. It raised questions about how to use the terms 'dialogic' and 'authoritative' as children appropriate the scientific ideas.

6.16 Lesson 10

In Lesson 10 the children worked in pairs to carry out their plans for how to make 'instant coffee' from ground coffee. The first episode was a non-interactive/authoritative recap on the sequence of actions that was planned in lesson 9. The children asked some questions about the organisation of resources and then began the practical work.

Clare made very few breaks for whole class discussion during this time when compared with the early lesson in the sequence, which were characterised by short episodes. This may be evidence of 'handover'. However an alternative interpretation is possible, as one effect of the VSRD was that the teacher became aware of the way in which she was using whole class teaching and decided she would try to leave the children uninterrupted for longer periods of time.

> The only thing I have thought it has made me reflect on is really sort of practical things like not stopping too often. One thing I was really very aware of in the first couple of lessons was that because, not because of, because of what I hadn't done in the sort of input, I was having to stop them too often, and that's incredibly frustrating I think for the children,..
>
> (VSRD 13.04.04)

The atmosphere was purposeful and the children mostly seemed to have a clear sense of what they were trying to achieve. Clare felt that the lesson had been successful, explaining that if she had gone through all the practical skills with them again at the start then: 'I'd never have known if they could do it' (field notes 04.02.04). This assessment of practical skills was an important part of the lesson for her, but this was done as informal observation, rather than as a systematic record of what each child had done.

The lesson concluded with an interactive/dialogic whole class episode when some children explained to the rest of the class how they had gone about planning their reports.

6.17 Lesson 11

Lesson 11 was not observed. In this lesson the children carried out pencils and paper summative assessment tests from the Ginn New Star Science scheme (Feasey et al. 2001 pp. 25, 27, 28) in silence. The results from this test have been analysed as part of the evidence of children's learning and referred to in Lesson 6 (section 6.12.2).

6.18 Lesson 12

The main focus of Lesson 12 was writing a report on how they had made their instant coffee granules. Clare felt that this was not so much a science lesson as a literacy lesson. However, the first episode involved a summary of the key vocabulary and ideas of the topic and formed a 'thematic nexus (Lemke, 1990) in drawing together the different strands of the topic.

6.18.1 CS1 Lesson 12 Episode 1-You know, actually you're not wrong

T: We've thought a lot about dissolving this term, we have thought a lot about things that are soluble and insoluble. We've thought about how to get back solids that are insoluble. How might we do that, if we had a solid that was insoluble mixed up with a liquid, how would we get it back? *(6 visible hands go up)*

C: Pour the water out?

T: We could pour the water out. *(intonation shows that the teacher accepts this)* What if it was so mixed up with the water that you couldn't separate it that way?

Annie: You could put it on the window sill and leave it for the water to go.

T: You know, actually you're not wrong Annie, you could do it that way. *(intonation suggests that this wasn't the answer the teacher had in mind,* *but it is a good idea)* But if you wanted to do it more quickly than let the water evaporate, how could you do that? Cos that would work…Yeh

C: You could filter it.

T: Yeah, you could filter it, or you could sieve it if the lumps were big enough couldn't you. But you're not wrong Annie, it would just take longer.

OK If we had a solid that was soluble in a liquid, and it was mixed up, up would we separate that out from the liquid?

C: Let the water evaporate

T: Yeh, let the water evaporate, which is exactly what you said *(to Annie)*, its just that we can't use a filter or a sieve, the quick way, with solids that are soluble. OK.

The pattern of interactions is IRE, and for this reason the episode was coded as interactive/authoritative. The children's responses demonstrate their understanding of the physical processes and properties, but it is also evident that they haven't leaned what kind of answer is being looked for in each case. Clare's response supports the scientific version, but also points out how there might be a better answer. As discussed in lesson 9, the label authoritative does not entirely capture the children's appropriation of the scientific knowledge.

6.19 Teacher Validation of this Case Study

Wow - reading that threw me back five years! - initially when I read all the descriptions I thought - what a controlling teacher I was! I can't argue with it's authenticity - I could almost see the lessons again. I do hope that some of the teaching style came from being heavily influenced by pressure for short term gains in knowledge and understanding. Also made me a bit frustrated with the impact SATs had on my teaching! Makes me realise also how many different influences there are on your style of teaching - would like to think I'd be a bit less authoritative now ... Very much "rings true"!! ...not everything in those lessons was done because of a pure, philosophical belief that that was the "best" kind of teaching there is (lots of pressures on the kind of teaching that one delivers)- from a professional point of view gives me plenty to think about and perhaps amend in my style of teaching in the future.

(Email communication 14.6.09)

6.20 Summary of Emergent Themes of Case Study 1

This summary draws together the insights of episode, level and sequence of lesson level analysis to comment on the use of the different communicative approaches in case study 1 and then summarises some more general emergent issues from the case. This addresses the research sub questions:

> *What is the nature of interactions within whole class interactive teaching in science?* and
> *How are teachers using 'interactive whole class teaching' in science lessons and to what extent is this consistent with the models of practice in the literature?* and
> *How does 'interactive whole class teaching' contribute to teaching about the nature of science and scientific processes and scientific knowledge and understanding?*

6.20.1 Interactive/Authoritative.

The dominant communicative approach in case study 1 was interactive/authoritative.

a. Interactive/authoritative episodes were frequently associated with review and recapping of conceptual ideas. This is in line with the proposition that they may have the role of 'maintaining the scientific story' during whole class teaching (Scott, 1997).

b. During some interactive/authoritative whole class episodes children were given the opportunity to practise using the same scientific terminology in a variety of contexts. This supported children in learning to speak the language of science (Lemke, 1990).

c. However, in this case study the high proportion of time spent in this communicative approach also led to the construction of a version of science in which the dominance of the authoritative 'scientific story' was perhaps overstated and children were not given much opportunity to link it with their everyday experiences and own ideas.

d. There was evidence that the teaching of science skills in interactive/authoritative whole class episodes led to careful accurate practical work – which can be seen as valuable as an end in itself, and meant the children were more likely to have results that were in line with scientific theory, making the process of linking ideas and evidence more productive (Harlen and Jelly, 1989).

e. An interactive/authoritative communicative approach was used when aspects of process of science were taught in an 'atomised' way; they were considered as distinct parts of the whole in line with the procedure-led social constructivist model of teaching science. Use of language of the processes of science was both modelled and made explicit and the children were given frequent opportunities to practise it. This seems to be in line with Lemke (1990)'s ideas that 'talking science' should be taught. However, where authoritative interactions were associated with the processes of science this also had the effect of constructing a version of science as a set of correct methods, rather than as a creative process of exploration and experimentation.

6.20.2 Non-interactive/Authoritative

Non-interactive/authoritative episodes often occurred before and during practical activity. Recognising the need of the teacher to maintain control of the class, using this communicative approach seems to support the teacher in being willing to have practical activities in most lessons, an important consideration given the constructivist assumption that hands-on experience is of vital importance in learning in science. However, tight control leading to lack of independence in practical work limited the opportunity for children to follow their own lines of enquiry which was not in line with the concept –led social constructivist models of teaching. This both limited the possibility of them applying their understanding of scientific processes and contributed to constructing a version of science as dominated by existing authoritative ideas, and not as led by new questions.

6.20.3 Interactive/Dialogic

a. There is the highest proportion of interactive/dialogic episodes in Lessons 1 and 2. This is in line with the concept-led social constructivist model of teaching as it suggests an emphasis on finding out the children's ideas early in the sequence of lessons prior to intervention. Dialogic whole class interaction supported elicitation by making it acceptable that a range of different ideas can exist. There is no evidence of elicitation of children's conceptual ideas being used to determine the planned activities as in the concept-led social constructivist model – it is not the nature of the planned activities that changes in response to elicitation but the nature of the discourse around them.

b. Interactive/dialogic episodes were also associated with discussions about the outcomes of practical work. The teacher saw relating the outcomes of practical work to scientific knowledge and understanding as an important purpose of interactive whole class teaching. In these episodes the ideas of other children and of science were made available to the children and the teacher on the social plane. At points in these episodes the teacher selected parts of children's ideas as being in line with the scientific story, by marking the relevance of aspects of evidence, and providing alternative possibilities so there were authoritative aspects within them too. It was mainly the higher attaining children taking part in these exchanges. The teacher saw this as a form of differentiation in that during non-whole class time she spent more time with lower attainers. She also saw it as a means of setting high expectations for all children. However, the dominance of some children may have created a message of the exclusion of the other children from science.

6.20.4 Non-interactive/Dialogic

I defined episodes in which the teacher talked about certain children's ideas, or short episodes of pair discussion, or 'talk partners' within a whole class section of the lesson as non-interactive/dialogic.

Talk partners were used for children to express their own ideas at the start of the topics linked with orientation and to practice phrasing sentences in the 'scientific way' presented by the teacher, this latter aspect being related to application. The use of talk partners supported wide participation (Moyles et al., 2003) and provided children with the opportunity to try out their ideas, but also rehearse their use of scientific language in a 'safe' context (Lemke, 2001).

6.20.5 Use of Whole Class Teaching

The case is characterised by short episodes created by the frequent use of talk partners and to the frequent stopping for 'checkpoints' during practical activity. So although the lessons often have a loose three part structure shaping the lesson, the use of interactive whole class teaching within this is more complex than the discussion at the start and end of the lesson suggested in the literature.

There is possible evidence of 'handover' over the sequence of lessons. The proportion of whole class teaching that was interactive increased somewhat in the latter half of the sequence of lessons while the proportion of whole class teaching decreased somewhat during the sequence of lessons. The episodes at the start of the sequence of lessons tend to be clearly defined by teacher signals, whereas later in the sequence the distinction tended to be less clearly defined. Alternative interpretations are that it was the result of the impact of teacher reflection on her teaching resulting from the VSRD or just that different lessons varied in approach and the pattern is incidental.

An awareness of these emergent themes will inevitably have informed my observations and interpretations of the second case study, but I also wanted to capture a holistic sense of each case and so they were initially seen as parallel rather than progressive. However, there were some adjustments to the analytic framework as an outcome of case study one and these are discussed in the next section.

6.20.6 Adjustments to Analytical Framework Taken Forward into Case Study 2

In the analysis of this case I identified several examples of where multi-modal communication (Kress et al., 2001) contributed to the communicative approach. For example, an open hand gesture and teacher's informal sitting position contributes to signalling that the episode is to be dialogic. In making field notes for Case Study 2 I paid more attention to gesture and position in the room and in the analysis of episodes for the case records explored further the role multimodal communication.

In the development of this case study I moved away from the in-field coding of the purpose(s) of each episode developed from Moyles et al. (2003) (section 5.7.2.1) Instead, post-field analysis of episodes generated an emergent understanding of the purpose of each episode that was embedded within the case.

Chapter 7: Case Study 2

7.1 Introduction

Taking a similar structure to the previous chapter, this chapter first explains the context of Case Study 2, considering the school, the class, and the teacher. The teacher's ideas about the nature of science and teaching and learning science are explored. The main body of this chapter goes on to construct the story of the lessons that took place, considering the sequence of lessons as a whole and presenting a more detailed analysis of selected episodes. Emerging themes are summarised at the end.

7.2 The School

The school was located in an area of a city that included both expensive private houses and social housing and the children attending the school had a wide variety of social backgrounds (Ofsted, 2002). It was regarded by Ofsted (2002) as having very good teaching, with above average achievement in science and a strong emphasis on experimentation and discovery.

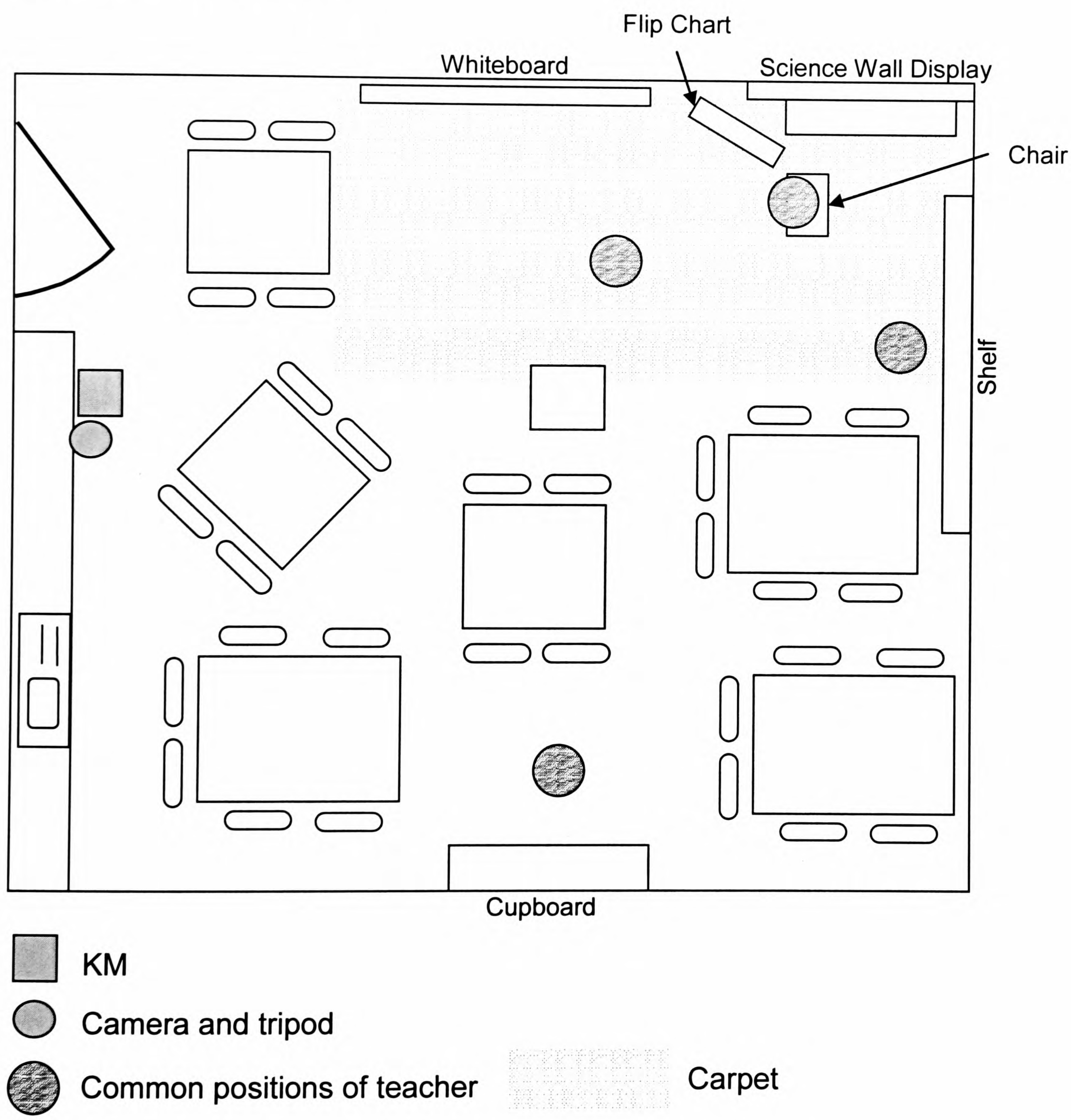
7.3 The Class

The class was made up of 33 children in Year 3 (7-8 years). The teacher described the class as being very responsive and as including a large number of very articulate children, some of who had parents who were scientists.

The classroom was arranged so that there was a carpet area at the front of the room, with a large whiteboard at the front defining the front of the room and a flip chart frame that also functioned as a smaller whiteboard and was next to the teacher's armchair at one end of the carpet. In the rest of the room the tables and chairs were organised so that the children sat in groups, with the children facing in all directions (See Figure 7.1). These table groupings were used flexibly during the science lessons; the children did not have fixed places in which they sat. A notice board on the front wall had been devoted to the topic and was added to during the topic. The majority of the lessons took place inside the classroom, but in lesson 7 the children went onto the school field and in lesson 8 the class went out onto the playground for a short time.

The topic was 'Helping plants grow'. In terms of its learning demand (Leach and Scott, 2002) the content was largely empirical; much of the content relates to the visible effect on plant growth of factors such as the amount of water or light provided. The vocabulary was similar to everyday vocabulary, using terms such as 'roots, leaves and stem. The National Curriculum (DfES, 1999) does not require a theoretical account of photosynthesis for Key stage 2, but does include 'the role of the leaf in producing new material for growth', which is not directly accessible to first hand experience. However, for this year group the expectations were not this high, and focussed on factors affecting plants growth. However, the movement of water through a plant was included in the teacher's planning and this is not directly observable.

Figure 7.1 Classroom Layout #2



7.4 The Teacher

The teacher, Anna, described herself as being used to being observed in the classroom, and that the children were also used to having visitors observing lessons. At the time of this study she was in her third year of teaching. Anna's first degree was in fine Art. She had done GCSEs in science – biology and physics and chemistry combined, but says that she was 'turned off science at school' having felt that she 'didn't have the ability to do it and I wasn't scientifically minded' and 'science at school was scary' (field notes 20.03.04)

Anna's initial teacher training had focussed on the Early Years and she expressed the view that teaching in the rest of the primary phase should be more like the approach taken in early years teaching; 'keep discussion and the children's interests alive' and that teaching in Key Stage 2 could be 'too formal' (field notes 20.03.04). She explained that:

> When I do my own art it's to do with exploring, intuition, finding out, and it's a similar process that you go through with science, you know; starting with a question and exploring it, it's just done in a very different way, though I'm not sure that it has to be... it's about trying to question the world and make some sense of it.
>
> (field notes 20.03.04).

I met Anna during a science subject leadership course that was I leading. She expressed the idea that she was hoping to learn from the process of reflecting with me on her teaching. However, she was confident in her own ideas about teaching and learning in general and was happy to express her own opinions.

7.4.1 The Teacher's Ideas about Science

In response to the statements' based on Lunn (2002) the teacher agreed strongly that 'All scientific knowledge is tentative' saying that in science ideas change. She repeatedly emphasised the role of intuition and imagination in science, for example;

> And this one as well I agree with [*science is rooted in attempts to construct explanations, which originate in speculation and imagination*']. I think that's

> really important; imagination and being inspired by something, then the processes you go through.
>
> (interview 20.3.04)

She didn't entirely agree with the statement: 'Scientific method will lead to the truth', saying; 'I just think there's lots more than science that gets to the truth'. But she disagreed that 'Science has no claims to specialness and is no more likely to be true than common sense', explaining her view that the processes of science help scientists to be more objective, but that they could never actually be completely objective.
(interview 20.3.04)

In terms of Lunn's characterisation of teacher's beliefs about science her dominant ideas were constructivist: about science as one way in which humans attempt to make sense of the world and as being rooted in imagination and speculation.

7.4.2 Teacher's Ideas about Teaching and Learning Science

This section directly addresses the research sub question:

> *What are teachers' understandings of how 'interactive whole class teaching' contributes to their teaching of science?,*

by presenting the views that this teacher espoused about the teaching and learning of science and the role of interactive whole class teaching within this. As in the previous chapter, a more contextualised account of the teacher's understanding of the role of interactive whole class teaching is embedded within the case study itself as they reflect on their lessons and on the episodes presented for VSRD.

The school in which Anna works placed a strong emphasis on developing collaborative group work and the teacher shared this commitment. She decided on learning objectives for collaborative group work to run in parallel with the science topic aims and in this unit aimed to develop the child's skills of planning, sharing ideas and giving constructive feedback.

She had a positive view of ideas about 'constructivist' approaches to teaching encountered on her PGCE in the context of 'scaffolding' – which she defined as:

> listening to a child, taking a child centred approach, by using their ideas and then trying to bring in the ideas that I've brought in. (field notes 20.03.04).

She placed an emphasis on questioning, dialogue and reflection, explaining that she tries to use questions to 'shape' the dialogue so they are looking at 'bigger ideas'.

She explained that she used whole class teaching at the start of every lesson, usually assembling the children on the carpet area because:

> They are still years 3, they are young, it helps with listening, eye contact and keeps them engaged – there is nothing for them to fiddle with. (field notes 10.2.04).

Although said that although she liked the 'containment' of having the children on the carpet, for the plenary that she always had at the end of the lesson, she would hold this with the children in their seats to save the time that would be spent moving. She added that she would sometimes stop the class during an activity either for time management, or 'if someone has come up with something and you want to share it with the whole class' (field notes 10.2.04)

Anna explained that she saw practical work as very important, that children should have time to explore equipment and that children should have autonomy in making decisions and choices. Her ideas were in line with the concept-led social constructivist models with the emphasis on eliciting children's ideas and then planning interventions in the form of practical activities and dialogue:

> At the beginning you need to unpick their ideas – talk and question, then go into practical work and questions are more carefully chosen. Practical work is also a dialogue with the materials.
>
> (field notes 20.03.04)

However, she also favoured the procedure-led approach in which specific process skills are identified as the focus of teaching:

> I've done team teaching now with three different classes using those kind of ways of learning, and its just so successful.
>
> (VSRD 3.6.04)

She said that the literacy and numeracy strategy had influenced her in always starting together as a whole class and having a plenary, but reflected that perhaps this wasn't always needed. For her the word interactive implied that it was 'a shared thing' and that the role of the teacher was not to tell the children what to do, but to be reflective and to help to shape the direction of the discussion. She saw using talk partners as part of interactive whole class teaching. Her view was that whole class discussion supported a collective understanding:

> I think it (discussing as a whole class) gives it a lot more because you're hearing, the whole class is then hearing, similar ideas and then maybe the odd, so they're kind of getting this idea that they are all thinking along the same lines, so we get this collective idea about what's going on.
>
> (VSRD 3.6.04)

7.5 Analysis at the Level of the Sequence of Lessons

There was sequence of 8 lessons, mostly taking place on Thursday afternoons, but with some variation which is shown in Table 7.1. The first six lessons ran up to the Easter holiday and the last two were in the first two weeks of the summer term. The length of the lessons varied from 50 minutes to just over 2 hours. Overall, this is what Alexander (2000) characterised as a 'flexible' way of structuring lessons.

Table 7.1 Summary of Content of Lessons in Case Study 2

No.	Description of lesson
1 Thursday pm 60 mins	Raising questions about plants Concept maps about plants in pairs Annotating prepared statements about plant growth with children's ideas
2 Thursday pm 57 mins	Whole class identification of variables for a fair test on what a plant needs to grow well using AKSIS 'post-it planner' approach. Discussion on the meaning of a fair test. Children work in pairs to plan a test into plant growth.

3 Thursday am 50 mins	Explanation of fair test as 'taking one thing away' from everything the plant needs Children work in pairs to make their own choices of which variable to 'take away'. Make oral predictions about the outcome.
4 Thursday pm 1 hr, 48 mins	Class discussion to identify 'what we could measure' Pairs identify what they will measure, units of measurement and equipment they will need. Children plant their seeds in pots Children are helped to decide where to put their two pots
5 Wednesday pm 1 hr, 7 mins	Children handle a range of fruit and vegetables at their tables and decide whether each has leaf, root, stem. Feedback on carpet and discussion about which parts can be eaten Where would the water go in celery? – observing and drawing a cross section – 'veins' (tubes) Children set up celery sticks in water and food colouring
5b Thursday	Unobserved short lesson – looking at outcomes of celery activity
6 Thursday pm 1hr, 22 mins	Looking at outcomes of fair tests on plant growth and interpreting and evaluating the results. Making observations in pairs. Feedback to the class as a whole what happened to those that had light, different amount of seeds, , temperature, then water. A 'concept cartoon' stimulated group and class discussion about why plants need leaves. Use a set of 'made up' results to work out what happened and make a prediction
7 Friday pm 2 hrs, 3 mins	Year 6 children work with the class. Children observe and measure their plants. In groups discuss with the Y6s why leaves matter to plants. Each table feeds back their observations and ideas. Go outside to observe variety of leaves – discuss these as groups. Back inside the groups make a poster reflecting their observations and ideas about the role of leaves.

	Posters are presented to the class.
8 Wednesday pm 1hr, 57 mins	Pairs review their initial concept map and annotate them maps with any changes in ideas. Use photographs of themselves doing practical science work and reflect on skills and process they used and developed. Make a poster using the photos and adding dialogue to explain what was happening. Feed these back to the whole class. In the playground move along a line to agree/disagree with different statements about plants.

7.5.1 Analysis in Relation to Models of Teaching Science

The teacher had devised a medium term plan for the topic based partly on the QCA Scheme of work 'Helping Plants Grow Well' (QCA, 1998) and Ginn New Star Science (Feasey et al., 2001b). The overall structure of the initial written plan was in line with the concept-led constructivist models of teaching in that the sequence was to begin with an elicitation of what ideas children held about plants through and through this generate a question to investigate. The teacher saw this investigation into plant growth as the core of the topic by providing the children with experiences to draw on;

> ...but also gives them a sort of ownership over what's going on. There's that strand of something running all the way through, every session has got a kind of meaningful link back to something,...
>
> (VSRD 3.6.04)

The procedure –led constructivist model was evident as the children were to plan fair tests into plant growth using the 'post-it' planning approach (Goldsworthy and Feasey, 1998) and a planned activity involved the use of pre-prepared data to analyse as a worksheet based task. Other planned activities were considering the parts of different plants that we eat, and making observations of celery stalks put in coloured water, drawn from the QCA scheme of work, apparently to develop children's ideas of the relationship between roots, stem and leaf and the flow of water within a plant. The planned sequence concluded with a review of how the children's ideas had changed, very much in line with the concept-led constructivist models. Anna explained that she did not see the plan as fixed and that the lessons within it might change:

> I like the freedom of not being tied into a specific learning objective for a lesson the ones we need to revisit we can tap back into - it's there as an overview of what I'd like to achieve over the whole time. (Field notes 4.03.04)

However, unlike the concept-led social constructivist models there was no suggestion that different children would undertake different activities in response to the elicitation. The children did choose to investigate different variables affecting plant growth, but there was no clear link between this and their existing ideas. Instead the assumption was that the plan would be changed for the whole class. In the case two additional lessons were developed; one in response to difficulties the children had with planning their tests using the 'post-it' approach and one in response to the teacher's assessment that the children could be introduced to higher level concepts than anticipated and so some older children were invited to work with them to develop some ideas about the role of the leaf in photosynthesis. The medium term plan identified focuses for 'whole class work' and a 'plenary', distinguishing these from group activities.

7.5.2 Communicative Approaches Adopted Across the Sequence of Lessons

As for Case Study 1, an indication of how the communicative approach (Mortimer and Scott, 2003) during whole class teaching varied across the sequence of lessons has been calculated by multiplying the length of the episode by the dominant communicative approach used during that episode, as shown

Table 7.2 Percentage of Lesson Time Spent in Whole Class Teaching Subdivided by Communicative Approach

Lesson	**Percentage of lesson time spent in whole class teaching in each communicative approach**				
	ID	**IA**	**ND**	**NA**	**Percentage of lesson time spent in WCT**
1	44	12	6	13	75
2	43	2	8	12	65
3	35	10	3	13	61
4	5	32	2	26	65
5	32	10	0	16	58
6	49	15	4	8	76
7	34	4	0	23	61
8	37	8	1	12	58

Key:

WCT	whole class teaching
ID	Interactive/dialogic
IA	Interactive/authoritative
ND	Non-interactive/dialogic
NA	Non-interactive/authoritative

There is a high proportion of whole class teaching in the lessons 58 – 76%, compared with the 50% found by Galton et al. (1999), again validating the focus of this research. In comparison with Case Study 1 (in which 10 of the 12 lessons were between 57-83%) the proportion is more consistent across the lessons.

- The dominant communicative approach during whole class teaching was interactive/dialogic 32-49% in 7 out of the 8 lessons. However, it is worth noting that many interactive/dialogic episodes were concerned with discussing collaborative group work processes rather than science content.

- The lesson with the lowest percentage of time spent in an interactive/dialogic communicative approach was associated with children being taught measuring skills and carrying out the practical work that involved a large range of resources in Lesson 4.

- Higher percentages of interactive/dialogic talk took place in the early lessons associated with elicitation of children's initial ideas and in Lesson 6 which was concerned with interpreting data, both data generated by the children's investigations and pre-prepared data from a teaching scheme. This seems to be in line with the concept-led constructivist models of teaching that focus on the use of empirical evidence to develop ideas.

- The tendency noted in Case Study 1 for the proportion of whole class teaching to decrease over the course of the sequence of lessons is not significantly evident in Case Study 2.

7.6 Analysis at the Level of Lessons and Episodes

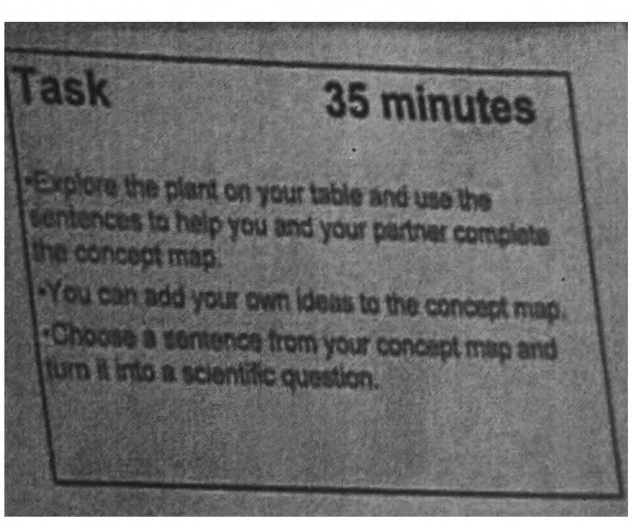
In the following sections the 'story' of the case is maintained to contextualise the more detailed analysis of episodes. The selection of lessons and episodes for more detailed analysis and discussion is summarised in Appendix 8.

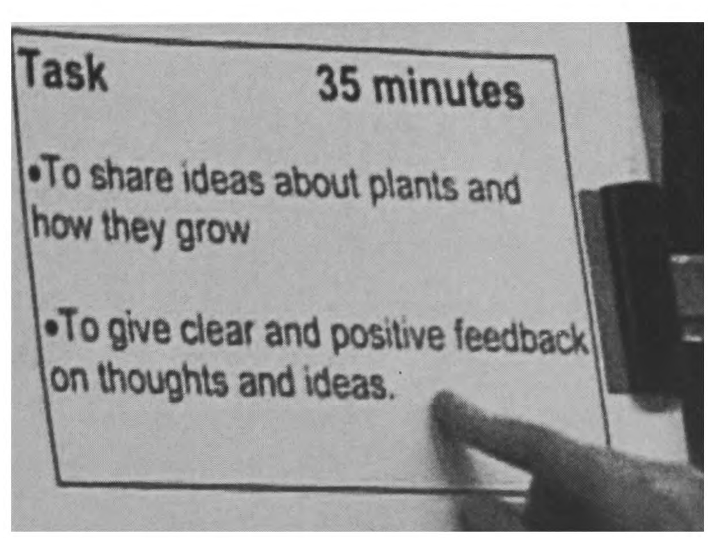
The analysis was adjusted so that more lessons were considered in detail than in analysis of Case 1 because threads of development of the elements of the scientific story appeared in most lessons and I wanted to track these over the whole sequence of lessons. Accordingly, unlike in Case Study 1 short summaries are provided for most lessons.

7.7 Lesson 1 - Raising Questions and Concept Mapping

The lesson began with the class sitting on an area of carpet and teacher sitting on a chair in front of them. Next to her was a flip chart that had two A4 sheets of paper on it with the tasks and aims for the session (
Figure 7.2).

Figure 7.2 Photo of Flip Chart Tasks and Aims





In the first episode Anna introduced the topic; how plants grow and told the class that they would be exploring their ideas about this by doing a concept map, inviting two children to recap what a concept map was.

7.7.1 CS2 Lesson 1 Episode 2-It's about getting to know what the person next to you knows about plants

In episode 2 Anna adopted a non-interactive/authoritative approach and explained that the aim of the lesson was to 'find out and share ideas and questions'. This focus on sharing ideas as the first step is a variation on the concept –led constructivist models, in which sharing ideas is seen more as a form of intervention by making comparisons (Scott et al. 1987; Bell, 1996).

T: I'm just going to look at what we are actually going to be focussing on in our learning. *(Pointing to task typed on sheet of paper and reads it).* We are going to be looking at sharing our ideas together about plants and how they grow, so its about getting to know what the person next to you knows about plants this afternoon. And then we're going to be looking at that collaborative group work focus that we had last term which was about giving clear and positive feedback about our thoughts and ideas.

7.7.2 CS2 Lesson 1 Episode 4-What would we like to find out about plants and how they grow?

Several children interpreted the statement of the aim 'what would we like to find out about plants and how they grow', as a question and bid to answer it. Although the teacher had not asked children to begin sharing their ideas, the children put their hands up to do so, and the teacher followed this up by inviting children to speak. In this way, the transition to episode four is initiated by the children, and allowed by the teacher. Although there is not a clearly defined signal between one episode and the next, I defined it as a separate episode as there was a transition from an interactive/authoritative communicative approach in episode 3 to an interactive/dialogic approach in episode 4.

T: Do you want to share an idea Maddy?

Maddy: Um you could grow, could see what's the longest plant, whose getting the tallest plant.

T: You could couldn't you. That would be super actually, what is the longest or the tallest plant a plant could grow to. Well done. Has anyone else got anything they are particularly interested in about plants? *(rolling open hand gesture to the class)* Or something that they know about plants to share, we can start putting up some ideas onto our concept map. Henry.

Henry: (inaudible)

T: How do roots suck up water, what a fantastic question. That's very interesting. I think we might be doing something about that during the topic so I'm really glad to hear someone is interested in that. Callum.

The teacher uses an 'invitation to participate'; 'Has anyone else got anything they are particularly interested in about plants?' accompanied by a hand gesture that sweeps around to develop a sense of inclusion that opens up the content of the discussion to the class. The teacher's response to Henry makes it clear that she has already made some decisions about what they will be doing in the topic, and the message is that the children's questions are not going to determine its content. However, there is no evidence that this has put the children off contributing their questions and they continued to offer suggestions.

The children were able to raise questions about plants and these were valued by the teacher; she repeated them back and praised the children, and their use of 'super scientific language'. The questions were not recorded, and there was no suggestion that these questions were to become the basis of empirical enquiries as would be advocated by the concept-led social constructivist models of teaching. The ideas were 'pooled' not discussed; there was a low level of interanimation (Scott et al., 2006)

Anna explained that in this episode she had wanted the children to gain some ownership of the task and gain a view of the children's ideas;

> Because this is the initial part, but partly for my assessment, I can hear their ideas so I can get a clear picture of where they are and kind of base the rest of their learning in this topic on these initial ideas…

(VSRD 24.3.04)

This comment reflects a concept-led social constructivist model – apparently referring to elicitation of the children's ideas at the start of a topic, but as in Case Study 1, Anna was seeking an overview of the ideas of the class., not the ideas of individuals

In the next five episodes (5-10) Anna introduced the class to a particular way of developing concept maps – linking given key words such as 'plant', 'light', 'soil' by gluing on prepared statements such as 'plants always need sunlight to grow', crossing out any words they did not agree with and adding in their own. This took place in episodes that were largely interactive/authoritative, with the children giving short answers to questions, but with almost all of the class putting up their hands in a bid to answer. The lower expectations of the children's use of language in the authoritative episodes supported less confident children in participating.

7.7.3 CS2 Lesson 1 Episode 6-Would you like to share an idea?

In this extract from episode 6 Anna established the communicative approach as interactive/dialogic by using an 'invitation to participate'; 'Would you like to share an idea' rather than a question requiring an answer and opened up the possibility of an extended response from Sophie.

Sara: *(standing at the front of the room and reading a statement on a strip of paper)* Plants sometimes need water to grow.

T: What do you think? I can see some hands going up. *(approx a third of the class have hands up)* Would you like to share an idea? Put your hand up to share an idea. Sophie

Sophie: They its.. Plants *always* need water to grow because it, because…it caught the water and… plants without the water they couldn't live (inaudible) in the soil cos they've got the sun.

T: Wow, Do you know, what I really like about your comment, and I'm going to give you a smiley face Sophie *(draws smiley face on the whiteboard)* because you are drawing on your previous learning about rocks and soils and thinking about when plants grow in soil. That's absolutely fantastic. So Sophie's given a really clear explanation. Thank you *(aside to Sara)*. about plants because she said, No, actually they do need water to grow, thinking about what she'd learned about rocks and soils. Callum, what's your idea?

Sohpie's response was evaluated, not in terms of the scientific content, but in terms of the teacher's view of the learning process: she was praised for making a link with previous knowledge. Callum made a bid to speak without waiting for a prompt from the teacher and so the control of the direction of the dialogue did not revert to Anna and Noah also made a bid to speak.

Callum: Well cactuses can pick up the (inaudible) water in quite dry soil, in the desert

T: Right, So you know that cactuses can pick up, can you say that again?

Callum: pick up nutrients from water

T: That cactuses can pick up nutrients from water. And we know that cactuses live in a very arid environment. Are we saying they still need water?

Callum: (Inaudible) they get water

T: Excellent, thank you. What's your idea Noah?

Noah: Well plants can't always have water cos they can have water and light and it makes them sometimes die,

T: Oh!

Noah: so the statement is right

T: Oh, so you think its right because plants need water and light . Do you think you could change that then to adapt it to your idea Noah? How could we rewrite that sentence to make it clearer?

Noah: Um,... plants need water at different times from sunlight.

T: Fantastic . OK. We'll I'm going to do that. *(writes it on the board)*

Callum's ideas build on those that have preceded it, a characteristic of an interactive/dialogic communicative approach. The exploration of the children's ideas is in line with the idea of elicitation in the concept-led constructivist based model – it is open to what ideas the children do have, rather than assessing them against pre-determined criteria. The statements that Anna had prepared set up this debate, introducing opportunities for conflict to arise through the process of children sharing their ideas. Noah's idea – that plants that have water and light together can die – appears to be in opposition to ideas about photosynthesis. Anna inadvertently said 'oh!' when this became apparent, her surprise jolting her out of 'accepting' mode. By asking Noah to clarify his idea as a statement and writing this down she showed that she valued it, but didn't probe it further or ask him why he thought it.

Anna was concerned that providing the key words and statements may have been too restrictive and invited the children to add in key words of their own.; 'I would like you to help me with these blank spaces – what shall we put in here?'. In episode 9 the children discussed with a partner what words they would like to add and some were invited to share these in episode 10. This use of talk partners within a whole class teaching episode supported broad participation (Moyles et al., 2003) after the process of sharing ideas had been modelled on the social plane of the class. Within the Ollerenshaw and Ritchie (1997) concept-led social constructivist model its purpose in this episode could be seen as providing the individual children with an opportunity to structure their ideas. An alternative, socio-cultural, interpretation would be that it supported the children's appropriation of the discourse of the intermental plane.

In episodes 11-16 Anna focussed on the collaborative group work, asking the children to come up with success criteria for judging how well they work together– 'What will show us we have been successful?'. Although these episodes will not be presented in detail here, they indicated Anna's commitment to making the processes of discussion explicit and discussing it with the children in the way that Mercer (2000) recommends.

In the middle section of the lesson the children were given a partner to work with and they set about the task of developing a concept map in pairs, changing the given statements and sticking them onto their sheets of paper. They worked for 15 minutes before the teacher stopped the class to feedback something she had noticed while circulating. This took place through the non-interactive/dialogic episode presented below.

7.7.4 CS2 Lesson 1 Episode 19-I wanted to just feedback some really interesting conversations

T: I wanted to let you know that you have ten minutes left on the task, and I wanted to just feedback some really interesting conversations I've been listening to. I have heard, one I would really like to point out is one on this table, cos I noticed that the skill of <u>observation</u> *(points to her eye)* is being used really well and there was a conversation between Mabel and Saavan and Mabel was saying, *(reading this from her notebook)* or Saavan was saying "Plants never always have flowers" and Mabel was saying " Yes I completely agree, look at that plant on the table it hasn't got flowers there's proof" So she's looking and using observation skills, thinking very carefully about what she's putting onto her concept map, making sure that her ideas are well thought out. Excellent, thank you I really enjoyed listening to that, ten minutes of your task left, time check, think about where you are.

Anna had selected this conversation to be made available on the social plane of the class as it developed the view of scientific she wanted to promote: the importance of making observations to support your ideas. The way the dialogue that had taken place between two children and how it led to the development of ideas was also emphasised. It had the additional purpose of setting the pace of the lesson, refocusing children on the task by warning them of the limited time left.

7.7.5 CS2 Lesson 1 Episode 23-If you weren't sure, what could you do about that?

In episode 23, classified overall as interactive/dialogic, some of the children fed back what they had written on their concept maps: 'Sometimes plants have stems' (Zak).'Plants sometimes use roots to help them grow' (Henry). In the extract below Anna followed up Stella's idea with a question to provoke the children's thinking about how the ideas might be tested.

Stella: Um Plants kind of like need leaves to grow well.

T: Plants need leaves to grow well, that's an interesting one isn't it. Quick, thumbs up if you agree with that. Plants need leaves to grow well. *(few children respond to this – two with thumb in non-committal half- way position)* Hm if you weren't sure what could you do about that? If you didn't know, *(wide open arm gesture)* If you didn't know if plants needed leaves or not what could you do? What could you do to find out about that? Sophie.

Sophie: You could get two plants exactly the same

T: uh huh *(folds arms and leans back)*

Sophie: and pick the leaves off one of them and leave the other one like it is.

Anna asked for a mass response – 'thumbs up', possibly to involve more children directly in the discussion. Their lack of a positive response suggested to her that there was general uncertainty about whether or not plants need leaves and she pursued this by asking how they might seek evidence for the idea. In the next section of the episode the teacher moved into a more authoritative communicative approach as she took Sophie's response as an opportunity to find out whether the class could identify and label it as a 'fair test'.

T: I see, What Sophie, what is Sophie talking about? *(Saajid's hand shoots up)* A certain way of testing things, absolutely fantastic to hear you thinking like that Sophie. Saajid

Saajid: An experiment

T: An experiment, good *(intonation of voice cautiously accepts)* She's thinking about two plants exactly the same, picking all the leaves off one, and leaving them on the other. What sort of experiment or test is that? Does anybody know how to describe a test like that? *(no hands up)* Hm, I think..Paul.

Paul: An operation to see what happens?

T: Not, well it's a bit like an operation isn't it, picking things apart, but its not called an operation. Ethan

Ethan: Would you call it a scientific test?

T: It is a scientific test, actually, have you got it Sara?

Sara: A fair test.

T: A fair test, Excellent. I'm so pleased at this age that you are talking that its really super and we will be doing some fair testing during our topic. OK.

This last section is a triadic dialogue, with the children making suggestions and the teacher evaluating them, until finally one child comes up with the right answer.

Anna explained that as well as providing her with an opportunity for assessment, she wanted to make the most of the opportunity to link the children's ideas with an aim of the topic– to develop the children's understanding of 'fair testing'.

> ... I think that was a really that, important that we were all in a whole class situation there to all have that exposure to her *(Sophie's)* idea and there, I was almost sort of determined to draws this fair test out of them because I thought that that would be a building block for the next lesson if you know what I mean, and also I was really surprised that they had that kind of developed idea at that point – I wasn't expecting that so I really wanted to find out how far I could go with it and you know for my own kind of planning...
>
> (VSRD 24.3.04)

She also made the point that having this expressed in a whole class situation made Sophie's' idea available to all the children.

In the next episode, Anna moved the discussion on and asked the children to feedback any questions that they had raised. Saajid's question: 'Do plants need air' was one the teacher was already aware of from listening to group work , and her selection of him to speak shows that the purpose of the section was to make the group discussion available to other children.

7.7.6 CS2 Lesson 1 Episode 24-Do plants need air?

T: OK. Did anyone think of a question they'd like to develop? Did anyone take their ideas a step further and turn them into a question? Saajid

Saajid: Do plants need air?

T: Do plants need air to grow? Actually Saajid I was on your table when you were talking about that and I was very interested about what you decided about how you would test that. What was your idea? Yours and Noah's?

Saajid: Er, encyclopaedia, Internet, Experiment, ask a scientist, explore different ways.

T: Excellent, and you talked about a specific way you could explore it – can you remember, Noah?

Noah: We thought about experimenting it by seeing if was by putting one in a plastic bag tied up and make no holes so no air gets in and then one, in a plant by some air um an air vent.

T: Excellent, that's another controlled experiment, excellent. Any other questions you'd like to share? Ethan

Ethan: Um, um…Can plants grow in rock soil

Archie: Why do plants have stems?

Emily: Um, Why do plants need roots?

As well as showing an apparent interest in the comments on the role of air - Saajid and Noah's ideas were selected to exemplify forming a scientific question and to develop the 'big idea' about the nature of science that ideas are generated and then ways of testing them are devised. The discussion was then opened out to the rest of the class with an invitation to share any other questions that had been raised.

Anna's reflection on this episode suggested that she saw the question raising as a general part of the process of science and stimulating learning rather than the specific start point to investigative work. Noah's idea for testing whether or not plants need air to grow was not followed up in subsequent lessons.

> Some interesting questions, and some that weren't really answerable – that's part of it, learning which are answerable, but also those that aren't, like plants need air. I also found interesting the stems debate – do all plants have stems or not?
>
> (field notes 04.03.04)

The tone of Anna's comment reflects her genuine interest in the discussion and it seems likely that this was communicated to the children at the time.

In the final episode (25) the process of sharing ideas was reviewed in an interactive/dialogic episode in which Anna and a child valued 'linking ideas together' very much as recommended by Mercer (2000) to develop 'Exploratory talk'.

Emily: I think maybe we could try and um link our ideas a bit more so it makes more a, a tiny bit bigger idea.

Anna explained her view of the benefits of a collective approach:

> I suppose you get the advantage of being whole class there is that you are able to listen to everybody's ideas, but particularly I think that's a strength for the less able children - they are able to listen to a child modelling good scientific language or to kind of very thought out ideas… and for the culture of the classroom, having those whole class experiences are really valuable for developing interpersonal listening skills and also being able to debate things, throw things around and ..see, you're getting a wide range of perspectives from different children I think.
>
> (VSRD 24.3.04)

At the start of the next lesson Anna talked about the outcomes of lesson 1.

> They are a lot more advanced in their knowledge and understanding than I anticipated. Also their use of language is more advanced.
>
> (field notes 04.03.04)

She felt that listening to the children's talk while they were concept mapping in pairs had been more a useful way of gaining an understanding of the children's ideas than the whole class discussion.

> In whole class you need to encourage some to participate, when you are not in whole class the children are much freer to express what they think – it highlights the conceptions and ideas that they have….Some children lead in whole class discussions.
>
> (field notes 04.03.04)

When asked why she tended to avoid explicit evaluation of the content of the children's ideas the teacher explained that:

> I really believe that they can work things out for themselves. I'm there to mediate, it's their ideas not mine. I want to encourage openness of discussion

> and sharing of ideas. I tend to say more about how they've worked, what the learning environment is, so I give feedback in that sense.
>
> (field notes 04.03.04)

In a later VSRD Anna confirmed her view that:

> sharing of ideas is quite risky for children to do, I think if I'm in a situation as an adult in those groups and I get up and I do it, you do feel a bit vulnerable and I want to encourage that actually at the beginning its just an opportunity to share what you know
>
> (VBRD 24.3.04)

This concern for children's emotional vulnerability and their self-esteem is similar to that expressed by Clare about exploring children's ideas in Case Study 1 and exemplifies this as a feature of primary teachers in England (Alexander, 2001).

7.7.7 Summary of Lesson 1

An interactive/dialogic communicative approach dominated whole class episodes. This is consistent with concept-led social constructivist models in that the lesson can be seen as 'orientation' to the topic of plant growth and 'elicitation' of existing ideas. There was little teacher evaluation of the content of children's utterances – instead she evaluated the process of sharing ideas Although, Anna said that it is not in whole class that she finds out most about children's ideas, 73% of the lesson was spent as a whole class.

When the communicative approach was interactive/dialogic the episode was often concerned with children modelling and valuing the processes that the teacher wanted them all to go through in subsequent pair work. Where it was non-interactive/dialogic it was about selecting from what had happened the ideas and processes that she wanted to mark as valuable and reporting these back to the whole class. Where it was authoritative it was sharing aims and objectives.

7.8 Lesson 2

This lesson has been chosen for detailed analysis as it illustrates the way in which the teacher used interactive whole class teaching to introduce elements of the Goldsworthy and Feasey (1998) 'post-it planning approach' for an enquiry into factors that affect plant growth. This was a feature of Case Study 1 and this focus facilitates cross case comparisons.

The lesson began with the teacher asking the children to review the previous science lesson.

7.8.1 CS2 Lesson 2 Episode 1-So we can get our minds thinking about plants again

T: Can anyone remember some of their ideas and would like to just remind us so we can get our minds thinking about plants again? Jack what was one of your ideas?

Jack Plants need leaves to help them grow well.

T: Plants need leaves to help them grow well. Excellent Thank you, Ethan

Ethan: Plants sometimes grow in water

T: Plants sometimes grow in water. Thank you I like the way that we're using that language again: sometimes, always and never. Maddy

Maddy: Plants always drink water.

T: Plants always drink water? That was a very interesting idea wasn't it? Noah what was one of your ideas?

Noah: Um Never give the plant water when its having sunlight.

T: Great, thank you, well that's some ideas.

This episode was interactive/dialogic in that it began with a focus on the children's ideas – those that had been previously expressed. Anna was evaluative in her feedback back, but does not evaluate the idea, rather the way it has been expressed, or provides praise for expressing an idea by thanking them for their contribution. There was a low level of interanimation (Scott et al., 2006) – the ideas were pooled, rather than discussed - with the purpose of re-establishing a shared intermental plane. This was now the third time that Noah had expressed this idea that plants shouldn't be given water at the same time as light in the whole class forum and it had not been explored in public.

7.8.2 CS2 Lesson 2 Episode 3-'Gloria the Ghastly Gardener'

In the second episode Anna introduced 'Gloria the Ghastly Gardener', and in this third episode she explained that Gloria would need the children's help to grow her grass. This story, intended to provide a context for devising fair tests into plant growth was recommended by the Ginn New Star Science scheme. The teacher's intention was to use this as a start point for identifying variables and then using the post-it note and planning board system (Goldsworthy and Feasey, 1998) to plan a fair test.

> T: We need to see if we can help her, cos she is such a bad gardener that she can't even get her grass to grow well. She's got some good soil to grow her grass in , and she knows what Maddy has just told us that she has to plant her seeds just under the top of the soil. But that's just about it, Caleb, that's all Gloria knows. What else do we think she needs to think about? You said some really key words already and I'd like to scribe some of your ideas and put them. What could we do to help Gloria to get her plants to grow well?...*(one hand goes up)* May.

The question the teacher asked here – 'What can we do to help Gloria to get her plants to grow well?' had two parts – 'how do we help Gloria?' – a social context which required thought about advice to a person , and 'what do plants need to grow well?' – which invited children to draw on their ideas about plant growth. Unusually for this class, initially only one child put their hand up and this may reflect the difficulty they had making sense of what was required. This interpretation is supported by the teacher's view of the episode:

> ...now I think Ahh! I'm talking about somebody else, I'm really trying to get them to do two things, which is quite hard for them, getting them to sort of use their ideas and put that in another context. But I felt that, (*sighs*) not, it was hard to engage them all in that situation.
>
> (VSRD 24.3.04)

May's answer addresses both parts of the request, providing advice to Gloria and, drawing on her ideas that plants need water, but not too much, in order to stay alive.

> May: Don't water them too much cos otherwise they'll probably die and ..
>
> T: (*Nodding*), right, so not too much water..(*writing on a post-it note)* Thank you May.

The teacher chose to write on the post-it note May's suggestion, 'not too much water' rather than May's form of words 'don't water it too much', extracting the 'science' from the personal advice. However, she did retain the specific idea that they mustn't have too much water rather than extend it to the variable 'the amount of water' at this point. The tension between wanting to use the children's ideas to inform the development of the topic and move towards a scientific version of them as variables within a fair test felt problematic for the teacher during this episode and she explained that:

> And I was really trying to connect that, so I wasn't saying, we've just done a session on your ideas but lets just shove those out the way now and look at what we're really learning about cos I want that to be, their ideas to weave through this whole topic and kind of almost shape it so they've got complete ownership over what they're doing...
>
> (VSRD 24.3.04)

The teacher continued to refer to the context of Gloria the Gardener as the episode developed:

T: What else could we do to help Gloria get her plants beautiful and blooming, so she can enter them in National Competitions! *(four children have their hands up)* Ethan. *(Looks down pen poised to write on a post-it)*

Ethan: You could just, show another packet or something?

T: *(Looks up)* You could just?

Ethan: Show her what the plant is, cos she has to know what the plants is.. because if she doesn't know what the plant is , she might plant water-lilies in soil.

T: Very important. Thank you, *(writing on a post –it)* so explain what the plant is. Thank you.

Ethan's suggestion that Gloria would need to know about the type of plant she was growing in order to get the right conditions shows that he is taking the context more literally than Anna had intended and illustrates the difficulties in abstracting and controlling variables from complex 'real' situations. Anna, simply accepts this and moves on.

T: What else might she need to think about to help her plant grow well? What might she need to think about? *(4 hands go up)* Noah?

Noah: Um, um, don't give it water when its having sunlight.

T: Right, Don't give it water when its having sunlight. *(moves to start writing then stops.)* Well there's two ideas there aren't there water and sunlight. Can we get really clear about that, what would we do, would we need to…always give sunlight, give it any sunlight? Can you help me class three 3? *(sounding a little desperate)- (several hands go up)* what would I need to write on my post-it so I can put a clear idea to help Gloria up on the board? Sophie

Sophie: You don't worry about the sunlight…*(Teacher nods)..*because if its outside it will get sunlight.

T: So does it need sunlight Sophie?

Sophie: Yes

T: Right. Thank you *(writes on a post-it)* Plants need sunlight *(spoken slowly as she writes it)* April

In this section above Anna either misunderstood or ignored Noah's more complex meaning in her intention to identify the variables 'sunlight' and 'water'. She selected from his response the two words she is looking for and asked the children to develop this. Sophie's idea that the sunlight was irrelevant, because the plants would get it anyway if they were outside, further exemplifies the difficulty between setting up an abstracted 'test' and relating it to a certain context. That the context was itself not real, but a story, may have added another layer of difficulty.

Two of the ideas expressed were those that the teacher had wanted or expected: sunlight and water would affect plant growth, the other two were less obvious: that they need room to grow, and the idea that different plants may need to be planted in different conditions. These ideas have not been expressed as in the abstracted form of variables required for a fair test, although they have been depersonalised.

Anna had felt that it had been unusually difficult to engage the children and decided that the context of Gloria the Ghastly Gardener had not been helpful because it had moved away from the children's ideas.

> I think they found that quite hard actually, to come out of the context of their own ideas and their own research, .. (VSRD 24.3.04)

She suggested that the children's own ideas may have provided a sufficiently meaningful context – the artificial story seemed to hinder, not help in this case. Anna did not introduce the second part of the post-it planner in the step by step way that Goldworthy and Feasey (1998) advocate, and it could be argued that there was insufficient scaffolding of the second stage of the use of the planning board. But Anna's further comments also indicated the difficultly she felt in using the children's ideas as a starting point, while attempting to move to a predetermined outcome.

> ...we're all acknowledging that we're kind of sifting out what we don't need, and some of that does, that's not just their ideas anymore, that's me kind of leading them, saying this is what we are, trying to value and use their ideas, ...when you're kind of in that equation as well it kind of it it does get quite tricky really ...
>
> (VSRD 24.3.04)

The tension that Anna has expressed between wanting to maintain the focus on the children's ideas, whilst 'sifting out' those that are not in line with the direction of the lesson illustrates the discomfort created by its emphasis in the concept-led social-constructivist models (Driver, 1983).

Anna briefly introduced the primary science language of 'fair testing' 'what to change and what to keep the same,' through a non-interactive/authoritative presentation. She then asked the children to explain their own understanding of a 'fair test' by discussing it with a talk partner. Most pairs seemed to be discussing earnestly. They were invited to feedback to the class in the next episode:

7.8.3 CS2 Lesson 2 Episode 7-If it was a weighing scales you could have equal

T: OK Class three, lets come back together and share some ideas, about what we said last week. I'm very interested that we are thinking about these ideas so soon in our topic. It will really help us, and really help Gloria the Ghastly gardener! What's your idea Holly?

Holly: Um me and Maddy thought you could um, if it was a weighing scales you could have equal

T: *(gasps and points towards Holly)* so something about equal. I like your analogy as well about it being weighing scales *(moves hands up and down alternately as if on ends of a balance)* and you can weigh things equally. Excellent. There's a clue, on our path. May.

Anna seized on the concept 'equal', using a 'weighing' gesture to develop its meaning as two things being the same, and emphasise its significance. Interrupting meant that Holly did not have the opportunity to explain what should be equal.

May: Well, say she didn't like one of them, and she liked the other the most, *(May's partner puts her hand up)* it doesn't mean that she's allowed to make one of them not as equal as the other one. *(teacher nods all through this)*

T: I think you're onto a really super idea an I really like the way you're explaining it. How could Gloria like one plant more than the other, that's outrageous! She couldn't do that. So what you're saying, is something, about, she has to do *(moving forearm back and forth, rather like a ticking metronome)* equal to one plant, and equal to the other plant. But what would she need to do equal May?

May: She would need to put them both in the sunlight and give both of them an equal amount of water.

T: Right. She might need to give them equal sunlight *(forearm 'ticks' to left)* and equal water *(forearm 'ticks' to right)*. I think you're getting there. Its got lots to do with a fair test. Sophie.

Sophie: Um It wouldn't be a fair test if you put the right amount of water in one plant and put it in the sunlight and if you gave the other plant hardly any water and put it in the dark.

T: Right, excellent *(very quietly and slowly)* Would it be a fair test if you did something to one plant, and not to the other? *(finger to mouth, as if 'wondering')*.. and I like your idea about putting one in the dark and one in the light. What would you be looking at in a plant, if you did that? Why on earth would you do that? Jack

Jack: To see what the difference was

T: *(open handed gesture, that turns into finger pointing and marking each word)* To see what the difference was. Excellent. Fair tests are about things being equal, but they're also about looking for a difference.

Sophie, who had already shown that she had an understanding of a fair test (Lesson 1, Episode 23), provides an example that 'wouldn't be a fair test'. Anna drew on this to develop the idea that although the everyday idea of equal treatment is useful, it is not sufficient, and moves towards the concept that you change only one variable in a fair test by 'wondering' why you might put one plant in the dark and one in the light. Another child, Jack explains; to see what the difference is'. Anna then provided a summary of the ideas that had been constructed about fair testing up to that point: 'Fair tests are about things being equal, but they're also about looking for a difference.' This has the additional outcome of focusing attention on the dependent variable too. This episode supported the joint construction of ideas about the processes of science, of the meaning of a fair test on the social plane of the class through an interactive/dialogic communicative approach.

The children returned to work in pairs for another 6 minutes. The impression I had observing from a distance was that many seemed unsure of what they should be doing.

7.8.4 CS2 Lesson 2 Episode 26–The same amount of soil and water

The teacher then asked them to talk together to evaluate their planning; 'Have you been able to decide what to change and what to measure to plan a fair test?' The children close to me seemed to have found this difficult and their conversation floundered. In episode 26 they were asked to feed back on this to the class. An extract from the episode is presented below.

Archie: What we changed , um, what we change , we changed um one might be in sunlight, and one might be in a dark cupboard.

T: Right, so you changed the amount of sunlight. What have you had to keep the same there Archie.

Archie: Um, um, the same amount of soil and water

T: Ah, the amount of soil used well done

Archie: and the water.

T: and the water: what else might Archie need to keep the same? Saajid?

Saajid: Um the nutrients and the location.

T: Right, that's another thought, the nutrients and the location,

In explaining his test, Archie began by using a comparison – he will put on in a dark cupboard, and one in the sunlight, rather than using the form that the planning board has set up – that he will change the amount of light. Anna's response reformulated (Mercer, 2000) his words in the form she wanted; 'so you changed the amount of sunlight'. Archie was then able to say what he would use 'the same amount of soil and water', using the notion of a quantity that the teacher has used in her response. Saajid was able to extend the range of variables beyond those anticipated by the teacher. Anna directly asked certain children to explain their plan and some, such as April in the extract below, were not able to do this without support.

T: What about this group here, can you tell us what you decided to keep the same and what you decided to measure? April.

April: We decided to um..

T: *(goes over to stand behind April and points out the section on the sheet that says 'what we will change')* What have you changed?

April: the water

T: The water. What have you decided to keep the same April?

April: Um *(looks to partner for help who points to the section 'what I will measure' on poster)*

T: What have got written down there? *(goes over to stand behind April and points out the section on the sheet that says 'what we will keep the same')*

April: Sunlight

T: Sunlight, I can see you've also got <u>temperature</u> and the roots. Another group talked about temperature.

This episode was coded as interactive/dialogic overall in that the children were feeding back decisions about variables they had made themselves and these were valued, but Anna was also making an evaluation of their procedural knowledge and in this way there was an authoritative element to the discussion. When the teacher reflected on the outcomes of the lesson she said;

> I thought I'd have something different, I thought they'd do it faster. Half way through I felt some had got it and some hadn't.. (field notes 4.03.04)

She said that at the end of the day she had asked the children what they thought about using the planning boards and that some had found it confusing and she had decided to 'take it a step back' next week and look at fair testing again. She also noted that:

> If I have just gone on what had happened on the carpet I wouldn't have known. I had to go round and help a lot. (field notes 4.03.04)

The assessment she was able to make from the interaction during whole class discussion alone would have given her a false impression of the degree of understanding, as those participating, were generally those with children who were developing a good understanding of a fair test.

7.8.5 Summary of Lesson 2

This lesson wasn't successful in identifying variables to test as the teacher had hoped. The teacher struggled to manage the tension she experienced between valuing the children's ideas and moving towards the outcome she wanted as described by Driver (1983). The children found it difficult to abstract variables from the imagined physical entities of a story to words on a post-it and the children who did participate in the discussion did not represent the extent of lack of understanding across the class.

According to the concept-led social constructivist model the questions that the children had raised in lesson 1 would have made a better start point for tests, and would have provided contexts that were meaningful as the children had developed them themselves. However, the teacher wanted to introduce the concept of fair testing to the class as whole and the post-it approach was recommended as a form of scaffolding in the teacher's guide she was using. This episode exemplifies a key difference between the procedure-led model and the concept-led models.

7.9 Lesson 3

In our discussion before Lesson 3 the teacher explained that she would be trying a different way of supporting the children in devising a fair test:

> Going back a step – some children found it too hard last week, So this time I'm using visual images, ...I'm giving them more of a structure this week – its slightly more prescriptive, but still based on their ideas – I find that hard – I want to base it on their ideas, but give them some support.
>
> (field notes 11.03.04)

This could be understood as scaffolding in (Wood et al.,1976) in terms of 'reducing the degrees of freedom', by 'demonstration' and thus providing 'frustration control' and in the teacher's responsiveness to the children (Wood 1986). However, she is responding to them as a whole class group, not as individuals. She prioritised maintaining a collective approach over responding to the achievement of those who already did understand a fair test.

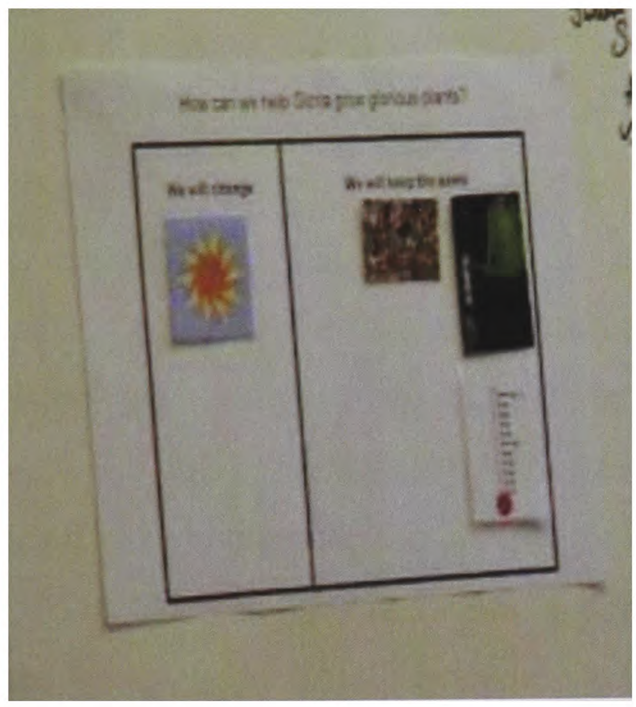
Anna explained that she had prepared images on cards to use in place of the post-its (a watering can for 'water, a sun for 'sunlight' ,a thermometer for temperature, and some seeds for 'seeds') and that the children would draw their plan rather then write it. Water and sunlight had been identified as important factors by the children in the first lesson. Temperature emerged as a variable in the whole class discussion at the end of Lesson two – Noah and Saajid used the terms hot and cold, and Mabel's' group used the term temperature. The inclusion of 'seeds' was not directly linked to the expressed ideas. Of the children's ideas that had emerged 'air' was not represented, and neither was the idea that plants need to be given 'room to grow'. The idea of removing the leaves from one plant had also not been included.

Anna began the lesson by explaining that they were going to continue their plants topic and that because they had found the structure the previous week difficult, she had planned a 'visual' way of doing it instead. This began as a non-interactive/authoritative episode and then became interactive/authoritative when she reviewed the context and the problem by asking the children to recap it.

Anna then removed a sheet of paper to reveal the set of images and a table stuck to the flipchart stand (Figure 7.3). The table had the title: 'How can we help Gloria grow Glorious plants?' and contained two columns: the right hand column was headed: 'We will keep the same', and the smaller left hand column was headed 'We will change'.

This table is a simplified version of the Goldsworthy and Feasey (1998) planning board in that it did not include the dependent variable 'things we will measure'. The next episodes established what the symbols represented before Anna went on to use the board to help the children understand a fair test.

Figure 7.3 Photograph of Anna's Flip Chart.



7.9.1 CS2 Lesson 3 Episode 6-What we are taking away?

This episode had a key role in Anna's introduction of a different version of what planning a fair test could be. She decided that it would be easier for the children to grasp the idea that only one thing would be 'taken away' from the plants (the independent variable), and that everything else would be left the same (the control variables). Crucially, this was more in line with the way that the children were understanding the context -: if the plant didn't have any water/sunlight/air it couldn't grow well.

T: So. The reason I've put all of these pictures into this 'we will keep the same' group, *(circling them with her hand)* is because this is what you've told me a healthy plant needs to grow well..If we took.. one away..we would be changing it (*indicates 'we will change column'*) to see if it does affect plant growth…So I'd like someone to put their hand up to tell me something that we could take away (gesture, circling group of pictures) from a plant, to see if that one thing matters. *(about a third of the class put their hands up)* To see if that one thing matters to whether a plant can grow well or not. I really like the way Ryan's showing me he's listening there. Its quite hard to keep focussed at the back, thank you Ryan. Stella

Stella: Um, the sun

T: The sun! Right, *(peels off picture of the sun)* what did we say this was, Jack, remind us, what did you say this represented?

Jack: the light

T: The light. I really like that choice actually Stella, cos that's the one we didn't know. So I'm going to *(holds picture of sun back in 'what we are keeping the same' column)* take that out of 'what we're keeping the same' *(lifts sun picture out)* and I'm going to put it into the 'thing we will change'....OK, Well that doesn't really make much sense at the moment *(hand circling around the chart)* So let's get really clear in our minds what we're doing...Imagine we have got two plants. We've got some things that we're keeping the same *(circles them)* and we've got one thing we're taking away. *(circles it).* Put your hand up to tell me <u>what we are taking away</u>. Then I can scribe your ideas. Maddy.

Maddy: We were taking the um sun away and also you could take the sun away from one of them, like put it in a cupboard, but keep all the rest the same, but then on the other one you could keep *everything* the same.

T: Right: Excellent, *(holds both forefingers up)* that's exactly it Maddy, we need to keep everything the same on one plant, but we need to change, like take the light away from one plant, see whether that matters.

Having introduced the idea of 'taking way' something they think the plant needs to see if it affects it, in the next section the Anna's intention is to develop the children's understanding of the logic of a fair test – why is it that only one thing can be changed?

In the VSRD Anna explained that she was 'breaking it up into manageable sections' (VSRD 24.3.04) and reduce the risk, creating a safer environment. This was intended to support broader participation:

> Lots of hands go up – the risk is less if you break it into simple steps and they can respond by putting their hands up. (VSRD 24.3.04)

Her use of closed questions in an interactive/authoritative communicative approach supported this reduction in cognitive demand.

But Anna had not just simplified the task, she has found a way of explaining it that the children could understand; she had created a new activity to build an intermental development zone (IDZ) (Mercer, 2000) and had been successful in doing so by introducing the phrase 'take away' to replace the word 'changing' that had been used in lesson 2, in her view, unsuccessfully.

> I repeated 'take away' – the missing link. 'Changing' was confusing for them.
>
> (VSRD 24.3.04)

Anna had responded to a lack of shared meaning by changing her vocabulary to words she thought would be better understood by more children, establishing shared meaning (Wertsch, 1985).

She felt that that lesson had been more successful in teaching the majority of children about fair testing.

> I think that using those visuals and guiding, and I did really guide them through that, and I do, I think its really supported their understanding, of not just knowing a fair test, is you know, a type of experiment, but how you would set up a fair test.
>
> (VSRD 24.3.04)

> [ ] and that kind of learning is really retained, for instance, today, we were talking about watering our fair test and the whole class was getting them out again and observing them and watering them and I was reiterating that whole thing of 'should we water the you know, the ones [ ] And they were really clear, so many children were really clear about this idea that we are only changing one thing.
>
> (VSRD 24.3.04)

7.9.2 CS2 Lesson 3 Episode 13-I've drawn the seeds like this because plants need room to grow

Episode 13 provides an example of interactive whole class teaching used for the purpose of sharing the ideas of a group of children with the whole class. It is considered in depth as it is an example of how the different views of the children were made available on the social plane and developed into an episode with a high level of interanimation (Scott et al.,2006). This episode was interactive/dialogic: the children's ideas were the trigger for the episode, they came up to the front of the class, the position often occupied by the teacher and were speaking directly to the class, not to the teacher. April, who had struggled to articulate her plan in the previous lesson (L2 Ep. 26) was able to explain it this time.

T: *(standing at the front of the room, facing all children).* April, *(moves to the table where April sits and picks up April's work)* I wonder whether you could share the comment you made with me in our conversation, *(gesturing to April that she should stand up and walk with the teacher).* Do you want to come up here a minute? *(holds up April's work for the class to see and April stands next to her facing the class)* April has done some really careful thinking when I questioned her about her drawing and I said to this table, it looks like you're doing some really careful thoughtful drawings, and I said to April, why have you drawn your seeds like this? *(points to the drawing of the seeds)*

April: Well, we done, um we put them ..not close to each other cos when they start to grow the roots might get tangled.

T: April actually said

April: (interrupts) they need space to grow

T: Thank you she said exactly that, she said I've drawn the seeds like this because plants need room to grow. And she thought very carefully about what she meant by that and said that when they are growing up they might get tangled and I said 'which parts?', and with the help of her group *(big circling gesture),* she thought and realised it might be the roots that are in the soil. *(looks at April)*

April: *(Nods)*

T: And that's some super thinking and wondering you've been doing this morning, so thank you, I've enjoyed listening to your comments. …

At the start of this episode, April has re-enacted the key ideas discussed in the group through prompts and reformulations by Anna, establishing one hypothesis; that if seeds are planted together the roots will tangle. Anna then invited another pair to the front, emphasising that this was the 'complete opposite' to set it up as a conflict.

T: And then Class three the <u>complete opposite</u> happened when I went to another table and I listened to Allie and Noah, and they had drawn their seeds, very differently, so can you come up and show your drawings, of your seeds. Thank you April.......*(Noah and Allie come up to the front with their work which the teacher takes and holds up , looking at it)* You might find it difficult to see Class three, but if you're close by, can you tell me how they've drawn their seeds very differently? I can see some very <u>careful observation</u> going on. Can you see from there Archie?

Archie: Um, Have they like, drawn it um, all close together?

T: All close together? And I was thinking, well, that's a good idea, that April was talking about, so I wonder why they've drawn theirs so close together? And they had an equally valid, and justified description. Or explanation rather. Can you tell me Noah, Allie, why did you draw your *(makes circle gesture around their drawing of seeds)*

Noah: Because um some plants need to grow close tog, sometimes look better if they are close together and sometimes grow in big clumps like grass.

T: So they though about what they'd <u>seen,</u> that grass grows really close together Allie, you had some ideas about that didn't you? Can you tell me?

Allie: Um, if you sprinkle them *(makes sprinkling action)* then when it grows really quickly it gets more like grass, when you put one seed, the grass grows (inaudible)

Having established the two different ideas by asking children in each group to explain their drawings, Anna then opened up the debate to the rest of the class.:

T: That's a completely different point of view, saying Allie, grass grows in you know, really big clumps and if you sprinkle it *(makes sprinkling action)* quite a lot of it, all close together and around each other it will grow better. What do you think Class three? About those two complete different *(moves alternate hands up and down)* ideas that have come out of this session. What do you think? Maddy?

Maddy: I think that that shows that all plants need different spaces to grow.

T: Right, so according to, depending on the plant, you might need a different space to grow. That's a super idea. What do you think Zak?

Zak: I think it shows different plants have different things about them

T: Thank you for that, so they'll have to really have that scientific skill of observing won't we during our fair tests based on these really super ideas. Fred.

Fred: I think it depends on, what you want to the plants to look like.

T: Mm, that's an interesting idea, it depends on what you want the plants to look like. Why would that make a difference? Why would you think about that Fred?

Fred: Because if you didn't want any plants really close together, you might not think about it and put them really close together, and you might want one plant to be in one place and another plant to be in another place.

T: Mm, thank you Fred. Can we go back to what April was saying. Why would it be important to make sure that plants had <u>room</u> to grow? Why could that be important? Mabel?

Mabel: Because, if people don't want them stuck together they may not, find it hard to make some flowers.

T: I see, thank you, that might be an important point. Um mm *(indicting that a child can talk)*

Stella: If you put them too close together, they might not have enough room to grow, so all the seeds would be um , um ,well if you put a seed before, before another seed, well the one which you put on top of the other seed, well the one which was on the bottom, wouldn't get, can't grow up because the seed is on top of it blocking it from growing.

T: Excellent.

This is an interactive/dialogic episode with a high level of interanimation (Scott et al., 2006) – making differences explicit and inviting comment. It draws on the children's ideas in a way that was not anticipated by Anna giving it the quality of a genuine debate. The teacher's role was first to prompt the children to explain their ideas and then to invite comments, asking children to justify their ideas by asking them further questions: 'Why would you think about that?' and 'Why would that be important?'.

7.9.3 Summary of Lesson 3

In lesson 3 the teacher responded to the lack of understanding of a fair test across the class evident at the end of lesson by devising a new means of explaining that took into account how the children understood the context and so created an IDZ (Mercer, 2000). The new, pictorial, approach simplified the task of controlling variables, and the teacher adopted an interactive/authoritative approach to model its use which supported broad participation. Lesson 3 also exemplified how interactive/dialogic episodes with a high level of interanimation (Scott et al., 2006) can be developed to model prediction and hypothesising and setting up alternative predictions and hypotheses.

7.10 Lesson 4

Anna explained that lesson 4 was planned to be in two halves; after a brief class introduction on the carpet the children would move to their seats, and in the first half of the lesson they would select the equipment that they needed, and then after another whole class discussion in the second half of the lesson they would set up their pots of seeds and label them. It was a long lesson (109 minutes) with 45 episodes, but contained fewer dialogic episodes than the previous lessons. It may be that this was linked with Anna feeling unwell that day, and not having as much energy as usual for the careful listening and thinking that the dialogic interactions require, or it may be the association with the practical activity and the organisation of equipment and consequent demands on class management.

The first half of the lesson, which will not be discussed in detail, was dominated by interactive/authoritative episodes as names and ways of using different pieces of equipment, were considered in turn. Anna's position in the room, standing at the front, using the whiteboard, with a gap between herself and the children who were seated at the tables, turned to face the front emphasised the authoritative nature of the interactions (Kress et al., 2001). This sequence of episodes supported broad participation (Moyles et al., 2003) – all the children were actively involved in using the thermometers and their attention was engaged. The children were then asked to fill in a worksheet explaining what equipment they would choose and what measurements they would need to make to carry out the fair test they had planned in the previous lesson.

The pairs of children planted seeds in two pots, with frequent authoritative whole class episodes directing the organisation of this. When this has been competed the teacher drew the class together to discuss where they should put their pots. These episodes showed that some of the children had a secure understanding that in a fair test only one variable can be changed and they were able to apply this to different situations, other children's comments show that they have not understood.

7.10.1 CS2 Lesson 4 Episode 41-It's quite a novelty putting plants in cupboards

The final episode of the lesson revealed some differences in commitment to the fair tests planned, even amongst the children who had demonstrated a secure understanding of fair testing. First each group at put their first pot of plants (plant A) on the window sill. Anna then asked those putting their 'plant Bs' in the cupboard to do so. A large number of children, (10) did this. Anna then asked the children who were changing the amount of seeds or water to put their second pot on the windowsill, if they hadn't already done so. At this point Holly put her hand up to say that she and some others had accidentally put their plants in the cupboard, and May put her hand up too- she had done the same, and the teacher retrieved them.

T: Noah, is that one you've accidentally put in?

Noah: Yes

T: That's your one back then. And May, shall you come and help me find yours, so we rescue it from the dark cupboard? Make sure you're sticking to your fair test. Right is everyone else happy, has anyone else 'accidentally' put theirs in the cupboard? Its quite a novelty putting plants in cupboards. *(Daniel puts hand up)*

T: Daniel have you done that too? Right come on then *(looks at me and grins)* Right, you were changing the?

Daniel: The water

That Noah and Holly, two children who appeared to have a very good understanding of the fair test, were among those who put their plants in the cupboard was fascinating. The teacher's interpretation, that it was a novelty to put plants in a cupboard may well have been right. What is striking, however, is the lack of commitment to the tests that have been planned over the course of several lessons. Those children were not really interested in the outcomes of those planned tests.

Goldsworthy et al. (2000) reported how one of the findings of the AKSIS project was that even when the teacher saw the aim of the lesson as learning about the process of scientific enquiry, the children were focussed on the conceptual content. The teacher in this case study had been very explicit about the focus on the skills, they are written on the board, and they have been referred to and evaluated in whole class discussions. The difficulty is in the motivation of the children – perhaps growing plants are more interesting than abstract notions of the procedures of science? This raises a critique of the procedure-led social constructivist model as being too abstracted from the children's interests leading to a lack of a shared sense of purpose.

7.10.2 Summary of Lesson 4

As in Case Study 1, practical work involving a large number of resources has been associated with a more authoritative communicative approach. Lesson 4 raises questions about the impact on children's motivation of the dissociation of context and process in the procedure-led social constructivist model of teaching.

7.11 Lesson 5

During the week before lesson 5 made records of their observations of any growth. There had been some discussion of observations 'the squiggly root is searching for water' (reported by teacher field notes 24.03.04) and teacher was keen to use these observations as a start point for the lesson. In a group activity in which the children observed a collection of fruit and vegetables and decided whether each had a leaf, root, and stem. In the subsequent interactive/authoritative whole class discussion Anna focussed the attention on the celery, asking where the roots would be. She asked what the roots were for and Holly said that they were to suck up water and stabilise the plant.

Then Anna asked where the children thought the water would go in the celery after it had been sucked up by the roots. Zak suggested that it would go to the leaves and when asked how it would get there, Noah suggested up the stem. Anna used this as a stimulus for further close observation of the celery stems:

> T: Right, that's an interesting idea, so, the waters been sucked up through the roots and it's *travelling* through the stem *(traces line of celery upwards with finger)*. How does it travel through the stem I wonder. *(several children put their hands up)* Well, I think we'll put our hands down for the moment because I'd like to find out about that this afternoon. I think you've got some very interesting ideas again, and we've got to be scientists and make sure that our ideas are correct.

Having valued empirical evidence, Anna then invited the children to pull apart and break up half a stick of celery and to draw where they thought the water would go.

7.11.1 CS2 Lesson 5 Episode 15-Little lines which looked a bit like roots

Anna stopped the class (Episode 15) to ask two children to repeat to the whole class what she had heard them say

> Saaven: Well um *(takes the celery and turns to face the class)* I um, I just snapped a little bit of the celery and them I looked in the middle and then I saw these little lines which looked a bit like ther um um roots, and then I thought they were very interesting because most of the roots um stay, go at the edges of the thing and but these actually go in the middle

This wasn't quite what she had hoped for as her response indicated she was focussed on selecting the ideas Saaven had expressed to her about veins and she presented this to the class herself.

> T: *(taking the celery)* Well you said <u>to me</u>, that I thought was very interesting, Saaven said 'Look Miss D they're like veins!' What are veins? Class three?

After a brief discussion about blood she then invited Archie to share his idea:

Archie: (inaudible) in the celery I saw these little gaps, under, underneath um the straight lines coming down and I thought the water might, the water might um go through there, cos there's only a little gap, but water might come through.

The function of this episode was to draw attention to the aspects of the celery that she wanted the children to focus their observations on. By asking children to share their ideas with the class, she was able to continue the appearance that the direction of the lesson was determined by the children's ideas rather than by hers, through careful selection from the children's comments. This episode also served to construct the idea that scientific hypotheses are developed through observation.

The children then made drawings of the celery, mostly of the side view, but a few had chosen to a draw a cross section. The teacher stopped the class and in a non-interactive/authoritative episode asked them all to draw a cross section. She then stopped the class again and asked them to 'come to a class decision about what is going on'

7.11.2 CS2 Lesson 5 Episode 19-Can we come to a class decision?

T: I wonder if we can come to a class decision about what <u>we think</u> is going on inside the celery. First of all, what have you <u>seen</u> inside your cross section? What have you seen inside the cross section? Can we put all the pencils down, so you can give a hundred percent active listening to who you're going to listen to, whoever's talking. Betty

Betty (inaudible)

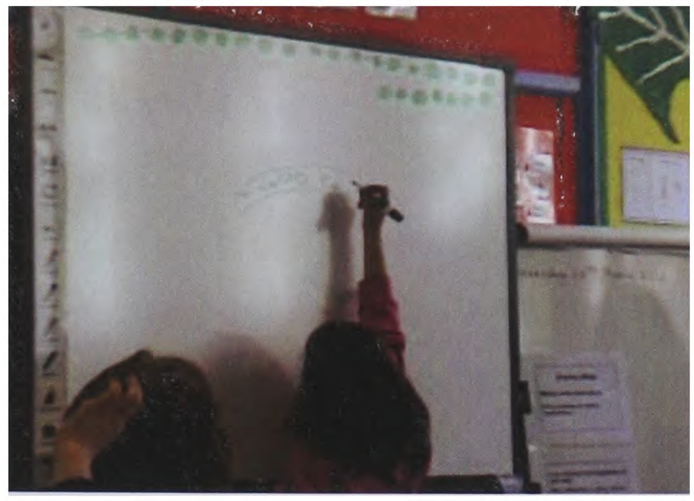
T: What have you seen inside the cross section. Can you describe to me what you <u>see</u>?

Betty: inaudible

T: Small circles! If I drew, on this board here, the cross section *(draws a bridge shape on the board)* Betty could you come and draw what you mean for us? Please.

Betty *(draws some circles inside the shape on the board*, see figure 7.4)

Figure 7.4 Photograph of Betty's Drawing



T: Well done Callum, I can see he's being an active listener, well done. Can you put your thumbs up, if you think, you've seen something similar. *(at least 6 hands up)* Right, fantastic, would you like to tell us something about that. What is it, very strange drawing, very careful observation. What do we think is going on there? Remember our focus is 'what happens to the water next?' Emily.

Emily: Um it looks like bits of the roots that um where you cut them off, it looks like they are the ends of the roots that *(pointing to the cut celery)* You've stopped them growing when you cut it in half.

T: OK, looks like it might be the end of the roots. Can anyone help explain that idea a little bit more or maybe they've got a different idea. What do you think class three? Fred.

Fred: I think we should broke it, and then in the middle like, there are um veins going up carrying water to the leaves and when we broke it we saw..

T: Excellent

Fred: and (inaudible)

T: Some things, Excellent, some <u>things</u> carry water to the leaves, what things? Would those circles carry water to the leaves? Remember we did a cross section *(slicing action)* What do we think is carrying water to the leaves? Maddy

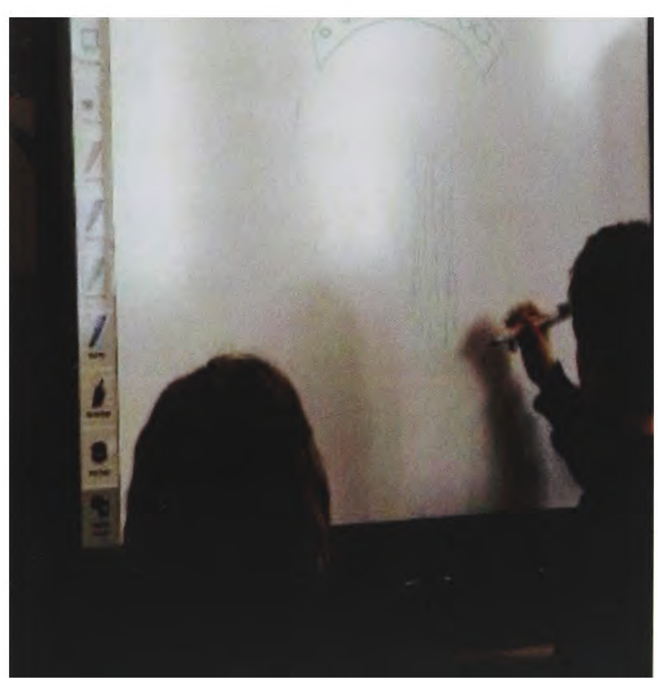
The early part of the episode was interactive/dialogic – Anna was open to the children's responses and the children's vocabulary, but the focus had already been determined and Anna had a clear outcome in mind, making this a 'scaffolded dialogue' (Alexander

2004a). After a discussion about several children's observations of the sticky and transparent properties of the celery, Anna focused attention back on the 'veins'.

T: Lets come back to Saavan's idea about veins *(moves hand upwards in a snaking gesture)* What do they look like. We're looking at a cross section on the board there, so if someone had to come and draw these veins (traces a line upwards in the air with a finger) that Saavan was talking about, what would they look like? Who would like to come and do that. Lets see, someone who hasn't said so much today, Zak can do that. (*Zak comes up to the board and starts to draw*) Imagine Zak, that we were drawing what these circles look like when they are not in a cross section (moving hand up and down) if you could se what they looked like, when they are vertical.

Zak: (*Draws a vertical line and then 5 others parallel to it.* See Figure 7.5). Like that.

Figure 7.5 Photograph of Zak's Vertical Lines



T: Thank you Zak, that's excellent. That looks to me like the outside of the celery. I wonder what these things could be if they were connected to the circles. Callum.

Callum: They would be, sometimes in plants you can sometimes see sort of, straight things that's the veins.

In video based reflective dialogue the teacher referred again to this:

> That was me desperately going 'come on' tell me that it's a tube, and they just weren't having it, and also, looking at that, they, you ask them to make careful observations and they really do don't they, and you're thinking, just notice there are some tubes in there and they notice about a thousand other things that you're not prepared for and then they kind of really bombard you with it and that throws you a little bit, but its really interesting. You just have to be able to listen don't you and kind of pick up on that and be able to go with it and kind of built it into what you want.
>
> (VSRD 03.06.04)

The way in which the children represented their ideas graphically introduced a strong multimodal element (Kress et al., 2001) to the lesson and made their ideas available to others to be built on in a similar way to the cumulative chaining of utterances that characterises dialogic teaching (Alexander, 2004a). Anna explicitly encouraged this: 'Can anyone help explain that idea a little bit more or maybe they've got a different idea'.

The children were then asked to follow the instructions on sheets on the table to set up sticks of celery in water with food colouring added to see what happened to the water, and these were left to one side to return to the following day in Lesson 5b. This lesson was not observed by me. The teacher reported that it had been approximately an hour, and the children had looked at the celery, and n the class discussion, it was established that the water 'went up' (field notes 1.4.04). The word 'tube' had not emerged in the discussion. On one stick of celery leaves had turned red with the food colouring, and the teacher explained that she was intending to develop the idea that the water goes to the leaves in lesson 6 (field notes 24.03.04).

7.11.3 Summary of Lesson 5

Interactive whole class teaching focussed the children's observations on salient features of the situation and drew the attention of the class as whole to those features. This supported an interactive/dialogic episode in which children built on each other's ideas. The children's drawing on the board can be interpreted as a graphical contribution to the interactive/dialogic communicative approach.

7.12 Lesson 6

Anna's aims for this lesson were that the children should make measurements of the growth of the plants they had set up as fair tests, and then use this data to make statements about patterns in results and as a basis for making simple predictions. She also wanted to develop the ideas from the previous lesson about how the water travels through the plants, and to consider the importance of the leaves. She explained that she had debated 'how far to take this' in terms of developing ideas about photosynthesis, and would be guided by the Ginn New Star Science book (Feasey et al., 2001) that establishing that 'leaves matter' was the main aim (field notes 1.4.04).

The lesson began with the children sitting on the carpet and in an interactive /dialogic episode Anna asked the children to think about what they expected to see when they looked at their pots. The first responses were general; they will have grown a lot, they might be bigger, they might have more leaves, they will have sucked up the water, and so she asked them: 'Do you think <u>all</u> of our plants will have grown?' focussing attention on the possibility of a difference. There was a chorus of 'nos' and some head shaking and some children were able to give examples of differences they expected to find between their two pots. Anna encouraged them to make careful observations of their plants and said that they would feedback together what they had noticed, which they did in episode 6.

7.12.1 CS2 Lesson 6 Episode 6-We found some mould on ours

T: *(Standing at the front of the class, but moving towards the tables where the children are sitting)* What have we noticed has happened to our plants, Class Three? Maddy?

Maddy: Our plant is the tallest.

T: Your plant is the tallest?! Compared to..?

Maddy: The whole class

T: The whole class. Wow, I didn't think about observing that kind of change, but that's a very interesting one isn't it. Caleb

Caleb: We found some mould on ours.

T: Right, you found some mould

C: *(Caleb's partner)*: One of our seeds has dissolved in it , so one of our (inaudible) one of our seeds has turned brown.

T: Right, So has yours, has any changes Emily, has it changed?

Emily: Um yes this seed, it used to be black, but um and it had round here a kind of stripe, but its all round

T: Class Three, why do you think that's happened to Emily's seed? I wonder. Maddy's just said 'Our plants grown the tallest', would you like to hold that plant up for us please, Maddy, and Holly.

C: Um

T: And Emily has said 'but our seed has gone brown' what do you think has happened class three?

The children's interest has been captured, not by the planned fair tests, but by other, unexpected outcomes – Maddy is excited that her plant has grown taller than all the others, Emily is interested in the change she has observed in the seed. Anna capitalised on this interest by drawing attention to the two different outcomes and encouraging the children to compare them. Some children speculated that they had been given different amounts of water; this seemed to be the only explanation they could come up with, and this discussion was left unresolved.

Episode 6 was coded as interactive/dialogic overall and began with the children's observations. Anna made connections between what they had observed and what she hoped might be productive comparisons. It was only possible to speculate about what caused the difference between the plants as they were part of different fair tests. In the subsequent episodes Anna focussed on comparisons between children who had the same independent variable, but this was still problematic as the control variables has not been controlled in a consistent way between the different pairs.

Because some groups had varied the amount of seeds they had put in their pots, the teacher was aware of an opportunity to develop the children's ideas about seeds needing space to grow and of them being in competition with each other.

The episodes presented below are long and quite difficult to follow, but that complexity is one of the outcomes of the open-ended approach the teacher has taken.

7.12.2 CS2 Lesson 6 Episode 12-That's really not what I expected

May: We put three, one wasn't a really (inaudible) and these two have just grown near each other.

T: Right, that's interesting, *(taking the pot that May was holding)* so how many, this is plant, (*looks at it*) B, where you put lots of seeds in and one of them, class three shot up really tall and May's just said, that where they put more seeds in, the plants have grown over each other. What do you think that's telling us, you two, what's your ideas about that?

May: We put our seeds too close together.

T: You put your seeds too close together. Thumbs up if you think that might be the case here. *(holds up the plant May was referring to Pot B*) OK. And what about your plant A?

Dan: *(hands his pot to T*) It hasn't done anything.

T: Oh! *(looking into the pot)* It hasn't done anything. How many seeds did you put in plant A?

Dan : One.

T: One seed! And nothing had happened. (*Holds up both plants)* That's really not what I expected. What do you think about that Maddy?

Here the teacher was apparently anticipating a simple relationship between the plant growth and the number of seeds in the pot and sought evidence to support this.

T: Put your hand up if you put one seed in plant pot A. Put your hand up if you put one seed in plant A. *(Only April and her partner put their hands up).* Can you tell us what happened to your plant A with one seed?

April: Well, it grew a bit, a little bit.

T: Right, so that one has started growing, Oh, so that's interesting.

When the evidence she was looking for was not forthcoming she returned to the example that matched the idea that 'plants need space to grow' and focussed the attention of the class on that.

T: What do you think Class three, that this plant, that's got lots of seeds in, and May and Dan's observation about plants growing over each other, is telling us about the amount of seeds you put into a plant pot. Think carefully about your own plant Saajid as well before answering. I' d like you to talk to the person next to you and have a think about what that is telling us about how many seeds we put into a plant, uh into soil, and how that affects a plant's growth. Can you talk to the person next to you please.

Asking talk partners to discuss it (Episode 13) and inviting them to reflect on the outcomes of their own investigations introduced a multivocal element (Wertsch, 1991). They were asked to share their thoughts in Episode 14.

7.12.3 CS2 Lesson 6 Episode 14-They're fighting over who gets the water

Fred: Well I think the plants leaves grow um because they've given them (inaudible) and its got lots of space and if you have more than one then there'll be more plants um drinking the water

T: Right, so you're saying its got something to do with the amount of space, that putting less seeds in is going to give the plants more space so that they've got a better chance of growing, but also an interesting ideas about there'd be more water for it to drink, I hadn't thought about that, an excellent idea. Thank you Fred, Ethan.

Ethan: Um, um the plant, needs space to grow, cos they might have put the two seeds quite close and when the roots have gone down, they've sort of tangled up and they're fighting over who gets the water.

T: That's really interesting, because that's one of your initial, your ideas, right at the beginning *(turns to look at display)* because you were very clear, I remember April being very clear, that you need to spread seeds out and not to put too many in to help a plant grow. Would you agree then class three, based on observing May and Dan's plant, that plants need space to grow. Put your thumb up if you would agree with that, plants need space to grow. *(Most children are putting their thumbs up)* OK thank you.

The teacher confirmed that it was her intention to reinforce the importance of evidence from observations in developing ideas:

> I think it was looking at ..they had an idea and they had some evidence to prove it, they had their own obs , they had made. As I remember they had really noticed about these roots coiling around and growing and so that was kind of linking back to their own idea and saying, this is the evidence that shows this and look at how we can confirm our ideas by looking at what has actually happened, if you like. (VSRD 03.06.04)

The 'thumbs up' assessment suggests that the majority of the class have accepted the idea that plants need space to grow well (although its validity as an assessment is clearly rather weak). Rather than this idea being deduced from evidence the children have been persuaded by the apparent internal sense of the argument and authority of the 'expert children' and teacher. The ideas had been made available on the social plane in everyday language such as 'tangled up and 'fighting over who gets that water'. But the sheer complexity of the line of discussion raises questions about what proportion of the class were really following it. The version of science that is being developed here apparently is based on an empirical view, while actually children's ideas are being developed through their social construction and it raises the concern that positioning the children as scientists who will develop logical proofs for their ideas, whilst simultaneously relying on authority to support ideas could ultimately lead children to see little value or purpose in their own work.

Anna trusted that the discussion would have a productive outcome if she allowed ideas to be generated and for children to respond to each other, but acknowledged the tension between this and having an aim determined by the curriculum.

> I find that they are more responsive when its like that. They are more likely to kind of interact, get going and and say something if it's a bit more kind of freeform if you like, it just comes out that we go with ideas as they happen, but it is difficult because sometimes you're thinking, well I really need to get this objective.
>
> (VSRD 03.06.04)

However, it would be unrepresentative of the case to suggest that this lengthy discussion was the only form of episode and in the next episode (L6 Ep. 16) there was a simple relationship between the data and scientific view.

7.12.4 CS2 Lesson 6 Episode 16-Plants need water to grow

T: There's one other thing we've tested, we've set up a fair test for seeds, temperature, light, what was the other change that we made? Ethan?

Ethan: Water.

T: Water! What's happened to those people who did a fair test and were taking away water from them? Maddy.

Maddy: Our plant has grown a bit, but not as much a plant A.

T: Right. So what is that telling you about helping plants grow?

Maddy: Um,

T: Wha

Maddy: (interrupts) Plants <u>need</u> water to grow.

T: Right. Thank you, that's a very clear description, well a very clear <u>statement</u> about helping plants grow. Thumbs up if you agree, if you think plants need water to grow well. *(most children put their thumbs up)* Yes we did talk about this right at the beginning of our topic and now we're actually observing, we can see from our fair tests, the changes.

This was interactive/dialogic in that the children constructed the scientific view from their own evidence, led by the teacher's sequence of questions to draw a conclusion in a 'scaffolded dialogue' (Alexander, 2004a). As Anna notes in her summary at the end of this episode, this is not new knowledge for the children as they began the topic with the idea that plants need water to grow. Instead, with similarities to the dissolving investigation above, the teaching point is about how the fair test provides proof of this idea.

The way this practical enquiry had been set up was an uncomfortable compromise – the limited available variables meant that it was never really the children's ideas being tested, but the children had the freedom to approach the task in a variety of ways that made interpretation and comparisons in a whole class context problematic. It points to a need to plan for children to carry out practical tests with view to how outcomes will be discussed. It might support a more genuine, honest discourse to distinguish between enquiries that are intended to develop certain conceptual points and so may need to be more controlled and enquires that can be more open-ended and reported and understood in their own terms without the pressure of reaching a predetermined conclusion. An alternative would be developing teacher's confidence in introducing the scientific view while acknowledging the reality of the children's results and leaving the difference as unresolved, but made explict.

The children were then asked to come and sit on the carpet again for the second part of the lesson. In this the teacher was presenting a page from Ginn New Star Science pupil's book (Feasey et al., 2000) in which fictional cartoon children are discussing a whether or not plants need leaves to grow and planning how to test their conflicting ideas. This was used as a stimulus for group discussion and the teacher invited individuals to represent the ideas being discussed by their group, supporting the development of an interactive/dialogic episode. In terms of the scientific story this episode opened up discussion about what the water might travel to the leaf.

They then looked at the fictional numerical data produced by the two characters comparing the growth of a plant with and without leaves and were encouraged to look for numerical patterns in an interactive/authoritative episode and draw conclusions about 'whether plants need leaves to grow' in an interactive/dialogic episode.

> And then the idea was they'd done some practical and they'd really looked at their own plants and made observations and then they could look at something slightly out of the contexts of their own fair test and see whether they would, you know to begin to make links.
>
> (VSRD 03.06.04)

In terms of the constructivist model this can be understood as application - the children were being invited to apply their idea about how to construct a fair test and interpretation of evidence to this new scenario. However, it also developed ideas about the importance of leaves for plant growth, which informed subsequent lessons.

7.12.5 Summary of Lesson 6

Sometimes generalisations could be made from the children's results that were in line with the scientific view and an interactive/dialogic communicative approach was not problematic. The children's investigations also produced unexpected outcomes that interested them and the teacher encouraged discussion of this in interactive/dialogic episodes. However the children's results also produced conflicting data, leaving the teacher to rely on an authoritative approach to establish the scientific view by selectively focussing on evidence and ideas that were in line with it. The lack of transparency in this process reduced the intellectual honesty of the dialogue.

7.13 Lesson 7

This lesson is considered in less detail for two reasons. Firstly a technical problem of a background buzz on the recording made reliable transcription difficult. Secondly, unusually the lesson had the involvement of six visiting older Year 6 children, introducing a further dimension beyond my main focus.

This lesson took place after the Easter holidays. I had expected the sequence of lessons making up this unit of work to end with the end of the spring term, but the teacher felt that the topic was not yet finished and wanted to continue for two more weeks.

The Year 6 children had recently been revising ideas about plants in preparation for their End of Key Stage Tests and the teacher intended that they would extend the children's ideas about why plants need light. She felt that the guidance offered by the scheme of work (QCA, 1998), that it was sufficient to know that plants need light, but not why, was not a sufficient explanation for some of the children. So here the teacher was actually going beyond the prescribed curriculum, extending the learning demand to include more theoretical conceptions of photosynthesis.

7.13.1 CS2 Lesson 7 Episode 1-What did we decide plants needed in order to grow well?

T: What did we decide plants needed in order to grow well? What do we think that plants need, there are some things we came to a decision after looking at our fair tests *(8 visible hands up)* our plant A and plant B. What were those things? Caleb?

Caleb: Leaves.

T: Excellent, right, they needed leaves *(counts off on a finger)* that was the last thing that we investigated wasn't it and we found out that plants needed leaves. What other things did they need? Paul.

Paul: They need water, seeds and temperature.

T: Excellent, yes they need water, *(counts off on finger)* seeds *(counts off on finger)* and temperature *(hesitantly)*. What sort of temperature did we decide? Callum?

Callum: Mild, warm.

T: A mild, warm temperature thank you. May.

May: Was it they needed light, cos the ones in the cupboard didn't grow, didn't grow at all.

T: Excellent, I really like the way you are using the evidence to justify your ideas. They need light, because our fair test proved to us that plants can't grow without light. Stella.

Stella: They, they mostly need water.

T: Ooh, *(head on one side)* They mostly need water? Would anyone like to share an idea about that. Ethan.

This episode was coded as interactive/authoritative as the scientific view is the only voice present and the exchanges take the IRE form. One interpretation could be that the teacher was making a summative assessment of their knowledge, but the tone that was established is of shared recollection and review, rather than of individuals being assessed. The ideas expressed are mostly in line with the scientific view that the teacher wants them to learn and so there is no contradiction between the authoritative version and the children's version. The children had appropriated the knowledge, though May was still tentative in her ownership of this suggesting she was at Stage 2 of appropriation (Mortimer and Scott, 2003, p. 115) in which she sees the ideas and half her own and half belonging to others.

As this episode occurred after a break of two weeks, it also offers an insight into the children's learning. The episode served as a thematic nexus (Lemke, 1990) in that it drew together both the outcomes of the children's fair test into plant growth and also the outcomes stimulated by the discussion of the fictional results on plants needing leaves.

The Year 6 children were asked to work with particular groups of the Year 3 children and to support them with observing their plant A and making records of observations and measurements of the height, the leaves and the colour. They were then asked to talk with each and with the Year 6 children about 'what you remember and your ideas about why leaves matter' and this was fed back to the class: The older children shared their developing ideas about photosynthesis with the Year 3 children. Back in the classroom, they were asked to present 'their learning' as a poster: 'coming to some firm ideas about why leaves matter.' (field notes 23.04.04). The children were then asked to feedback to the whole class.

The sense of 'handover' (Bruner, 1983) was evident in Anna's reflection on the lesson:

> [ ] you can almost hand it to them their previous knowledge over the last six weeks [ ] they have got the confidence they have reached a level where you can remove yourself from the equation and encourage them to extend themselves. [ ] Because Year 3 were confident in their own understanding they have something to give back so it is a dialogue not just year 6 telling them. It might not have worked earlier in the sequence.
>
> (field notes 23.4.05)

7.14 Lesson 8

Before the lesson the children's tables had been set up with the concept maps that they had made at the start of the topic in lesson 1. Anna began the lesson with the children together on the carpet and explained that this was the last lesson on the topic of plants and praised them for their learning.

In the second episode the children were asked to talk with the person next to them about whether their ideas had changed or not. They were then asked to feedback these ideas to the whole class. Most children who were invited to comment explained that they would change some of their ideas, but not all. Only one child gave a reason for their comment – this child said that they had had ideas about what plants needed to grow at the start and talking to the Year 6 child had confirmed these ideas. None of the children referred to the practical experiences they had had. This metacognitive process, is linked with the 'review' that is advocated in some concept-led constructivist-based models.

The teacher referred to an example of a concept map that a pair of children had done during the first lesson, having it on the board next to her. She chose one of the statements; 'Plants always need roots to help them grow' and asked the children to think about whether or not they would still agree with it, or would want to change or add to it in any way. A lengthy section of this episode is presented below as it led to an extended debate.

7.14.1 CS2 Lesson 8 Episode 6 - Plants always use roots to help them grow?

T: So when you say you would change some, I 'm quite interested in that ideas Class three, and I'm going to read one of these statements out and I'd like you to think about how you might change it.....'Plants always use roots to help them grow'...How would you add to that, *(makes writing gesture with a hand)* or change it *(makes writing gesture with a hand)* . or would you leave it the same?. What would you do? Based on what we've been learning, what do you think? *(five visible hands go up)* Saajid.

Saajid: Plants always need roots to grow cos they get nutrients from the soil and if there's no roots they wont get the nutrients.

T: Right, excellent, so you're extending something about the idea of roots, *(indicates the statements on the concept map)* thank you. Archie.

Archie: (inaudible)

T: Right

Archie: inaudible

T: Right, thank you, so, you've got another ideas there (*moves hand along the statement*) that roots are kind of holding *(moved upturned hand sharply downwards)* the plant in the ground. Mabel.

Mabel: Plants, obviously need roots to grow because if you pick a flower, *(Maddy's hand shoots up)* if you tried to stand it up it would just fall down.

T: Right, so that's anchoring them isn't it? *(makes a fist and pulls it downwards)* Sort of holding them into the soil. Maddy.

Maddy: Um, I would say sometimes they need roots, *(Mabel and several other children have turned to look at her)* because say a flower, you bought it in a shop, well they wont have roots, cos they've cut the roots off, but you put them in water so they still survive.

T: Right. So, perhaps you could change that statement, from 'plants always need roots to help them grow', to something else to do with water *(finger to lips and head slightly to one side, as if wondering)* and that's what we're going to do this afternoon. I'll just hear a few more comments, cos its really interesting, you're really showing <u>me</u> *(double open handed gesture, bringing hands clasped and pointing towards herself)* how you can take a simple statement and make it into a much more complex statement based on your ideas and your learning. Callum.

Callum: Sometimes they don't need their roots because, you you can pull up fungi and they don't have roots so so how will, how would it stay in the ground?

T: hmm, that's very interesting that idea about fungi and how we classify and how we group some of our plants. Callum we'll talk maybe a bit about that later cos fungi are slightly different (*fingers make running motion to the left*) from ...OK. Saaven.

Saaven: If you've got um, lets say you had a type of vegetable that was just on top of the ground so , like um a cauliflower, if the cauliflower didn't have a root, then it would um it would just stay in the ground and um wouldn't even try to shoot up.

T: Right, so that's another idea that we've been learning about. Fred

Fred: Um going back to what Maddy said, if you buy shops, buy flowers in the shops, um they don't have roots, but they die, much quicker than they would have, if they were in the soil and had roots.

T: *(nodding)* Thank you, I really like the way you're relating to something somebody's said thank you Fred, I like that way people really <u>think</u> (*moving alternate fists towards herself as if 'wrestling' with an idea)* , not just listening but thinking hmm *(puts hand to head*) what do I *(indicates self)* think about that, then able to share *(open hand gesture)* something aswell. Thank you. Ethan.

Ethan: Um well…I forgot.

T: Sorry, you've waited a while. Jack.

Jack: I was going to say about Maddy's idea that you do have plants in shops that don't have roots, but if you put them in water, they just keep alive a bit and, for bit longer, but they wouldn't actually help it, it isn't helping it grow.

T: (interrupting) excellent.

Jack: (continuing) it just keeps it alive for a bit longer.

T: Very interesting, cos you did say that didn't you Maddy, that that by putting water in a vase, and the *(makes upward gesture to indicate long*

> *stems)* that would help the flower stay alive, and then we thought maybe *(turning to statement on concept map)* we could change this statement and Jack's now made it really explicit that that word grow *(circling the word grow)* isn't perhaps relevant to that statement or that idea. What a dialogue, a conversation we're having about one idea! How much have you learned about one (*holds up one finger)* idea, its absolutely fantastic to hear.

This was coded as interactive/dialogic – the children's utterances were prolonged, and they built on each other's ideas, chaining them together (Alexander, 2004a). There was high level of interanimation of ideas (Scott et al., 2006) The teacher acted as 'chair – enabling different ideas to be expressed, and provided evaluative feedback, in the form of 'excellent'. Although it is not clear whether this refers to the content of the idea or the expression of a thoughtful contribution, her comments all concern the way in which ideas were expressed or linked, rather than to the conceptual content, suggesting the latter.

Anna was aware of the way in which children were chaining ideas and valued it highly:

> I really like that, I like hearing that I like the way they do start thinking about what somebody else has said or kind of extend an idea its good it shows they are listening and working and are really aware of what someone else is saying, or it sparks off an idea in them.
>
> (VSRD 3.6.04)

The notion of knowledge as problematic and open to debate was encouraged though this episode; the ideas that were developed were those of the children who participated, and not strongly directed by the teacher, positioning the children as active agents within science.

The children then worked on their concept maps, making changes to them. In episode 9, Anna asked for feedback to the whole class on what changes they had decided to make.

7.14.2 CS2 Lesson 8 Episode 9-You've really got some evidence to back that up

T: I've been, as I normally do, moving around and listening to everybody talking about what they have learned about plants, and I'm just wondering if you would like to share some ideas or some changes you have made to your concept maps. Ethan

Ethan: Well, um we had 'All plants have stems', but not all plants do, cos duckweed, are just like a type of leaf, that grows in the water and they don't really have a stem.

T: Right, OK, *(sounds unsure that it is OK)* Lets have another idea. Maddy.

Maddy: Um well I, me and Sara thought that well, on here it says that 'All plants need sunlight to grow' and we didn't change that in the first place, and then in the end, now we said, well that is true because, think of the plants that have been in the cupboard, they haven't grown, so..

T: Right. So you've really got some <u>evidence</u> to back that up. Our observations from our fair test have really shown you that that statement is true. Thank you. Mabel

Mabel: Well, um we had plants um sometimes need roots to grow and we said um (inaudible)

T: Right, can you say that again. In a really big voice.

Mabel: Well, me Julie and we put where it says plants sometime use roots to grow we put roots help plants have water

T: Right, Can anybody add to that? What happens to the water after the roots? Whose thought about that on their maps? *(Archie's hand is up fast)* Archie

Archie: Well the plant sucks it up so the roots can um they can it just has to go up the plant

T: Yes, goes up where?

Archie: up the stem, to the leaves

T: Right, how does it get up there then? Emily?

Emily: Well, what happens is, you do plant, the water have water, then it um, the stem sucks it up and it starts further up the stem by when it's sucking it up and it goes into the leaves.

T: Right how do we know that class three? How do we know that that's right and correct? Daisy

Daisy: Um, we know that when we did it with the celery (inaudible, extended)

T: Right, thank you, so we are actually finding out for ourselves, actually testing to find out. What about this table. What can you tell me about what you've added? Betty.

Betty: (inaudible)

T: So the roots are important because…?

Betty: (inaudible) water

T: They help the plants get some water?

Betty: And it goes up (*makes upward motion with hand*)

T: Right so that's taking it upwards *(T copies upwards hand gesture Betty made)* through the plant. Thank you Betty.

In this episode Anna's questions prompted the children to review their conceptual learning and also to make links to the evidence base for those ideas.

> That was sort of reviewing their ideas and trying to get them to make a link between the fact they'd done this fair test and they'd explored plants and kind of from their learning be kind of able to re-evaluate what, where they started from.
>
> (VSRD 3.6.04)

Concluding a sequence of lessons with a review of learning is congruent with the concept-led social constructivist models of teaching science (section 4.4.2) . The episode also proved a thematic nexus (Lemke, 1990), drawing together the themes about the journey of water through the plant that had been developed over the course of several lessons into a coherent story. This was achieved through an interactive episode of IRE triads. Classifying it as authoritative fails to capture the sense of shared understanding of the episode, but classifying it as dialogic doesn't capture that the ideas being discussed are consistent with the scientific view. The children have appropriated the ideas and have taken ownership of them, but the teacher prompts are still required to support the telling of the whole story, in line with Stage 2 of appropriation in Mortimer and Scott's model (2003).

In the next section of the lesson the teacher gave the children photographs she had taken when they had been planting the seeds for their fair tests. She asked them to look at the photographs together and discuss the 'science skills' they had learned. The class then fed these back in episode 12.

7.14.3 CS2 Lesson 8 Episode 12-Why do you think those are important skills?

The episode began with children giving examples of skills they had learned: making careful observations, setting up a test, and measuring before Paul's contribution

Paul: Concentrating.

T: Concentrating. That's really interesting Paul, because this table said something similar. Saajid can you say what you said when you first came over to this table. You were having to be...?

Saajid: Balanced and patient.

T: You had to be patient *(holds up thumb),* you had to have some balance *(holds up first finger*) and Paul said you had to concentrate *(holds up second finger).* Do you think those are important skills to have when doing science? Why? Why do think those are important skills? Daisy?

Daisy: Well, you need to be able to balance when you're watering the plant, otherwise you're just going to spill it everywhere.

T: Right, thank you. Why is concentration, and patience so important then? It's very interesting that they've come up. Jack

Jack: If you weren't very patient then its quite unlikely that you're going to get something right the first time when you you're doing a test,

T: (into a pause) right

Jack: so um you need to do it loads of times and if you aren't patient you get really annoyed and want to stop.

T: Right. So in science you might need to do a test more than once. Why might you need to do a fair test more than once? I've been thinking about certain people's plants. Fred, why might you need to do a test more than once?

Fred: Because if you are, if something happens, you might need to um try to again to make sure anything is happening when you (inaudible)

T: Right, so to get reliable results, to get things to work for you, you might need to do it more than once. What do you think about that Zak?

Zak: I think um, we should um. I forgotten.

T: OK, Maddy.

Maddy: Say, you were changing the light, and put something in the cupboard, you might be like, Oh I think I might have left the door open, so I don't, so that would let some light in, I really need to try it again.

T: Right, so to make sure you are really accurate, you might need to try thing more than once again. That goes back to that idea about being patient. What a lovely link, thank you for that this table.

The episode began as pooling a list of skills and procedures, also some attitudinal attributes, with Anna selecting certain children to repeat what they had said in the small group discussions. Probing publicly why two children had included 'patience' led to a discussion of reliability and the episode became more dialogic as Anna opened out the discussion by asking the class 'What do you think about that?' using an invitation to participate. Issues of reliability had not discussed at all in the whole class forum prior to this episode as Anna noted as she reflected on the episode.

> Yes, that seemed to work a little bit better at getting them to think about what they had been doing, having that picture, ..., and then talking about relia you know, having reliable results and something we hadn't really touched on much in that topic, which was quite nice to have that drawn out at the end of it.
>
> (VSRD 3.6.04)

These episodes were not explicitly pre-planned for by the teacher but were part of her general approach and the class was familiar the pattern in which group work was punctuated by whole class episodes selecting from their work. The strategy used in this episode of first drawing the selected ideas to the attention of the whole class, making it available on the whole class plane, but then inviting further comment to encourage other children to take ownership of the idea on the idea is congruent with the second and third stages of appropriation presented by Mortimer and Scott (2003).

7.14.4 CS2 Lesson 8 Episode 26-Run around

In the last episode the class went outside and the children ran to and fro across the playground to show they agreed or disagreed with a statement Anna read out as follows.

> 'Roots need to spread out to take in water effectively.' - all agreed

'We can eat all types of plants.' – all disagreed

'Water is transported to other parts of the plant through the stem.' - all agreed

'Plants need leaves to grow well.' - Half the class stayed at the 'agree' end of the playground, half ran to other side, and then when those on 'agree' shouted laughed, they came back again. Then a few children moved into the middle, and about half the class followed, indicating that this was a more controversial statement.

This strategy was presented an assessment of individual learning, but its effect was to reinforce a consensual view of the nature of scientific knowledge as the children tended to follow each other.

7.14.5 Summary of Lesson 8

Lesson 8 can be understood as review in the concept-led social constructivist models of teaching. It exemplified how through an interactive/dialogic communicative approach the children could chain their ideas together into a coherent, cumulative discussion, and had appropriated the scientific discourse of evidence –based argument.
A review of conceptual understanding took place through an interactive/authoritative communicative approach, in which the teacher's role was to prompt the recall of information and connections between ideas. A review of skills and procedural understanding through an interactive/dialogic communicative approach made children's ideas about reliability generated through group discussion available on the social plane of the whole class.

7.15 Teacher Validation of this Case Study

[ ] It has been very thought provoking reading and is a valuable tool for reflection and analysis of my approaches to learning and teaching. In retrospect, taking part in this case study was pivotal to shaping some of my approaches to learning and teaching. I really believe that have the opportunity to observe, reflect and think so carefully about what is happening in your own lessons is the best form of professional development. The study does ring true – all the biographical references seem correct and it definitely feels like me and the class. I do feel that the study represents the sessions accurately and that there are insightful interpretations of the teaching methods - although there is

much I would change now! [ ] it seems a very relevant focus and I would like to read more about the theories behind whole class teaching. The case study has certainly had me questioning its different functions/purposes!

(Email communication 27.05.09)

7.16 Summary of Emergent Themes of Case Study 2

This summary draws together the insights of episode, level and sequence of lesson level analysis to comment on the use of the different communicative approaches in case study 2 and then summarise some more general emergent issues from the case. Together with the summary at the end of Case Study 1 (section 6.20) this addresses the research sub questions:

> *What is the nature of interactions within whole class interactive teaching in science,*
> *How are teachers using 'interactive whole class teaching' in science lessons and to what extent is this consistent with the models of practice in the literature?* and
> *How does 'interactive whole class teaching' contribute to teaching about the nature of science and scientific processes and scientific knowledge and understanding?*

7.16.1 Interactive /Dialogic

There was higher proportion of time spent in interactive/dialogic episodes compared with Case Study 1. Its purposes/functions in the case are listed below.

a. Relating the teacher's aims to children's previous experience

b. Collecting and pooling ideas, including question raising, in episodes with a low level of interanimation were evident at the start of the sequence of lessons.

c. Episodes of high levels of interanimation in the middle of the sequence of lessons were associated with relating observations to explanations. This made up a large proportion of the interactive/dialogic episodes that were science specific rather than related to group collaboration.

d. Unlike in Case Study 1, interactive/dialogic episodes were associated with constructing plan for a fair test and making predictions, although this was not successful for the whole class. Many did not grasp either the logic or purpose of a fair test as they were unable to decontextualise the variables. In Piagetian terms the children may not have been developmentally ready for this kind of abstractions, but the multicultural work of Reiss (1993) offers an alternative perspective, that such decontextualised ways of addressing problems may be culturally different to the children's way of approaching things and require a significant shift, an epistemological shift (Millar, 1998).

e. Different meanings of words were discussed and related to children's own vocabulary.

f. Interactive/dialogic episodes with high levels of interanimation in which the children built on each other's ideas occurred later in the sequence of lessons, suggesting that children were appropriating the discourse of this domain.

g. Selected children feeding back from group work in interactive/dialogic episodes made their ideas available on the social plane of the class, supporting a collaborative ethos, but raising questions about how they were selected.

Interactive/dialogic episodes were frequently associated with discussing processes of collaborative group work not the science content.

7.16.2 Non-interactive/Dialogic

a. The teacher sometimes reported selected children's ideas to the class using a non-interactive/dialogic communicative approach, although the frequent selection of ideas that would develop the scientific story introduced an authoritative element.

b. Talk partners were asked to discuss questions or issues on the social plane in relation to their personal ideas and were invited to feed these back to the class.

7.16.3 Interactive/Authoritative

a. An interactive/authoritative communicative approach was adopted for planning for a fair test.

The impression I gained was that a broader range of children participated when the communicative approach was interactive/authoritative.

b. Interactive/authoritative episodes often had the purpose of clarification of tasks or organisation of resources.

7.16.4 Non-interactive/Authoritative

a. Non-interactive/authoritative episodes were associated with organisation, all through the case, but strongly associated with practical work as in Case 1

b. The teacher sometimes adopted a non-interactive authoritative approach to sharing her aims for the lesson at the start of lessons.

7.16.5 Whole Class Teaching

- The teacher did not value whole class teaching as means of learning – as in her view this takes place in collaborative group work, but none the less the proportion of time as whole class was high.

- Participation in whole class interactions was dominated by articulate, confident children who made up about a third of the class.

- The concept-led and procedure –led social constructivist models were both evident. The questions and ideas that the children had expressed early in the sequence of lessons were not directly tested through investigations, but they were evident in the talk associated with practical work.

Chapter 8: Discussion

8.1 Introduction to Chapter 8

This chapter is in two sections. I will first review the methodology and methods used and explain how this constrained the findings. I will then discuss how whole class teaching was used in the cases and suggest how these insights could develop the existing models of teaching science at Key Stage 2.

8.2 Review of Methodology

Here I will first reflect on different aspects of the analytic framework I adopted and then review the validity of the study.

8.2.1 Reviewing the Analytic Framework: Purposes of Episodes

I found that the list of pedagogic purposes of episodes derived from Moyles et al. (2003) and including elements of concept-led and procedure-led social constructivist models of teaching science (Appendix 3) was not an adequate means of capturing the purposes of the episodes. Defining the purposes of episodes both in the field and in later analysis was problematic due to both the multiple purposes of episodes and the particular and varied 'lenses' that the different models of teaching science brought to their interpretation. There is a distinction to be made between the apparent purpose of the episode as the teacher may have conceived it at the time, and of its function within a sequence of episodes, that is a more emergent quality. As an utterance can be retrospectively assigned meaning depending on what follows it (Mercer, 2000), so can an episode. Rather than trying to code the purpose of an episode using the list I discussed the apparent purposes and my interpretation of the outcomes, in an approach more consistent with critical discourse analysis (Fairclough, 1992).

The 'deep purposes' would have benefited from being more theorised at the outset, for example, use of the analysis of the knowledge content in Mortimer and Scott's flow of discourse model (Mortimer and Scott, 2000). This may have informed the selection of episodes for transcription.

8.2.2 Reviewing the Analytic Framework: Categorising Episodes as a Single Communicative Approach

By categorising episodes in terms of overall communicative approach, some of the detail was lost, especially in those cases that were not transcribed and considered in further depth, but contributed to the quantitative overview. For example, I looked for evidence of the cycling of communicative approaches described by Mortimer and Scott (2003) and Scott and Ametller (2007), across the whole teaching sequences, and found no clear pattern, but some of the subtle shifts within episodes, might be masked by the overall label of the episode. For example, the very short authoritative, teacher summaries at the end of some otherwise dialogic episodes (e.g. CS2 L2 Ep 7) were only evident from the detailed transcription. This validated the need for 'zooming in' to a finer level of analysis (section 5.8).

8.2.3 Applying the Analytic Framework: Interactive-Non-interactive Dimension - Which children were participating?

Although, in the case studies I have indicated the proportion of children who were engaged, the single camera was focussed on the teacher and therefore provided limited data on children's facial expressions and I was not always clear which child had made an utterance. The practicalities of my position in a small classroom meant that I could not always have the whole class in camera shot and capture what the teacher was doing. My use of Mortimer and Scott's analytic dimension 'interactive – non-interactive' takes no account of *which* children are interacting. There is a large body of literature that recognises children's different participation in classroom interaction, on the basis of cultural grouping such as social class (Lemke, 1990; Bernstein, 1971), gender and 'ability' (e.g. Myhill et al., 2006). Although I formed the impression, that interactive/authoritative episodes supported broad participation and participation in interactive/dialogic episodes was dominated by children labelled as 'high attainers', I did not produce evidence to explore how the teachers' use of different communicative approaches had an impact on who participated in interactive whole class teaching. The framework could be developed to provide further analysis of this dimension and the way in which a collective Intermental Development Zone (IDZ) is created and maintained (Mercer and Littleton, 2007).

8.2.4 Applying the Analytic Framework: Developing Non-verbal Features of the Communicative Approach

The meaning of a whole class discussion may be influenced by its location and the teachers and children's positions (Kress et al., 2001 p 21; Roth, 2005, p. 230-1). For example, both teachers frequently led a whole class episode from positions other than at the front of the room – perhaps near a group whose ideas they were presenting to the class, or from the side or back of the room, again possibly signalling a shift of the ownership of knowledge away from the teacher, handing it over to the children. In both case studies the teachers used what I described as 'open handed gestures', that signalled the children's ownership of ideas and in Case Study 2 Anna's hand gestures often physically marked out different views; visually communicating 'on the one hand, on the other hand'. The ways in which non-verbal modes were identified as contributing to the authoritative or dialogic nature of the episodes is summarised in Table 8.1.

Table 8.1 Non-verbal Contributions to Communicative Approach

Non-verbal indicators– 'authoritative'	**Non-verbal indicators - 'dialogic'**
Teacher standing	Teacher sitting, or 'perched'
Teacher at front of the room	Teacher may be at back of room, or amongst children
Holding up 'scientific' artefacts and pointing to diagrams.	Open handed gestures towards child, head on one side when listening
	Hand gestures support multiple views, e.g. 'weighing up' movements
	Children respond to each other's visual representations of ideas.

8.2.5 Applying the Analytic Framework: Categorising episodes as Interactive/Authoritative as Ideas Became Shared

Mortimer (1998) suggests that across a series of lessons the aim is to move from a multivocal (dialogic) discourse to a univocal (authoritative) discourse. I found that as children come to share the scientific view and use it, appropriate it, the decision of whether to classify the episode as authoritative or dialogic became more problematic. The discourse became increasingly univocal, but the classification of authoritative alone did not capture the sense of children's confident ownership, for example during a recap to produce a 'dictionary' (CS1 L9 Ep 8) in contrast to episodes earlier in the sequence in which the ownership was with the teacher (for example; CS1 L1 Ep 22). I found that an additional reference to the stage of appropriation (Mortimer and Scott, 2003, p. 115) was helpful in clarifying this.

8.2.6 Review of Validity and VSRD

The use of whole class teaching was much greater than I had anticipated and this meant that there was more video data for analysis and greater selection required for teacher validation and to present the case studies to the reader. One effect was that the pace of the selected episodes had been distorted by the repeated viewing for transcription and VSRD – they seemed much faster when viewed in context of the whole lesson, supporting the 'zooming in and out' approach I adopted.

I was not able to validate as high a proportion of the teaching through VSRD as I had envisaged as each VSRD was time consuming. However, the VSRD proved to be a productive way of generating insights into the teachers' pedagogical decisions. It was important to see these dialogues themselves as dialogic and as contributing a different perspective rather than privileging the teachers' accounts, which would have reduced the validity of the case studies. Presenting the teacher's utterances along with my interpretations contributed a multivocal element to the case studies. However an ethical concern I had at the outset about my taking ownership of their practice through this study remains unresolved.

My approach to analysis was difficult to manage within a reasonable time frame and there was a 5 year gap between the lessons and the final teacher validation of the cases. Using computer based tools to analyse the transcripts might have accelerated this and would have supported tracking themes through the sequence of lessons (Mercer, 2007). However, the teachers' responses to the completed case studies validates them as capturing the 'feel' of the events.

8.3 Discussion of Interactive Whole Class Teaching in the Case Studies

In Chapter 4 I identified a lack of specific guidance on how to use whole class teaching in the professional literature on teaching science. In the concept-led social constructivist models of teaching the purposes of whole class teaching were seen as motivating and engaging children, comparing ideas, explaining tasks and then discussing findings and reaching conclusions (Harlen, 2000, 2006; Ollerenshaw and Ritchie, 1997). In the procedure–led models (for example; Goldsworthy et al., 2000) interactive whole class teaching was seen as a strategy for developing children's procedural knowledge.

In the following sections I will discuss the relationship between the different communicative approaches (Mortimer and Scott, 2003) (section 3.3.2) that were evident and the purposes of whole class teaching that emerged from the case studies. First I will consider the relationship between the four different classes of communicative approach and the ways in which the teacher used them for teaching purposes, addressing my research sub-question:

> *How does 'interactive whole class teaching' contribute to teaching about the nature of science and scientific processes and scientific knowledge and understanding?*

Then I will go on to reflect on the ways in which whole class teaching structures lessons and finally I will consider what can be learned from considering the sequences of lessons as whole, addressing my main research question:

> *How can an understanding of 'interactive whole class teaching' make a contribution to the development of models of science teaching at Key Stage Two?*

By constructing a case we are inviting the reader to make an implicit comparison with other cases (Yin, 2003). Making that comparison explicit, enables a further discussion of the relationship between the context and content of the case, and helps to raise questions about what possibilities there are for doing things differently. Where it illuminates issues I shall make a direct comparison between the cases, at other times I shall draw from the case that best exemplified the issue.

8.4 Episode Level of Analysis

The concern that a high proportion of whole class teaching in Key Stage 2 science lessons is not in line with constructivist approaches to learning science (Galton et al. 1999) was based on their observations of whole class teaching in which children had limited opportunity to explore their own ideas and that twice as many teacher statements dealt with facts than ideas. In their versions of 'dialogic' teaching Mortimer and Scott (2003) and Alexander (2004a) provide a view of how talk during whole class teaching could be very different. Drawing on Bakhtin's conception of dialogic they have identified classroom discourse that is multivocal; in which children's ideas and the culturally defined knowledge of educational goals are both discussed rather than univocal in which only the culturally defined knowledge is presented. Scott et al. (2006) argue that moving between univocal and multivocal discourses is fundamental to supporting children's appropriation of culturally defined knowledge. The case studies presented here have developed an understanding of the contribution that whole class teaching can make to multivoicedness and univoicedness in Science at Key Stage 2 by exemplifying how communicative approaches can be used for different teaching purposes in Key Stage 2. This is not to suggest that there is a simple relationship between pedagogical purpose and discourse, but to begin to illuminate it with a view to helping teachers make pedagogic decisions. Alexander (2008) identified the need to develop teachers' repertoire of pedagogical strategies associated with different domains of knowledge and this contributes to the repertoire for science. It is important to note that further possibilities might emerge from a different selection of cases. A summary of the ways in which the four classes of communicative approach were used in whole class teaching for different purposes in the case studies is provided in Table 8.2.

Table 8.2 How Different Communicative Approaches were used for Different Purposes in the Case Studies

Interactive/Dialogic	**Interactive/Authoritative**
Pooling ideas (conceptual and procedural) Recapping previously pooled ideas Discussing the meaning of procedural terminology (e.g. a fair test) Discussing ideas developed by different groups of children Discussing the outcomes of practical work and relating them to the scientific view Debating and applying ideas Review of skills and processes used	Modelling and rehearsing aspects of processes of science Recaps and summaries of conceptual knowledge Introducing the scientific story by selecting children to rehearse it.
Non-interactive/Dialogic	**Non-interactive/Authoritative**
Teacher presents selected ideas from group work Talk partners	Explaining aims Introducing tasks Organisational instructions

The relationship between each of these purposes and the associated communicative approach is discussed further in the next section. More space is devoted to those that were more significant in the cases and discussing those that challenge or develop aspects of the existing models of teaching science.

8.4.1 Uses of an Interactive/Dialogic Communicative Approach

8.4.1.1 Pooling Ideas

In both cases the teachers were drawing on a concept–led social constructivist model of eliciting children's ideas at the start of the topic, but there were differences between the cases in whether this was seen as an individual or social process. In Case Study 1 the children's ideas were discussed with another child but not in the whole class forum. The notion that these ideas may change was established, but there was not a sense that the process of change would be a collective one, it was set up as a personal process (CS1 L1 Ep 1). In Case Study 1, this may have partly been a response to what Clare described as the competitive culture of the class, reducing any perceived threat to esteem by giving the children time to compare ideas with a peer.

In contrast, in Case Study 2 establishing what ideas the children had at the start was introduced as a collaborative activity (CS2 L1 Ep 2) and later in the lesson children were invited to share ideas they had written (e.g. CS2 L1 Ep 23). Anna repeated back the child's words and didn't probe them; there was low level of interanimation (Scott et al., 2006). The talk has some characteristics of cumulative talk (Mercer, 2000) in that it is collaborative, uncritical and non-competitive, and seeks to build a shared framework of understanding, but is different in that rather than seeking to minimize differences, these are identified, and held, in preparation for more critical discussion later.

The collective nature of the enterprise in Case Study 2 was supported by the way in which Anna tended to use the pronoun 'we', whereas Clare used 'you' and 'me'. Anna used 'invitations to participate' such as; 'Would you like to share an idea' and 'Has anyone come up with an idea that they haven't shared this afternoon?' that initiate and sustain the pooling of ideas.

By expressing ideas in the context of the whole class there is the potential to pool the broadest range of perspectives available. Acknowledging the cultural concerns with children's self-esteem (Alexander, 2001), this may be a 'safe' way of participating in whole class discussion. By holding the range of ideas as a class, with a sense of collective ownership, the ideas can then be subjected to scrutiny later without individual children feeling under personal attack, in a similar way to the use of Concept Cartoons (Naylor et al., 2007).

The concept-led social constructivist models of teaching recommend that children share their ideas with each other and that the process of encountering differences between their ideas and those of others can be a stimulus for change (Scott et al., 1987; Ollerenshaw and Ritchie, 1997), but focus on what happens within the minds of the individuals. Taking a sociocultural view, the pooling of ideas supports multivoicedness, providing a rich range of ideas on the social plane, establishing a shared framework of reference to support the development of an Intermental Development Zone (Mercer, 2000) and to act as a shared linguistic resource for future dialogues. Recapping previously pooled ideas also took place in interactive /dialogic episodes in Case Study 2.

Summary:

Pooling ideas in a whole class context enables ideas to be held collectively providing a rich resource of different ideas and making it emotionally safer to express ideas. The communicative approach associated with this is interactive/dialogic episodes involving a low level of interanimation (Scott et al., 2006). 'Invitations to participate' from the teacher support the pooling of ideas from a broad range of children and supports the multivocality of the discourse (Wertsch, 1991) and the creation of an intermental development zone (Mercer, 2000).

8.4.1.2 Discussing the Meaning of Procedural Terminology

In Case Study 2 the meaning of the term 'fair test' was discussed in relation to children's existing ideas about the meaning of 'fair' (CS2 L2 Ep7) linking the children's everyday understandings of fairness in human terms with the specific scientific meaning of the term. This example helps to make sense of the positive way in which the procedure-led models can explicitly identify differences between children's everyday views and scientific views in a similar way to concepts in the concept-led model.

It is worth noting that the meaning of a fair test was not successfully developed for all the class in this case. Many did not grasp either the logic or purpose of a fair test as they were unable to decontextualise the variables. This could be interpreted as supporting the arguments of the concept-led models of teaching that teaching of procedural knowledge should be embedded within children's own enquires (section 4.4.2). An alternative interpretation is that more scaffolding was required and this is supported by the children's response when the teacher devised a simpler approach (CS2 L3 Ep 6).

Summary: Adapting an interactive/dialogic communicative approach when introducing procedural terms helps to link children's everyday language with the language of scientific procedures and so establish an intermental development zone for the construction of abstract logical procedures such as 'a fair test'.

8.4.1.3 Discussing Different Ideas Emerging From Group Discussion

A feature of both cases was how the teachers monitored group work and frequently stopped the class for a short, unplanned episode of whole class teaching to draw attention to something they had noticed. In one example of this (CS2 L3 Ep 13) the teacher selected children with different predictions and hypotheses about the outcome of their tests and through the support of teacher prompts they rehearsed these for the whole class. An important action in developing the dialogicality was inviting the rest of the class to comment on the ideas and add their own views. This interaction between the social planes created by groups of children and the whole class supports multivocality (Wertsch, 1991) by making a wider range of views available and giving children's ideas status. The teacher's role in the selection of children is also important in sustaining a broad range of voices.

Summary: Through adopting an interactive/dialogic communicative approach to discussing explicit differences in children's ideas the teacher had identified from group work a high level of interanimation (Scott et al., 2006) of ideas was achieved. This had the additional purpose of valuing the children's independent talk as worthy of inclusion on the social plane on the class as a whole.

8.4.1.4 Discussing the Outcomes of Practical Work and Relating them to Scientific Explanations

In Chapter 4 I discussed how the concept-led social-constructivist models privilege the role of empirical evidence and see a role for talk in discussing the outcomes of children's enquiries, but offer limited advice on achieving how this can develop children's understanding of scientific concepts. A distinction needs to be made between discussions related to 'illustrative activities' with the aim of examining phenomena and to 'investigations' that seek to make generalisations from empirical data. Clarifying the kind of knowledge that the teacher intends as the outcome is important as children cannot develop an understanding of existing theoretical knowledge by empirical means alone (Driver et al.,1994; Leach and Scott, 2002; Mortimer and Scott, 2003).

In Case Study 1 illustrative activities were used to open out an existing narrow conception of dissolving (CS1 L1 Ep. 22). The teacher's role was firstly drawing together a range of observations, and secondly valuing those that went beyond a simple dissolved/didn't dissolve categorisation. When discussing what happened when sand was put into water, to extend the immediate response: 'fell to the bottom' Clare asked 'did anyone see anything different?' a key question in extending the range of evidence available to consider. In this way she elicited some descriptive responses that challenged a simple definition of dissolving: 'The water went murky', 'Most sank, some floated', 'Like a layer of skin'.

Another strategy Clare used was breaking a simplistic connection between observation and explanation (CS1 L1 Ep. 22) using this to challenge the idea of dissolving as disappearing. This distinction challenges a naïve empirical view of science and provided an opportunity for the teacher to discuss different explanations.

In comparison in Case Study 2, when the class discussed their observations of celery (CS2 L5 Ep. 19), the overall dialogic class ethos meant that more time was spent on 'irrelevant' observations, giving this open ended discussion more value before similarly selecting and focussing attention on the salient features and elements of the discussion that were required to develop the concept of water travelling inside the stem in tubes: 'Lets come back to Saaven's idea about veins'.

In the closely framed investigation into seed growth under different conditions in Case Study 2 (CS2 L5 Eps. 12,14,15) interactive whole class teaching had a role in drawing together different variables that different groups of children had investigated and making the results of different experiments available to all. However, looking for similarities between the results of children who had the same independent variable sometimes produced a generalisation that was in line with the scientific view (e.g. how much water the plants were given), but sometimes (e.g. how close the seeds were) was made problematic by the different ways in which other variables had been controlled. In this example the teacher resorted to selecting the data that fitted the scientific view best and focussing the class's attention on providing an explanation for why having seeds too close together might reduce their growth. This selection seemed more 'dishonest' in this context in which the apparent aim was to generalise from the children's findings.

Variations in the physical phenomenon itself contributes to the multivoicedness, multiplied by the ways in which different children perceive and make sense of it. In order to develop the univocal, scientific view (Mortimer, 1998) both teachers drew attention to certain visible features of the situation and focussed discussion on that. In summary:

Strategies for developing multivocality were:

- Drawing together a range of different observations
- Valuing observations phrased in everyday or poetic language

Strategies for developing univocality were:

- Focussing attention on salient features
- Selecting discussion points that are developed
- Drawing attention to observations that may not have been explicitly formulated
- Examining the relationship between observation and explanation.

Summary: Interactive whole class teaching can enable children to interpret practical experiences in terms of a scientific perspective and introduce scientific explanations that relate to phenomena experienced by the children. By adopting an interactive/dialogic communicative approach with interanimation (Scott et al., 2006) between the children's experiences and scientific view the teacher can draw attention to salient features of their experiences of the phenomenon while also valuing the children's observations.

The way in which practical work has been set up constrains the possibilities for discussion. A genuine dialogue may be more likely when there is congruence between the degree of freedom children have in planning and carrying out practical work and the ways in which the outcomes are discussed.

8.4.1.5 Debating and Applying Ideas

In Case Study 2 (CS2 L8 Ep 6) there is a sequence in which children discussed whether plants need roots and they chained their ideas together, sometimes supporting each other, some times disagreeing with other, sometimes introducing a different idea in an episode that epitomises the cumulative characteristic of dialogic talk (Mortimer and Scott, 2003; Alexander, 2004a). The children sometimes made explicit reference to each other's ideas. The teacher sustained this as she took a turn between each of the children's contribution, but was not asking questions, frequently rephrasing to summarise the idea, she acted as a 'chairperson' maintaining the flow by valuing the contributions and choosing the next child to speak.

The children had appropriated the ideas about roots, the stem and the role of water in keeping plants alive such that they are able to hold a sophisticated debate. The teacher has handed over the responsibility for the discussion to the children as in Mortimer and Scott's stage 3 of appropriation (Mortimer and Scott, 2003. p. 115) As well as appropriating the conceptual knowledge, they have appropriated the form of discourse in which ideas can be built on, extended and challenged and are confident that they can do so without fear of ridicule. The development or sustaining of this class culture seems likely to be an outcome of the amount of time spent in an interactive/dialogic communicative approach in Case Study 2. The form of the discussion contributes to the development of a version of science as discursive and positions the children as active agents within it, not passive receivers of it.

Key idea: Interactive/dialogic episodes with a high level of interanimation (Scott et al., 2006) provide a supportive forum for children to apply their more scientific ideas in the later stages of their appropriation. This was supported by the teacher acting as 'chair person' and children's enculturation into a generally discursive, dialogic class ethos.

8.4.1.6 Reviewing Skills and Processes

In one episode in the cases (CS2 L8 Ep. 12) children reflected on the procedural knowledge they had developed. The interactive/dialogic communicative approach supported children in the cumulative development of a concept of reliability. The teacher's prompt questions:

> Do you think those are important skills to have when doing science? and
> Why might you need to do a fair test more than once?

were the stimulus for going beyond a listing of skills towards a more sophisticated view of the value of scientific knowledge. As specific procedural knowledge – of reliability - was constructed on the social plane of the class this developed a scientific discourse in which the relationship between the procedure and reliability of the result was questioned.

Summary: An interactive/dialogic communicative approach with a high level of interanimation can develop an understanding of procedural knowledge that goes beyond 'recipe following' towards a deeper understanding of the reliability of scientific knowledge.

8.4.2 Uses of a Non-interactive/Dialogic Communicative Approach

8.4.2.1 Teacher Presents Selected Ideas from Group Work

The literature has established how teachers select from children's responses to develop particular meanings (Edwards and Mercer, 1987, Mercer, 2000; Lemke, 1990). Mortimer and Scott (2003) relate this to the development of the scientific story on the social plane. As this is well established in the literature I will not dwell on the purposes of selecting, but note that here I am using it to describe when a teacher creates a whole class episode in order to present ideas selected from group work on the social plane of the whole class in a similar way to Scott, (1997). The teacher herself presents the ideas, rephrasing them to some extent.

This is exemplified in Case Study 2 (CS2 L1 Ep19) when Anna reports on two children using the evidence from their observations of plant material to draw conclusions about whether all plants have flowers. The idea of the importance of observations as a basis for scientific knowledge was thus made available and developed on the social plane of the class. There is a tension in this between supporting a community of enquiry in which all contributions are shared, and the teacher's authoritative role in selecting what is to be shared and hence valued most highly.

Summary: By selecting from the ideas expressed by children during group work those to be expressed within a whole class episode the teacher is able to develop the scientific story on the social plane of the class. In adopting a non-interactive/dialogic communicative approach the teacher reports the children's ideas, generally rephrasing them to a greater or lesser extent so the ownership of those ideas is taken by the teacher for the class.

8.4.2.2 Talk Partners

Short episodes in which children talked to a partner were problematic to classify as whole class teaching. In combination with other episodes they formed elements of lessons that were whole class teaching, but do not meet the criterion of making utterances available on the social plane of the class. Characterizing the communicative approach as non-interactive is clearly open to challenge as all the children were interacting with each other, but I chose to interpret it as non-interactive/dialogic, rather than interactive/dialogic to avoid giving a misleading impression of the teacher's engagement with the children's ideas. As I did not record the children's utterances my assumption is that they were dialogic exchanges, but one child could have taken an authoritative role and coding them as dialogic is actually referring to my presumption of their purpose within a sequence of episodes as contributing to overall multivocality.

In Case Study 2 the focus for the talk with a partner was often on generating ideas to share in the whole class forum, For example, discussing their interpretations of observations reported by others. Whereas in Case Study 1 the emphasis was frequently on asking the children to apply ideas developed in the whole class discussion to do a short task, for example, phrasing a prediction in a particular way. Talk partners provides opportunities for different stages in children's appropriation of ideas (Mortimer and Scott, 2003): exploring the children's ideas in stage 1, practising and rehearsing in stage 2.

Considering the role of talk partners exemplifies the problem in considering the 'social plane of the class' as a simple singular entity. In episodes around talk partners there is a complex relationship between the intramental planes of individuals, the intermental planes constructed between pairs of children and the intermental plane of the class.

Summary: Episodes involving discussion between 'Talk partners' were elements of sequences of episodes that formed a whole class discussion. They were coded as non-interactive/dialogic in that the children and teacher were not interacting and the children were asked to bring their own voices to discuss or rehearse themes that arose in the whole class context. Thus they contribute to the multivocality of the overall discourse.

8.4.3 Uses of an Interactive/Authoritative Communicative Approach

8.4.3.1 Modelling and Rehearsing Aspects of Processes of Science

The authors of materials advocating atomised approaches to teaching scientific processes (Goldsworthy et al., 1999, 2000) emphasise the role that it plays in terms of assessment for learning – making explicit the success criteria against which children are to be judged. In both cases the use of such episodes of atomised focussed teaching of science enquiry formed part of setting up practical 'fair test' investigations. Teaching on identifying variables was embedded within planning an investigation into factors affecting dissolving in Case Study 1 and on factors affecting plant growth within Case Study 2. In Case Study 1 the atomised approach was also used to make generalisations of the outcomes, whereas in Case Study 2 an interactive/dialogic communicative approach was adopted in a more open ended discussion, though with some problems in generalising from the outcomes as discussed (in section 8.4.1.4) above.

Both case studies demonstrated the difficulties involved in identifying variables in a scientific language that abstracts them from everyday contexts and meanings (e.g. CS1 L5 Ep. 14, CS2 L3 Ep6). Talking about an experience is in itself an abstraction to the symbolic representation of language. In Vygotskian terms the construction of a variable can be seen as an example the role of talk in creating decontextualised generalisations that support a transition from 'everyday' to 'scientific' concepts (Wertsch, 1991). The whole class interactions around the vocabulary and grammatical forms required by scientific conventions seemed to broaden access to science as a language by making these available on the social plane (Lemke, 1990). It is in the process of working with the children's observations and existing ideas about materials and dissolving, or about plant growth, through talk that that the variables as entities are 'talked into being' (Ogborn et al., 1996). The whole class interaction provides some children with an opportunity to use scientific language within dialogues with the teacher, to participate in performances with the teacher acting as a 'discourse guide' (Mercer, 2000).

A more critical view of the teaching is that the concept of a variable as an abstraction remained meaningless for the children who only made sense of it through the specific context (dissolving sugar or growing seeds). Meanings arise in a specific context (Cole and Wertsch, 1996) so the knowledge can remain situated in the discourse context in which it was developed. Within the time boundaries of case studies there was no opportunity for the children to applying their understanding of the concept of a variable in other contexts so there was no evidence of the extent of its appropriation.

A further criticism is how the procedural knowledge can become disassociated from the concepts it is concerned with. For example in Case Study 1 (CS1 L5 Ep14) the emphasis of the teacher was on the process of generalising, not about the findings themselves. There was no discussion of why stirring might have affected the rate of dissolving sugar that could have made some development of the children's conceptions of the process of dissolving. The procedural knowledge presented the greater learning demand than the level of conceptual knowledge as it required an epistemological understanding of science as concerned with generalisable statements. A question is whether the procedural knowledge is sufficiently motivating and whether it supports a naïve empirical view of science.

The evidence from the teacher's end of term assessments was that most of the children had appropriated the desired two part structure of a generalisation to some extent. However, it appears to act against the spirit of children taking ownership of their own investigations that is encouraged by the concept-led social constructivist model of teaching science.

Summary: Planned interventions using an interactive/authoritative communicative approach in a whole class context can support the understanding of aspects of processes of scientific enquiry and support broad access to the language of science by modelling and rehearsing their use on the social plane of the class. However this univocal discourse can also depersonalize and decrease children's ownership of enquiry activities and support a naïve empirical view of science underemphasising the role of creativity and imagination.

8.4.3.2 Selected Children Rehearse the Scientific View

The development of conceptual science knowledge on the social plane by selecting and prompting accounts from children that rehearse the scientific view has been documented in the literature in secondary school contexts (Scott, 1997; Lemke, 1990) and I found similar use of interactive/authoritative episodes of whole class teaching in the cases (e.g.

CS1 L8 Ep16). Due to the constraints of my methods I did not explore whether this role was being performed by a limited group of children and what the impact of that might be.

Summary: Through selecting 'expert' children who have already gained an understanding of the scientific view to rehearse this in response to teacher prompts the scientific view can be made available on the social plane of the class. This raises questions about which children are selected.

8.4.3.3 Recaps, Summaries and Assessment

In Case Study 1 (CS1 L 9 Eps 2,3) the teacher explained that: 'There are some words we are going to need before we even talk about what we are going to do today'. The purpose of the episode was activating this shared vocabulary and reviewing previous learning so that the class were aware of the knowledge that the teacher is expecting them to apply to solve the problem she went on to challenge them with (making their own instant coffee granules). This episode was later in the sequence and the teacher was assuming that there was common knowledge to draw on to create an IDZ (Mercer, 2000).

A similar form of discourse later in the lesson (CS1 L9 Ep8) had the different purpose of providing a collective summary of the meanings of scientific vocabulary. The interactive approach taken to generating the summary produced a sense of handover (Bruner, 1983) as the children provide explanations of words that are in line with the authoritative view. Joint construction of this summary conducted through an interactive episode signalled the shared ownership, but also provided the teacher with a means of assessing the extent of appropriation.

Later in the sequence of lessons, summaries produced through interactive/authoritative episodes were also a recap of previous learning, such as this episode at the start of lesson 7 (e.g. CS2 L7 Ep. 1, CS1 L12 Ep1). These had the function of linking lessons over time and also providing a thematic nexus (Lemke, 1990) to the development of the scientific story on the social plane (Mortimer and Scott, 2003). Repetition of key ideas through recaps and summaries marks them as significant (Lemke, 1990)

There were occasional examples of the teachers using a whole class episode to make an assessment of all the children in the class against a narrow criterion. In Case Study 2 the teacher planned a 'run around' activity in which children ran to one side of the playground to the other depending on whether they agreed or disagreed with statements (CS1 L8 Ep. 26). However, neither teacher made any great use of this kind of explicit assessment. There was no evidence in these case studies of the kind of focussed assessment advocated by the NNS (DfEE, 1999b) such as every child writing an answer on a mini whiteboard and holding it up for the teacher to check immediately. The teacher's judgments of children's learning were made based on children's utterances in other episodes and on teacher observations of their group work and looking at written work.

Summary: Recapping previous learning in interactive/authoritative episodes of whole class teaching activates and repeats shared vocabulary and meanings and relates the aims of the lesson to previous learning supporting the maintenance of a shared intermental plane and a univocal discourse. An interactive/authoritative communicative approach to developing a summary involves the children in taking ownership of it, supporting appropriation. Both often have the dual function of an assessment of the extent to which a shared intermental plane has been created and to which ideas have been appropriated by individuals.

8.4.4 Uses of a Non-interactive/Authoritative Communicative Approach

The introduction of concepts through non-interactive/authoritative episodes was notable by its absence in both cases. In Case Study 2 there is rarely (5 episodes across the case) an entire episode devoted to a non-interactive/authoritative summary, although Anna does provide paraphrases within and summaries at the end of interactive/dialogic episodes (e.g. CS2 L2 Ep7). This had the effect of leaving the responsibility for ideas with the children and avoiding a sense that knowledge is ever complete or unchallengeable, but it also led to a lack of clarity in relation to the development of the scientific story.

8.4.4.1 Explaining Aims

Both teachers used a visual mode of communicating the aims of the lesson. Clare had a learning objective written on the whiteboard at the start of the lesson and Anna had A4 sheets of paper with the tasks printed on displayed on a flip chart stand. All the children were sitting facing these at the start of each lesson. This communicated the authority of the teacher in setting the agenda of the lesson and so can be conceived as a centripetal action (Bahktin, 1981). In order to help the children make sense of these objectives both case study teachers sometimes asked the children to discuss them with talk partners (e.g. CS1 L1 Ep3, CS2 L1 Ep12) shifting the ownership of the purpose of the lesson towards the children and supporting a more multivoiced approach overall.

However in Case Study 2 the statements of aims did not communicate an authoritative view of knowledge, but referred to the social processes the teacher wanted the children to undertake, for example;

> To share ideas about plants and how they grow
> To give clear and positive feedback on thoughts and ideas. (CS2 L1)

There is some congruence between this conception of establishing a shared purpose and 'orientation' in some social constructivist model of teaching science (Scott et al., 1987; Ollerenshaw and Ritchie, 1997), but with a shift of emphasis from engaging individuals to engaging the commitment of the class as a group. From a sociocultural perspective establishing a shared purpose can be conceived of as a deeper level recruitment to a collective enterprise, and so to a learning community (Wells, 1999). It is questionable how effectively this was done within the cases. It seems likely that more use of an interactive/dialogic communicative approach to sharing aims may have been more successful in engaging the children.

Summary: Episodes of whole class teaching can be used to promote children's understanding of the teacher's purposes through an authoritative communicative approach. Establishing a shared purpose can be conceived as a centripetal action (Bakhtin, 1981) to support univocality. The lack of dialogic interactions on the whole class plane in creating a shared purpose in the case studies may have reduced the children's motivation and engagement.

8.4.4.2 Introducing Tasks, Organisation and Management

The dominant use of non-interactive/authoritative episodes in the cases was associated with organisation such as explaining tasks, grouping children or organising the distribution of resources. It includes short episodes in which the teacher sets the pace by telling the children how long they have left on a task have also been included in this category. Their purpose is more organisational than relating to the content of the science, these episodes contribute to the episodic shaping of lessons in the cases discussed in the next section.

8.5 Lesson Level of Analysis- The Episodic Structure of Lessons

Both teachers made considerable use of whole class teaching. As shown in Table 8.3 the proportions of the lesson spent in whole class teaching were above the 50% average found by Galton et al. (1999) and in line with the 47 to 73% found in literacy lessons after the introduction of the NLS by Moyles et al. (2003). In Case Study 1 between 57% and 83 % of the observed lessons spent as a whole class. In Case Study 2 it varied between 61% and 77 %.

Table 8.3 Percentage of Lesson Time Spent in Whole Class Teaching

Lesson		1	2	3	4	5	6	7	8	9	10	11	12
% time spent in WC	CS1	70	76	68	75	83	59	58	57	61	27	No data	57
	CS2	73	65	61	64	58	76	61	58	-	-	-	-

A striking feature of both cases was that the teachers did not restrict their use of whole class teaching to the start and end of lessons as assumed by the concept-led models of teaching science at Key Stage 2 (e.g. Harlen, 2000), they also made frequent use of short episodes of whole class teaching at points throughout the lessons. However, the ways in which the episodes of whole class teaching structured the lessons were slightly different in each case. Case 1 was characterised by short episodes in which the children carried out a tightly prescribed task before some kind of whole class intervention by the teacher, so that the overall pattern is what Alexander would characterise as 'episodic' in a similar way to what he observed in French and Russian classrooms (Alexander, 2001). As shown in Table 8.4 the longest period without an episode of whole class teaching varied between three and eleven minutes in all but one lesson where there was an episode of eighteen minutes duration. Case Study 2 (Table 8.5) was characterised by somewhat longer periods in which the children work before a whole class teacher intervention and the longest uninterrupted period in each lesson was between nine and twenty-two minutes but the episodic structure was still strong.

There is some correspondence between the greater use of dialogic talk in Case Study 2 and the flexibility in lesson length compared to the fixed lesson length in Case Study 1.

Table 8.4 Episodic Structure of Case Study 1

CS1 Lesson	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**
Length of lesson (mins)	58	59	60	60	56	60	61	62	54	59	52
Number of episodes	29	25	25	23	25	18	20	26	31	16	19
Length of longest NWC episode (mins)	4	3	5	7	3	9	11	6	5	18	9

Table 8.5 Episodic Structure of Case Study 2

CS2 Lesson	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Length of lesson (mins)	62	64	50	108	71	88	120	172
Number of episodes	26	29	18	45	22	29	35	29
Length of longest Non Whole Class episode (mins)	15	15	9	8	7	10	11	22

Edwards and Mercer (1987) argue that a central purpose of whole class talk is for the teacher to maintain control of both behaviour and knowledge and that the two are entwined. Whole class teaching provides the teacher with more control over the meanings that are developed in the intermental space than when children are working more independently, but raises concerns about how children are to fully appropriate these if they do not have the opportunity to become more independent. 'Handover' (Bruner, 1983) could be supported by decreasing the episodic interventions towards the end of a sequence of lessons. But the nature of the communicative approach in the episodes is also important and if children have more control over the content of the episodes as the sequence of lessons progresses this would be another way of conceiving 'handover' in terms of whole class teaching. As discussed (in section 8.2.5) the term authoritative/interactive doesn't fully capture the sense of appropriation.

In the case studies, teacher control through frequent episodes, of authoritative, interactive as well as non interactive communicative approaches, was strongly evident in association with practical work. Whole class teaching in the cases provides framing that supports teacher confidence in managing the classroom organisation associated with practical work, but also affects the emergence of ideas from practical work. The emergence of concepts is contingent on the physical environment, but the language available to children and teachers provides both resources and constraints on this (Roth, 2005).

8.6 Sequence of Lesson Level of Analysis

In this section I will consider how insights generated by the case studies relate to aspects of the existing models of teaching science.

8.6.1 The Aims of Science Education at Key Stage 2

A sociocultural perspective develops models of teaching science by establishing a view of the dual nature of the purpose of education as transmission of cultural knowledge and transformation of it:

> From its inception, one of the central concerns of sociocultural theory has been to gain a greater understanding of the Practice of Education with its two interrelated goals. These are, first, to ensure cultural continuity through the transmission to each new generation of the artefacts which embody the achievements of the past; and second, to enable individual students to appropriate these artefacts and to transform the associated knowledge and practices into a resource that both empowers them personally and enables them to contribute to the solution of problems facing the larger culture in innovative ways.
>
> (Wells, 1999, p. 204)

The models of teaching science need to clarify this duality for teachers so they can choose appropriate teaching strategies for conceptual and procedural knowledge in the understanding that the purpose here is children's appropriation of existing cultural knowledge. Although some sense of 'transformation' is already embedded within the concept of appropriation, 'transformation' also suggests a more radical change or development of it. Transformation requires a dissatisfaction with given explanations and a sense of curiosity about the natural world and imagination.

The case studies presented in chapters 6 and 7 illustrate that whole class teaching at Key Stage 2 can contribute to developing procedural and conceptual knowledge on the social plane of the whole class. However, the procedural knowledge focussed on the 'testing' and validating aspects of scientific processes rather than the more creative 'hypothesising'. The greater use of an interactive/dialogic communicative approach in Case Study 2 did offer more examples of children raising questions and suggesting explanations. Missing from both case studies was a sense of the children undertaking their own enquiries with a strong sense of purpose rooted in curiosity.

Corresponding to the dual aims of 'transmission' and transformation there are two purposes for dialogic/interactive whole class teaching that could be made explicit in the models of teaching:

- to develop shared understanding of meanings in order to create an intermental development zone and to enable children to understand the scientific point of view, and
- to value the differences of viewpoints and reflect on how these lead to new variations of meaning of the scientific view and to ask new questions.

The first of these was more predominant in the case studies. However, in Case Study 2, 'local knowledge' developed was that when you grow lots of seeds in a yoghurt pot the roots get tangled up, or seeds can go mouldy. Although this knowledge is related to an authoritative version of science, it is local to the class and directly related to the experiences of the children and not necessarily the outcome the teacher had in mind.

In the case studies the aims of the lessons were mostly presented as predetermined by the teacher, using a non-interactive/authoritative or interactive/authoritative communicative approach and supporting transmission. Adopting a dialogic communicative approach at this stage would support transformation.

Another contribution of the sociocultural perspective to developing a model of teaching science is the argument that 'Any efficacious pedagogy must be a judicious mix of immersion in a community of practice and overt focusing and scaffolding from "masters" or "more advanced" peers.' (Gee, 2000, pp. 2001-2). Both case studies provided strong examples of overt focussing and scaffolding of learning science concepts and procedures, while the class in Case Study 2 was closer to being a community of practice with a scientific discourse. One of the challenges for teachers may be to develop their repertoire of moving between a 'scaffolding discourse' or a 'discursive discourse' and the concept of communicative approach (Mortimer and Scott, 2003) has proved to be a useful tool in relating teaching discourse to purposes and outcomes.

8.6.2 The Role of Elicitation of Children's Ideas

In the concept-led social constructivist literature one purpose of the elicitation of children's ideas is for planning future lessons, in line with notions of 'assessment for learning' (Harlen, 2006). Threlfall (2005) argues that that this interpretation of assessment for learning places high demands on the pedagogic knowledge of teachers and in practice assessment for learning is not used for 'planning the next steps' and does not affect the sequence of preplanned lessons, although it may affect the pace the sequence is gone through or repetition of elements. In the case studies there were no examples of a lesson being planned in response to elicitation at the start of the topic. However, there were adjustments made to the plans during the sequence of lessons in response to the teachers' assessments of children's understanding: a simplified, visual approach to planning a fair test (CS2, L3), inviting older children to introduce ideas about photosynthesis (CS2, L7) and the challenge to make 'instant coffee granules' (CS1 L9,10).

The case studies suggest a role for elicitation of children's existing ideas that is not concerned with identifying children's 'alternative ideas' as hypotheses for enquiries. The emphasis was more on 'getting on the same wavelength' - or 'interthinking' – constructing and maintaining an intermental plane or Intermental Development Zone (IDZ) in which there is sufficient mutual understanding for different ideas to be considered; (Wertsch, 1985, Mercer, 2000). If children are to develop each other's ideas effectively through chaining in interactive/dialogic whole class discussions with a high level of interanimation (Scott et al., 2006) then they need to become aware of them. This requires constructing a collective IDZ for a class rather than between teacher and child (Mercer and Littleton, 2007). In the case studies pooling ideas can be seen as a shared linguistic as well as conceptual knowledge resource for all to draw on. Understanding elicitation of existing ideas in this way also teachers need to bridge everyday and scientific language by using both and signalling which they are using

(Lemke, 1990). In both cases the use of an interactive/authoritative communicative approach across the sequence of lessons to recap and activate ideas previously on the intermental plane functioned to check on the existence of an IDZ and help to re-establish it. Using this sociocultural perspective means that language is not seen as a window onto ideas, but a part of how meanings are developed between people.

8.6.3 The Role of Practical Work

In the concept-led social constructivist models of teaching science children undertaking investigations to test their own ideas is privileged as the most important strategy for developing children's understanding of scientific concepts, with other strategies being recommended only when this is not seen as possible (section 4.4.2). Critics of this (Wellington, 1998; Millar, 1998, Driver et al. 1994) suggest that there are a range of reasons for doing practical work and point out that theory cannot be made visible by doing experiments. However, Leach and Scott (2002) distinguish between 'empirical knowledge' that can be generated from first hand enquiry and 'theoretical knowledge' that cannot. In Case Study 1, the outcome of the investigation into factors affecting dissolving was empirically grounded generalisations such as; 'dissolving is faster in hotter water'. In Case Study 2 when the teacher wanted the children to go beyond generalisations about plant growth, such as 'plants need water to grow' towards a theoretical model of plants generating their own food, she relied on 'expert children' within the class and older children to introduce this idea.

Woolnough (1998) argues for distinguishing between practical work for conceptual and procedural understanding. In a recent study only 28% of primary teachers put concept development in their top three reasons for doing practical work, instead focussing on the teaching of skills, the development of an understanding of investigative processes and to encourage science enquiry (Abrahams and Millar, 2008). In the case studies children's ideas were not directly tested, but the teachers did see practical work as important in supporting children's learning of scientific concepts. However, they also saw procedural understanding as important in its own right and developed procedural knowledge on the social plane of the class through modelling specific skills and procedures in association with an interactive/authoritative communicative approach.

If the role of practical work is not direct testing of alternative ideas as hypotheses then its role in relation to children's conceptual development needs to be clarified. One function is the creation of shared experiences, or of related but different experiences, in order to make discussion meaningful and relevant. For example in Case Study 1 all the children mixed the same range of materials with water and their observations were discussed as a class (CS1 L1). Whole class teaching would then have a role in establishing this common ground by setting up similar practical experiences for the class and focussing attention on salient features and discussing their significance. Seeing humans as 'meaning makers' Wells (1999) argues that although language is a powerful tool, it is the physical action that speech and thinking mediates that links people to the external world; an observable event is essential because the gap in understanding between the participants would otherwise be too great. Whole class teaching can provide a structure that supports talking about practical experiences: the process of communicating to another requires the idea to be labelled with words, it becomes abstracted, and this abstraction supports scientific thinking (Wertsch, 1991). Both 'illustrative activities' and structured investigations can generate empirical knowledge on the social plane of the class through dialogic communicative approaches, but an authoritative intervention is needed to develop theoretical knowledge.

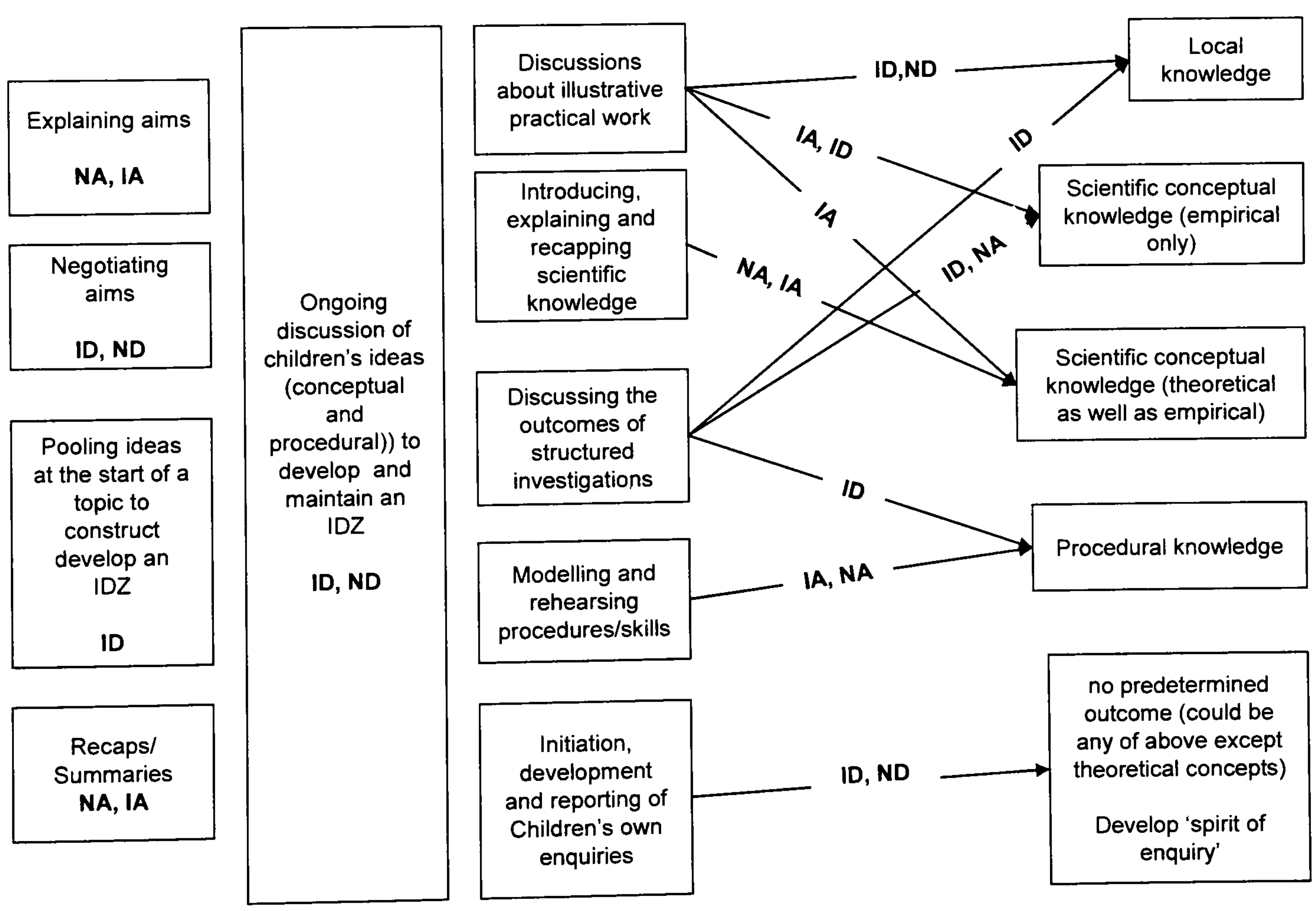
There is a further distinction to be made between the teacher providing structured, modelled investigations and children carrying out independent enquiries (Hodson, 1998). In order for children to experience the 'spirit of enquiry' and this could be an opportunity for stage 3 of appropriation (Mortimer and Scott, 2003), or handover in terms of procedural knowledge rather than concepts. But it may also be useful to note the difference between the creative, imaginative hypothesis generation phase and verification/testing phase of science (Millar, 1998, p. 19) and see independent enquiry as an opportunity to develop imaginative explanations and support children's ownership of science.

Practical work can be seen as a source of multivoicedness, but this can be valued rather than seen as a problem to overcome. Differences between individual perceptions of the physical world can be pooled, as Anna did with the children's initial observations of celery stems and of seed growth. Valuing 'local knowledge' outcomes of practical investigations and enquiries has the dual purpose of providing meaningful examples of phenomena with which to make sense of the authoritative views and situating the children as contributors to science.

8.7 Towards Linking Activity, Communicative Approach and Outcomes in the Models of Teaching Science

In this section I aim to show how by considering interactive whole class teaching I can make a contribution to the development of models of science teaching at Key Stage Two by linking activity types and outcomes in the models of science teaching to communicative approach, providing an answer to my main research question: *How can an understanding of 'interactive whole class teaching' make a contribution to the development of models of science teaching at Key Stage Two?*. Figure 8.1 attempts to capture the relationships between communicative approach, focus of episode and outcomes that emerged from the cases and is explained in the following paragraphs. Putting a temporal dimension on the figure is problematic as there is no clear sequence, rather the figure attempts to collect together elements of a teaching repertoire for Key Stage 2 science.

Figure 8.1 Roles of Different Communicative Approaches in Whole Class Teaching of Science



Key :

ID	Interactive/dialogic
IA	Interactive/authoritative
ND	Non-interactive/dialogic
NA	Non-interactive/authoritative

The aims of the topic or lesson can be explained by the teacher through a non-interactive/authoritative communicative approach to define the parameters, but adopting an interactive/authoritative approach would help to make connections with children's existing knowledge. Adopting an interactive/dialogic approach to the aims would establish the parameters as negotiable for the class. Pooling ideas at the start of a topic through interactive/dialogic episodes with a low level of interanimation (Scott et al., 2006) supports broad involvement and thus helps to create an IDZ for the class as a whole. Recaps and summaries conducted through interactive/authoritative episodes serve to check on the existence of an IDZ. Frequent dialogic episodes through lessons serve to maintain the IDZ as new ideas are introduced or developed, and to respond if the teacher identifies a lack of shared understanding.

Different aims of different kinds of practical activity can be supported through the communicative approach adopted (indicated by the long arrows). Discussions about illustrative practical work conducted through interactive/authoritative or interactive/dialogic episodes can support the development of scientific conceptual knowledge that is empirical, if it is theoretical conceptual knowledge then an interactive/authoritative communicative approach could be adopted, possibly in combination with explicit introduction of the theoretical scientific ideas through a non-interactive/authoritative approach. Where a dialogic/ interactive or dialogic/non interactive approach is taken to discussing the outcomes of illustrative work, local outcomes that were unplanned can be valued too.

Aspects of procedural knowledge can be modelled through non-interactive/authoritative or interactive/authoritative approaches, the latter also supporting the rehearsal of elements. This focus on procedural knowledge could take place within a structured investigation as in the case studies. The outcomes of a structured investigation, in which children have undertaken, say a fair test, or a survey, can lead to generalisations that support the development of empirical conceptual knowledge, through interactive/dialogic or interactive/authoritative communicative approaches. The emergent discussion of reliability in Case Study 2 also provides an example of how interactive/dialogic episodes can lead to unplanned procedural knowledge.

By including elements that were made significant by their absence from the cases it also suggests how non-interactive/authoritative episodes could be used to introduce the scientific view and how interactive/dialogic discussion about children's own enquiries might contribute to developing a 'spirit of scientific enquiry'.

This figure does not represent the full range of activities and experiences in primary science, but comments on those that the case studies illuminated. The sense of children's ownership of their enquiries that was missing from the cases would require further dialogic interactions in setting up their planning and discussion of outcomes. I have not addressed the range of types of practical based enquiry that AKSIS (Goldsworthy et al., 2000, p.5) identified, so enquiry through 'pattern seeking', 'making things or developing systems' are not included as these were not explored through the cases.

Considering the whole curriculum, not just the scientific domain, Galton (2007) suggests that learning different 'ways of knowing' requires different teaching approaches, identifying similar relationships to those I have found between communicative approach, teaching purposes and different kinds of outcomes in the specific domain of scientific knowledge. He suggests that the development of concepts can be achieved through what he describes as 'interactive teaching' (which could be equated with ID and IA), that procedural knowledge and skills acquisition require 'direct instruction' (as in IA and NA) and that learning 'strategic thinking' requires participation in problem solving and investigations (arguably requiring ID, ND) (Galton, 2007, p. 91).

8.8 Reflections on Research Design, Methodology and Data Presentation

In this research I wanted to capture the development of ideas across the full sequence of lessons that would make up a unit of science teaching in a natural way and this is a distinctive feature of the research. However, the challenge of managing, analysing, and selecting from 10-12 lessons was enormous. In retrospect, it may have been preferable, in negotiation with the teacher, to plan to focus on a short sequence of 4-6 lessons that would illuminate aspects of whole class interaction in relation to the different models of teaching science. The inevitable loss of the more holistic view would have been more than offset by a greater of depth analysis of the selected lessons and less time between data gathering and completion of the analysis. This acknowledges that qualitative approach to discourse analysis often means a small data set with attendant issues around reliability (Mercer, 2004, p.143) as qualitative researchers select and represent their own interpretations of key episodes and forming narratives (Stake, 1995, p.40). The potential of case study for reader relatability (Bassey, 1981, p. 85) requires the engagement of the reader to be sustained and the length of the case studies and necessary selection of episodes worked against the sense of narrative I had aimed to create.

In this research VSRD was used both as a triangulation tool and as a source of data. Particularly in terms of the latter, there are methodological concerns that about stimulated recall in general (summarised by Lyle, 2003) about the extent to which events, the associated meanings are remembering or reconstruction and explanation. Following Moyles et al. (2003) I had tried to establish two phases to the VSRD, firstly with a focus on remembering before moving into a post-event analysis mode. However, in practice the discussions were mainly on later interpretations and as 'joint meaning making' (Mercer, 2000). There was a tension here between retaining the difference of perspectives that supports triangulation and the development of a shared understanding of whole class interactions in each case as the VSRD themselves became multivocal, dialogic discussions. It would have supported the reliability of the interpretations if people other than the teachers involved had offered interpretations of the video clips. In particular, it would have improved the research if reliability tests on my judgements of communicative approach had been included in the design. Having someone doing coding alongside me and checking inter-rater reliability for a sample of the episodes or lessons, would have improved the reliability of my judgements. This would have been of particular importance for the overall quantitative data which is not open to reader validation.

Although the teacher's viewpoints were sought through the VSRD and offered a source of triangulation, I had originally decided against interviewing children as my experience in the pilot study was that this made it impossible to be to retain my role as non-participant observer. However, the children's perspectives could have been sought at the end of the sequence of lessons, offering further triangulation and an insight into their experience of whole class teaching.

8.9 Summary of Chapter 8

First the methodology and research methods were reviewed: the limitations of my original coding of 'purposes' in my analytical framework were considered. I reflected on the validity of the construction of the case studies and I suggested how the research design could have been improved.

Then different ways in which episodes of teaching in the cases were associated with different communicative approaches and how these contribute to different kinds of outcomes within a scientific discourse were considered at episode level and again at sequence of lesson level. The episodic structure of the lessons in the cases was also discussed.

Chapter 9: Conclusions and Recommendations

9.1 The Contribution of this Thesis

Since I began this research in 2001 with the aim of understanding the contribution that 'interactive whole class teaching' could make to models of teaching science, there has been increased emphasis on the role of talk in the classroom (for example; Mortimer and Scott, 2003; Alexander, 2004a; 2008; Mercer, 2007; Galton 2007). I began this study imagining that in focussing on whole class teaching I would be making a specific contribution to developing the existing social constructivist models of teaching science. The development of sociocultural theory has meant that the focus on the collective development of ideas through talk on the intermental plane of the whole class has proved to be more significant than I had imagined.

The convergence of research supports the value of the focus of this study and approaches to analysis of talk I have adopted. This study makes a distinctive contribution to the discussion of talk in science education by:

- Developing unique, detailed, case studies, situated historically within the approaches to teaching science being advocated and the wider context of policy developments affecting primary schools;
- Taking a holistic view of units of teaching – episodes and lessons are understood within the whole sequence of lessons that constitute a science topic, and
- Addressing the relationship between scientific processes and concepts that has been at the heart of models of teaching science in primary schools, unlike Mortimer and Scott (2003) and Mercer (2007) who have focussed on conceptual understanding.

9.2 Conclusions of the Study

The case studies developed in this thesis that form the main body of this study enable readers to access and relate to the situated action of teachers to exemplify their use of different communicative approaches (Mortimer and Scott, 2003) for different purposes at different points in the sequence of lessons.

The case studies show that whole class teaching in science can play a role in the ongoing elicitation and discussion of children's ideas about concepts and procedures, creating and maintaining an intermental development zone for the class. Holding ideas collectively rather than individually enables them to be discussed with less threat to the self-esteem of individuals, although the methods I adopted meant that I was not able to fully judge the extent of inclusion of individual children. This conclusion is in line with the findings of similar studies that dialogic talk has a role in bridging children's ideas and scientific concepts (Mortimer and Scott, 2003, Mercer, 2007); dialogic talk can support a univocal outcome.

In the case studies different forms of whole class talk were associated with practical work that was concerned with modelling specific scientific procedures, illustrating a phenomenon and structured investigations designed to lead to predetermined conceptual knowledge. Practical work was often associated with interactive/authoritative talk that enabled children to access and rehearse procedural knowledge, but over a whole sequence of lessons tended to construct a naïve empirical version of science, even when the teachers themselves did not hold such a view. Illustrative practical work often had dialogic elements as children's observations were discussed, this was concerned with a univocal endpoint, the appropriation of scientific conceptual knowledge.

Alexander's 'definitive' version of dialogic teaching (Alexander, 2008), emphasises the transformative potential of dialogic teaching ultimately to support children's thoughtful engagement with democratic processes; he emphasises multivocal outcomes more than in an earlier edition of the text (Alexander, 2004a). In a similar way, Wegerif argues for a version of 'dialogic' as an ontology, as fundamental to how things are – and that dialogicality is itself the endpoint of education (Wegerif, 2006). How this might be put into practice might be illuminated by Wegerif's association of creativity with 'playful' dialogic talk, and his suggestion that this is missing from an account of a dialogic education that focuses only on reasoning (Wegerif, 2005). Comparing my two main case studies suggested that where there was a greater proportion of dialogic talk there was a class culture which supported children generating and debating ideas within the whole class forum, but there was no sense of playfulness, although there was some evidence of this in the exploratory case study when children wondered about the function of flowers. (In a publication for teachers, McMahon, (2006) I discuss the creative potential of dialogic interactions in relation to this extract.) Attention to children's enculturation to the scientific discourse as an imaginative, passionate field of enquiry as well as explicit, focussed teaching of its established knowledge domains is in need of development. If children are to be politically empowered through dialogic teaching (Alexander, 2008) then developing dialogic discourse in science is not only about bridging children's and scientific ideas with the aim of univocality, but also valuing multivocal discourse as end in itself.

Whole class discussion is important in constructing a view of science at Key Stage 2 as not only about experiencing the natural world but theorising it and aiming to come to a shared understanding of it. However in the process of theorising and the focus on rational argument, there is the possibility that the abstractions become so far removed from the social concerns of humans that it devalues this dimension of life and might lead children to reject science as not personally meaningful. In dialogic talk primary teachers need to attend not only to the conceptual content of children's ideas, but also the cultural contexts and personal experiences that situate them. This is entirely consistent with a sociocultural approach to science education that goes beyond conceptual change to the construction of identities (Lemke, 2001).

9.3 Recommendations for science education practitioners

In order to develop a dialogic approach overall, it would help Key Stage 2 teachers to develop a more 'genuinely reciprocal' (Alexander, 2004a) discourse around science with children if the aims of different elements of science teaching were made more explicit so that they can try to develop a match between the aim and the communicative approach they adopt as summarised in section 8.7. This includes recognising when an authoritative approach *is* appropriate, and distinguishing between dialogic talk with a univocal and a multivocal aim. This would be supported by the development of professional literature on teaching science that has greater clarity on these issues than at present and this research has provided a direction for the development of the models of teaching.

The case study teachers' response to the use of VSRD suggest that it would be a productive strategy for professional development by enabling teachers to become more aware of how they are using talk and reflecting on teaching purposes and outcomes. By comparing their practice with the findings of this research they could develop their own use of interactive whole class teaching in science.

Tutors involved in initial teacher training, or continued professional development, could examine the repertoire of teaching activities they present and consider how the aims would be supported by a particular communicative approach. They also need to consider their own use of talk and the nature of the discourse into which their students are being encultured, as colleagues and I (Davies et al., 2008) have begun doing with trainees on the Bath Spa University Primary PGCE course.

9.4 Recommendations for future research

Further research is needed to:

- Analyse the learning demand (Leach and Scott, 2002) of knowledge in different domains of the primary science curriculum, including procedural knowledge, and relate this to teaching approaches, including the nature of whole class interactions, that would support children's appropriation of it.
- Consider the relationship between communicative approach and different children's participation in whole class interactions, including developing an understanding of the relationship between talk partners and whole class discussion.
- Find ways of helping teachers develop their repertoire of talk in whole class teaching for different purposes in science including exploring the use of Video Stimulated Reflective Dialogues (VSRD).

The primary curriculum is currently under review. The consultation draft of the new primary curriculum (Rose, 2009) offers a broader, less atomistic account of procedural knowledge than the current version of the National Curriculum (DfES, 1999). It proposes 'key skills' for science; firstly to: 'Observe and explore to generate ideas, define problems and pose questions…', and secondly to '…gather and record evidence by observation and measurements.' echoing the distinction noted by Millar (1998) between how scientific ideas are generated and how they are validated. The words 'generate ideas' suggest a multivocal aim for primary science. However, the labelling of procedural knowledge as 'skills' rather than as tool and as ways of thinking presents a limited view of the nature of procedural knowledge (Cambridge Primary Review, 2009b) and analysis of the detail of the content raises concerns that the apparent openness masks a more univocal agenda. The document (Rose, 2009) emphasises processes in the main body of the text, for example:

> L10. to investigate the properties and behaviour of light and sound in order to describe and explain familiar effects [40]

and in a foot note below says that ' 40. This includes how we see things'

Assuming that 'how we see things' is interpreted in a similar way to the current National Curriculum, this involves a theoretical account of seeing when reflected light enters the eye that is not generalisable from enquiry. Putting this as a footnote and given the general emphasis in the document on enquiry maintains the insoluble tension for teachers of trying to make predetermined ideas emerge from children's enquiries (Driver, 1983) resulting in a dishonest form of interactions (Alexander, 2003), rather than establishing the dual aims of science education as appropriation of existing scientific knowledge and developing a discourse that also supports its transformation.

Primary science has become content-driven by national testing, reducing the space for personal curiosity and questioning (Cambridge Primary Review, 2009a) and shaped by the dominant concern of the historical period for 'standards' and a performance culture (Galton, 2007). The impact of this culture is evident in the case studies which lack the development of scientific attitudes such as curiosity and the sense of ownership of scientific enquiry that was promoted in the constructivist and early social constructivist models of teaching. Children are positioned more as receivers of transmitted science, than transformers of it. The removal of the End of Key Stage 2 Test for Science (SATs) on the discourse in science lessons in upper Key Stage 2 and its likely replacement with teacher assessment with an emphasis on practical work (Directgov, 2009) provides a new context in which to research talk in science lessons at Key Stage 2.

In the recent publication of the fifth edition of the key professional text *The Teaching of Science in Primary schools (*Harlen and Qualter, 2009) the authors have devoted a new section to 'Whole-class dialogic teaching' (pp.102-103), that adopts Alexander's (2004) version of dialogic teaching. In this section they also warn that whole class teaching can be the context for 'authoritative and controlling' interactions: and that:

> It is important that good examples of whole-class dialogic teaching are not interpreted as reasons for wholesale use of whole class teaching where most children are passive receivers. (ibid. p102)

While my findings agree that over-use of authoritative exchanges situates children as passive receivers of science, the continued resistance to any authoritative introduction of ideas does not take into account the insights of Scott et al. (2006) that the tension between authoritative and dialogic dialogue is fundamental to appropriating the scientific discourse.

The nature of the organisation of teaching forms part of the context in which the meaning is developed (Wertsch, 1991). The medium of whole class teaching, signals the high status, and the shared nature of knowledge. This may be one of the reasons that it is associated with transmission. But this high status is also the very reason for challenging practice that is overly authoritative and supporting ways of using whole class teaching that are more dialogic and supportive of the deeper aims of science education; providing an opportunity for children to develop an understanding of the nature of science as cultural activity.

This thesis makes a contribution to the ongoing dialogue about how teachers should go about teaching science.

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Appendices

Appendix 1: Defining the Communicative approach

Communicative approach – after Scott (1998) and extended by adding Alexander (2004a) (additions based on Alexander shown in italics). My own additions are shown in Tahoma font.

Features of Interactive – Non-interactive whole class teaching

Non-interactive	**Interactive**
Teacher talks or demonstrates Pupils listen and /or look in silence	Teacher asks questions or makes other utterance that requires an oral or physical response from one or more children Children speak in response to questions, or spontaneously, either as individuals or chorally Children may interact with objects at the front of the group, holding, pointing, writing Children may communicate non-verbally e.g. by writing on mini-whiteboards or holding up signs or making signals with their bodies, e.g. thumbs up

Features of Authoritative and dialogic discourse:

Authoritative	Dialogic
General features:	
Focussed principally on the 'information transmitting' voice	Involving several voices *Reciprocal – listen to each other, share ideas, consider alternative viewpoints*
'Closed' – new voices not acknowledged unless supporting message to be transmitted	*Collective – teachers and pupils address learning tasks together* 'Open' – new voices contribute to the act of developing meaning
Fixed intent – outcome controlled	Generative intent – outcome may not be anticipated *Purposeful – teachers plan and steer classroom talk with specific educational goals in view.*

Nature of teacher utterances:

Invested with authority which tends to discourage interventions	Framed in such a way as to be open to challenge and debate
Intended to convey information	Intended to act as 'thinking devices' or 'generators of meaning'
Exchanges are often left 'stranded and disconnected Often based on instructional questions (to which the teacher already has the answer)	Often based on open or genuine questions where the answer is not obvious
Often involving formal reviews or factual statements which offer few 'invitations' to dialogue	Directed towards sustaining dialogue *Answers provoke further questions and are seen as the building blocks of dialogue rather than its terminal point.*
Selectively drawing on other voices	Representing other voices

Nature of pupil utterances

Often in response to teacher questions	Often spontaneously offered and triggered by comments from other students *Pupils ask questions and provide explanations*
Often consisting of single, detached words interspersed in teacher delivery	Often consisting of ideas expressed in whole phrases and in the context of on-going dialogue *Cumulative – building on their own and each other's ideas and chaining of ideas into coherent lines of enquiry*
Often direct assertions	Often tentative suggestions open to interpretation and development by others *Supportive – children articulate their ideas freely without fear of embarrassment over 'wrong answers' and they help each other to reach common understandings*

Appendix 2: Summary of Terms from Discourse Analysis

Term	Description and Purpose(s)	Source
Triadic dialogue	Teachers ask questions, call on students to answer them, teachers evaluate the answers. /Initiation /Response/Evaluation IRE A common form of dialogue in classrooms. It maintains teacher control. A series of thematically linked questions may construct a series of linked semantic relations	Sinclair and Coulthard (1975) Lemke (1990)
Teacher exposition	Teacher presents new material in a monologue Introducing new material Explanation in response to question	Lemke (1990)
Teacher Summary	Teacher monologue in which they summarise the themes of the lesson	Lemke (1990)
Student questioning dialogue	Students initiate questions and teacher answers them	Lemke (1990)
True dialogue	Teachers and students ask and answer each other questions and response with comments as in normal conversation – with symmetrical status	Lemke (1990)
Cross discussion	Students speak to each other about the subject, teacher acts as moderator or as equal participant	Lemke (1990)
Signalling boundaries	Teachers indicate end of one episode and beginning of the next	Lemke (1990)
Interrupting students	Teachers break into student's question or answer	Lemke (1990)
Retroactive redefinition, retroactive recontextualisation,	Especially in triadic dialogue, teachers may redefine the status of a students move, or their meaning of their utterance through the evaluation or feedback move	Lemke (1990)
Asserting irrelevance	Teachers declare a students answer, off the topic, or not germane to the question	Lemke (1990)
Marking New/Old information	Teachers signal that information is new, or that it is something the students should already know	Lemke (1990)
Repetition with variation	'global thematic strategy – for developing a theme over an extended period of time	Lemke (1990)
Thematic Nexus	Bringing together several themes	Lemke (1990)
Cued elicitation	Use prompts to elicit key ideas from children, rather then telling them directly.	Edwards and Mercer (1987)
special enunciation	Marking knowledge as significant and joint through tone and expression of voice	Lemke (1990)

Repetition	Marking knowledge as significant and joint through repetition	Lemke (1990)
use of formulaic phrases	Marking knowledge as significant and joint through use of formulaic phrases	Lemke (1990)
Repeat back of student utterance	accepting, holding up the response , unless is in a quizzical tone	Mercer (2000)
Selection and modification (also reformulations, Paraphrasing, reconstructive recaps)	Restatement of a selected student answer that may also modify it to fit a thematic pattern	Lemke (1990), Mercer (2000)
Joint construction	A thematic pattern is jointly constructed by contributions to dialogue from both teacher and student, with each completing or extending clauses begun by the other.	Lemke (1990)
Joint knowledge markers	– e.g. simultaneous speech, or use of the term 'we'	Edwards and Mercer (1987)
Shared frame of reference	No need to make explicit what terms mean as they are shared by the participants.	Mercer (2000)
Cumulative talk	Participants not striving for control, talk is mutual, and generally supportive, with little critical dimension	Mercer (2000)
Disputational talk	Participants are striving for control	Mercer (2000)
Exploratory talk	Participants engage critically, but constructively with each others ideas	Mercer (2000)

Appendix 3: **Pedagogic** Purposes of Whole Class Teaching Episodes

General purpose (After Moyles et al 2003)	**More specific purposes**	**Derived from/underpinned by**
Engaging Pupils	engaging interest relating to previous learning making it relevant to pupils	Moyles et al (2003) Relates to social constructivist model – orientation (Scott et al. 1987)
Sharing aims	Explicit sharing of success criteria Giving feedback on assessment against criteria Viewing work in progress and evaluating it	Moyles et al. (2003) Goldsworthy et al (2000) Harlen and Qualter (2004)
Pupil practical and active involvement	maintaining interest making it fun	Moyles et al. (2003) Moyles et al. (2003) Relates to Piagetian constructivism
Broad Pupil participation	engaging pupils in interaction assessing specific knowledge teacher efficiency	Moyles et al. (2003) Moyles et al. (2003) Moyles et al. (2003)
Collaborative activity	Developing speaking and listening skills sharing ideas	Moyles et al. (2003) Moyles et al. (2003)
Conveying knowledge	Explaining a concept Specific skills teaching Specific process teaching	Moyles et al. (2003) Goldsworthy et al. (2000) Goldsworthy et al. (2000)
Assessing and extending knowledge	assessing and extending addressing deeper or implicit understanding by extended interaction	Moyles et al. (2003) Moyles et al. (2003)
Reciprocity and meaning making	digging deeper into meanings promoting a two way process Negotiating aims/success criteria,	Moyles et al. (2003) Moyles et al. (2003)
Attention to thinking and	promoting questioning promoting prediction and hypothesising	*(related to National Curriculum Sc1*

learning skills	promoting explaining promoting evaluating	*and definitions of thinking skills)*
Attention to pupils' social and emotional needs	promoting self-esteem promoting cognitive risk taking giving pupils' ideas status developing an implicit moral/political stance	Moyles et al. (2003) Moyles et al. (2003) Moyles et al. (2003) Moyles et al. (2003)
Organisational	Grouping, Resources Behaviour management	Harlen (1992)

Appendix 4: Interview 1 (Preliminary interview)

Overview

This will be a semi-structured interview with some general areas of discussion and some particular questions. Where particular aspects have not been discussed as naturally arising from the dialogue I will ask more direct questions to elicit this information. Use the list on the following page as a prompt and checklist.

I will address the nature of our relationship and explain that I am concerned about the ethical issue that case studies can be seen as exploitative of a relationship and I want to minimise this. It seems that maintaining a professional approach throughout, e.g. not sharing more personal details that might be more indicative of a friendship, would be helpful in this. There is a tension here between having relaxed, friendly open discussions and my need to maintain enough distance for analysis without identifying too closely with the teacher.

As the teachers have been identified as the result of science subject leader courses and/or professional meetings in which my role has been as 'consultant/ I will make explicit that views that I have previously expressed during, for example science subject leaders courses, are ones that I am currently seeking to explore and develop and I am not considering them as unproblematic versions of 'good practice'.

I will make clear that the process of observing lessons and discussing them is not about evaluating them against fixed criteria and providing feedback. Instead the process is one in which I will look at how what the teacher is doing compares with existing models of teaching science and considering what aspects of those models is problematic in the classroom context, or where they could be developed. I will make explicit that their expertise and reflection will play an important role in this and I intend that the dialogue between us will develop our understanding of teaching science.

Recording

As this is the first meeting and I want the teachers to feel as much at ease as possible I will make written notes in the case study notebook. This will slow the pace of discussion, but I believe this will allow time for reflection during the discussion, possibly supporting a depth and richness of data.

Location

The discussion will take place in the teacher's school – on their 'home territory'.

Areas for Discussion.

Science teaching

How do you go about medium term planning for science?
Discuss particular plan for the case study (take a copy)
What is source of current practice? – govmnt/scheme/school/LEA/ courses/reading?
Whole class teaching - how would you define it? What might make it 'interactive'?
What role does whole class teaching play in your teaching? What are the reasons for this?
Does whole class teaching play a part in your teaching of scientific enquiry/and /or the knowledge and understanding 'content' of science.
Classroom organisation – what structures for lessons would you use in science?
Information about the particular class in which the case study will be developed. E.g. recent history, children with impairments, TA support,
What are the main things you believe that KS2 children should learn from their science? Why these?

Practical details

Times and days of lessons
Sketch of classroom layout
Discuss location of myself and camera
Discuss how I will be introduced to the children, and how I will interact with them. (i.e. as little as possible – will very much be there as a 'researcher' not a teacher or TA)

Appendix 5: Interview 2 (professional biography and ideas about science and teaching and learning science)

Understandings and beliefs about the nature of science (15mins)

Use controversial statements (based on Lunn 2002) as a pyramid activity as a start point, but follow the discussion. Use Lunn's (2002) characterisation to develop my understanding of this teacher's perspective.

Personal and professional biography in relation to science and teaching science (15mins)

Check have details about own science education right from interview 1.

Where do your ideas about teaching science come from?

How has being a leading science teacher/AST affected your ideas about science? What does this role involve?

What do you see as the purposes and aims of teaching science in primary schools?

Reasons and purposes for approaches to science – what models of science teaching does she espouse? What ideas does she have about children's learning in science?

What would you list as important attributes of a successful science lesson?
Why have you chosen the STAR science scheme to work from?
In what ways is it better/worse than other approaches to teaching science you have taken in the past?
Have any other books/sources influenced your practice?
How has training influenced your practice? Who led this – what were the main messages?
How do children learn best in science? – How do they learn concepts; how to they learn about processes; how do they learn about science?

To be 'up-front' about some of my concerns about the more teacher led and controlled model of teaching science, and to explore with the teacher what the implications are for children's learning.

Explain that one thing I am looking for is:
Participation- non-participation
Dialogic- authoritative

Share Moyles et al – features of interactive teaching - surface- deep

Any feedback for me – how is it going from the Teacher's point of view? Anything she would like me to change?

Appendix 6: Characterisations of Science

From Lunn (2002) Teacher's views on the nature of science

Characterisations of and commentaries on the six factors.

Factor	Characterisation	Commentary
Scientism	Scientific method will lead to the truth. There are no mysteries that will not eventually yield. Science is the only way of finding out about the reality behind phenomena.	Uncritical enthusiasm for science and acceptance of scientific findings as fact.
Naïve empiricism	Science proceeds by trying things out to 'see what happens', and is driven by data derived from such observations. Progress is represented by the steady accumulation of facts.	A lay view of science as process uninformed by theory.
New-age-ism	Progress in science is illusory. It consists in the development of new ways of talking about the world that are not intrinsically better than older ways, just different.	A kind of relativism, which has taken on board paradigm change, but sees it as change of linguistic or explanatory fashion rather than progress.
Constructivism	Science is rooted in attempts to construct explanations, which originate in discursive speculation and imagination. The explanations are of phenomena, which form part of theory-mediated experience.	Science as joint human sense-making and disciplined curiosity.
Pragmatism	Truth, coherence, and correspondence with 'reality' are not worth pursuing or are unattainable: what matters is the usefulness of science in helping us understand and influence our experience.	This could represent a frustration with philosophical nit-picking, or a positive philosophical position.
Scepticism	Science has no claims to specialness, and is no more likely to be true than common sense.	This could represent simple rejection of the non-commonsensical, or a kind of pan-epistemological relativism.

Appendix 7: Eliciting teachers views of the nature of science

Statements derived from Lunn, 2002

Which of these statements do you strongly agree with, agree with, disagree with?

Scientific method will lead to the truth.
Science is the only way of finding out about the reality behind phenomena.
Science proceeds by trying things out to 'see what happens', and is driven by data derived from such observations.
Scientists can observe the world objectively
Progress in science is represented by the steady accumulation of facts.
Progress in science is illusory. It consists in the development of new ways of talking about the world that are not intrinsically better than older ways, just different.
Science is rooted in attempts to construct explanations, which originate in speculation and imagination.
Intuition is as important in science as careful experimentation.
Truth, and describing and explaining 'reality' are not worth pursuing or are unattainable.
All scientific knowledge is tentative
What matters is the usefulness of science in helping us understand and influence our experience.
Science has no claims to specialness, and is no more likely to be true than common sense.

Appendix 8: Overview of Protocol including Selection of Episodes

Analysis at the level of episodes

While in the field I split the lesson into episodes as they were taking place, based on either a clear transition for example from whole class to group work, or on a shift in the discourse or clear change in the communicative approach, often signalled by the teacher saying 'Right' or 'Now' (Lemke, 1990).

For each episode I recorded a brief description of what had taken place, coding the 'communicative approach' episode (ID, ND, IA, NA) after Mortimer and Scott (2003) and a list of my teaching purposes of the lesson, as I judged them at the time.

Selection of episodes for more detailed analysis was made using a combination of the following criteria:

1. Episodes exemplifying the different communicative approaches (Mortimer and Scott, 2003) to examine how these are created through interactions within episodes.
2. Exploring relationships between the teaching purposes and the communicative approach and nature of teacher interventions.
3. Episodes that seemed to be significant as 'critical incidents' (Cohen et al., 2000) and considering their role in lessons or sequences of lessons.

Selected episodes were transferred to Windows Movie maker as clips. Each episode was first viewed in its entirety, then a rough transcript was made of the talk, and any teacher gestures, actions and movements judged to be significant.

Analysis at the level of lessons

Selection of lessons was based on:

1. Being judged by me as significant in the sequence of lessons, for example, being the first lesson
2. Illustrating use of whole class teaching that I judge to be 'typical' of the case,
3. Exploring aspects of models of teaching science identified in the literature.

4. Quantitative analysis suggest there are features of the lesson worth exploring further, e.g. a high or low proportion of whole class teaching, or a high or low proportion of a particular communicative approach.

Table 1: Case Study 1 Selection of episodes

Lesson observed	Episodes for VBRD	Episodes selected for transcription	Episodes discussed in case study
1	1, 2, 3, 4, 22, 23	1,2,3,4,13,22,23,26,28	1,4,13,22,23,28
2		2	2
3			
4			
5	12, 14,	5,12,14,20,22	12,14,22
6	3, 12, 16	3,6,12,16,17	3,16
7			
8	16	16	
9	2	2,6,8,11,16,26	2,8,
10			
12		1,13,18	1

Table 2: Case Study 2 Selection of episodes

Lesson observed	Episodes subjected to VSRD	Episodes selected for transcription	Episodes discussed in case study
1	4, 23	2,3,4,6,10,19,23,24,25	2,4,6,19,23,24
2	3	1,3,4,5,7,8,,9,10,11,18,20,26	1,3,7,26
3	2, 3, 6	1,2,3,4,6, 7, 12, 13,14,	6,13
4	14	1,2,5,7,14,17,26,28,29,41	28,29,41
5	19	10,15,19	15,19
6	14	6,8,9,11,12,14,16,18,21,,25,27,28	6,12,14,16
7	20, 28	1,7,28,29,	1
8	9, 12	6,9,12,22,	6,9,12,26

Appendix 9: Case Study 1 End of Unit test results based on Ginn New Star Science Dissolving Assessment Task sheet A (Feasey et al. 2001)

31 children took the test

Question and responses
Interpreting table of data – which type of salt dissolved fastest/slowest
31 all correct
Why did she do the test more than once?
Good understanding of variation and/or anomalous results – 10 Some sense of checking/accuracy – 14, of which 7 referred to 'doing it wrong' rather than natural variation Incorrect response - e.g. to make it fair 7
How does the size of the salt pieces affect the time it takes the salt to dissolve?
2 part Pattern followed - independent and dependent variable, and general pattern – 4 2 part Pattern followed, but related to explanation, not related to time (dependent variable) – 4 Pattern followed, but doubled, suggesting new development from 'extremes only) – 2 2 part pattern, and some generalisation e.g. Using er – er, but still emphasising 2 extremes - 8 Emphasising one extreme of independent variable, inclusion of dependent variable, With some evidence of generalisation, ('er') – 3 individual independent variable noted, no mention of dependent variable or general pattern – 2 Extremes of independent variable noted, inclusion of dependent variable but not general pattern – 2 Explanation only given - 4 (didn't correctly interpret the kind of response required) No response - 2