Developing science concepts in secondary classrooms: An analysis of pedagogical interactions from a Vygotskian perspective.

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

Abstract

This study is concerned with how teachers use and guide classroom talk to support students in developing an understanding of scientific conceptual knowledge. The focus is on teachers and teaching. The study involves developing theoretical tools for describing the ways in which teachers make scientific ways of talking and knowing available to their students in classroom settings.

The study has both theoretical and empirical components. The theoretical component involves drawing on aspects of Vygotsky's socio-cultural theory of learning and development and the work of other neo-Vygotskian scholars to develop theoretical tools, based on the concept of the teaching narrative, for analysing the teaching interactions of the classroom. The empirical part involves taking those theoretical tools and applying them to real classroom situations. It is anticipated that the process of applying the theoretical tools to particular classroom situations will enable elaboration and further development of those tools; in this respect there is close interlinking between theoretical and empirical components of the study. The empirical component is based on two case studies. These case studies detail short teaching sequences in which two teachers introduce their classes to particular scientific concepts. The first case involves teaching and learning about chemical change (focussing on the process of rusting) and the second about air pressure.

In summary, the main aim of this thesis is to draw upon Vygotskian theory to develop ways of talking and thinking about language-based pedagogical strategies of science teaching. The intention is that such ways of talking and thinking, framed in terms of the teaching narrative, should contribute to the professional language of science teaching providing tools for reflecting on and developing teaching practice.

This thesis is dedicated to my parents

Ralph Harland Scott, 1917-1960
Florence Mary Scott, 1925-1971

and to my 'other parents'

Eunice and Jimmy Bewick
Freda and Jack Bradwell
Renee and Findlay Harrison

...especially to Findlay Harrison whose wisdom, love and support have always meant so much to me.

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Special thanks to Rosalind Driver who got me into all of this in the first place...a great friend and inspirational colleague.
Thanks for everything Ros!

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The notation and conventions used in the transcripts

The following notation and conventions are used in the presentation of all transcripts:

- dashes (-) indicate places where the speaker abandons one way of expressing an idea and starts again.

- question marks (?) used at the end of an utterance or after a word indicate a questionning intonation.

- commas (,) indicate places where there is a pause in the speaker's delivery

- comments in italics in square brackets provide additional contextual information for the reader.

- three dots (...) indicates that a section of transcript has been omitted. Three dots at the start of a new speaker's utterance indicates that the transcription presented is not taken from the start of the utterance.

- where turns to speak are taken normally, each speaker's text begins with a capital letter. Where one person interrupts another, and takes over the speaking term, the first speaker's transcript is broken off with two dots and the new speaker's words are started with two dots and without a capital letter.

- underlining (<u>surely</u>) is used to demonstrate special emphasis by the speaker.

- [ ] indicates a noticeable pause by the speaker

- throughout the two cases the Yorkshire dialect of the pupils is retained in the transcripts: 'it could rust a lot quicker wi' t'small one 'cos there's not as much metal to rust'. In examples of pupils' written work all original spellings are retained.

Chapter 1: An introduction to and an overview of the study

1.1 Introduction

Classrooms are peculiarly interesting places. It is in the classroom that young people are introduced to the public knowledge which societies regard as being sufficiently important to pass on from generation to generation. It is in the classroom that the teacher is charged with the responsibility of establishing shared understandings of that knowledge with relatively large groups of young people. Secondary school classrooms provide the setting for this study which in broad terms addresses the issue of how teachers use and guide classroom talk to support students in developing an understanding of scientific conceptual knowledge.

The study has a number of different facets each of which requires introduction and elaboration and in the following paragraphs key aspects of the study are outlined for the reader. These aspects are then explored in greater detail in subsequent chapters of the thesis. Given the focus of the study on scientific conceptual knowledge the first issue to be addressed concerns the position taken by the author on the nature of scientific knowledge and the implications of that view of scientific knowledge for science learning.

1.2 A view of scientific knowledge and science learning

At the start of instruction about a particular scientific concept it is quite likely that the students will be unaware of the scientific view to be introduced, although they may be familiar with various phenomena to which the scientific concept relates. Thus, for example, students' everyday experiences are likely to include events such as drinking orange through a straw, noticing the growth of plants and playing on bicycles. They are, however, unlikely to be familiar with the scientific concepts of air pressure, photosynthesis and Newton's Laws of motion. Furthermore, these scientific concepts are not something which students are likely to discover for themselves through their own experiences with phenomena.

Whilst current thinking (see for example Chalmers, 1982) emphasises the point that there is no single, widely accepted view of the nature of scientific knowledge, there tends to be general agreement about the consensual nature of scientific knowledge and the 'imaginative leap' which separates empirical data from

scientific theories. That is the concepts of science are constructs which have been developed within the scientific community in an attempt to interpret and explain natural phenomena. Scientific knowledge is developed and tested, validated and transmitted through the cultural and social institutions of science. Learning science involves, therefore, being introduced to the ways of talking and knowing of the scientific community (see, for example, Lemke, 1990).

If learning science involves being introduced to the ways of talking and knowing of the scientific community, it is also the case that individual students live within a community whose members have developed, and continuously re-enact, 'everyday ways' of talking and knowing about the events and phenomena which are of interest to scientists. Returning to the earlier example of air pressure, the action of drinking orange through a straw is referred to in 'everyday ways' of talking in terms of 'sucking'. This way of talking and knowing is unlikely to be considered problematic or difficult to understand; for example, children from an early age are able to respond to parents' exhortations to 'suck quietly' as they drink through a straw. There is little difficulty involved in establishing a shared understanding of what is meant, the child is immersed in this kind of talk from birth; this is how such events are referred to on a day-to-day basis.

However, potential difficulties in establishing shared understandings *do* arise when the child revisits these familiar events, with their associated ways of talking, in school science lessons. It is here, in the classroom, that the teacher faces the challenge of introducing students to the scientific ways of interpreting and explaining phenomena which the students already talk and know about in their own everyday ways. A three-way relationship exists between the common reference point of a particular phenomenon and the everyday and scientific ways of talking about that phenomenon.

The challenge for the teacher is one of introducing students to scientific ways of talking and knowing which draw upon scientific concepts in particular ways and which are quite likely to be different from everyday ways of talking and knowing. Thus in our example, drinking orange through a straw is explained scientifically not in terms of the human action of sucking but in terms of differences in air pressure. In a very real sense the learner is required to change part of their world-view in coming to accept this particular scientific explanation. The scientific view is based on the fundamental ideas that air is substantial and can exert very large pressures, a perspective which is likely to be counter-intuitive for most learners. Therefore, coming to understand and accept this particular part of

science involves a challenge to basic ontological beliefs or personal commitments about the real nature of the world, which have developed over the years through day-to-day experiences and talk.

Of course learning science does not always involve challenges to fundamental personal beliefs. In some areas of science there may be substantial commonality between everyday and scientific views. The nature of the differences between everyday and scientific views has been referred to as the *learning demand* of coming to understand a particular scientific concept or conceptual area (see Leach and Scott 1995; Scott and Driver, in press). The learning demand is a description of the cognitive changes or developments which the learner must undergo in developing a scientific perspective on a given topic, given the conceptual and epistemological starting point of their existing knowledge structures. Whether the differences between scientific and everyday views are great or not, this distinction between ways of knowing underlies all science learning and frames the challenge for the teacher in promoting science learning.

In summary, within this study science learning is viewed as developing new ways of talking and knowing about the natural world. These new ways of talking and knowing differ to a greater or lesser extent from existing everyday views according to the domain of science study and therefore present differing intellectual challenges, or learning demands, for the learner.

1.3 The focus of this study

As stated earlier this study is concerned with the issue of how teachers use and guide classroom talk to support students in developing an understanding of scientific conceptual knowledge. The main focus is on teachers and teaching; the study involves exploring, and developing theoretical tools for describing, the ways in which teachers make scientific ways of talking and knowing available to their students in classroom settings.

This is a wide brief. However, in a paper prepared in the early stages of development of this thesis (Scott, Asoko and Driver, 1991) a distinction was made between two aspects of the teacher's performance and this distinction is drawn upon in further focussing of the study. The distinction is between *instructional activities* on the one hand and *pedagogical strategies* on the other. Instructional activities can be thought of as the teaching activities (including, for example, teacher demonstrations and student practical activities) which teachers use to

address particular learning demands. Instructional activities would be recognised as the major teaching activities which constitute science lessons. Pedagogical strategies, on the other hand, are the ways in which teachers 'talk around' instructional activities; they are the forms of discursive intervention or forms of talk which the teacher uses to support students in their learning.

In the field of science education, developing new teaching approaches tends to be synonymous with developing new instructional activities. In the *School Science Review* (the most widely read journal for secondary school science teachers in the UK) there is a prominent section in which new teaching approaches are regularly reported and these consist almost entirely of demonstrations for teachers to perform or practical activities for students to engage in. This pre-occupation with developing key instructional activities to address particular learning goals is also evident in the science education research literature where numerous studies have focussed on specific content domains and give accounts of research-based instructional activities aimed at promoting more effective conceptual understanding (see, for example, Johnston and Scott 1991; Camp and Clement 1994; Andersson and Bach 1996).

What has tended to be missing from the attentions of both science teacher and science education research communities has been systematic consideration of the ways in which teachers draw on various pedagogical strategies to promote opportunities for teacher and students to 'talk around' instructional activities. In this thesis an attempt is made to redress this balance. It is clearly the case that instructional activities are a fundamental part of any teaching but this is only one part of the teaching story. Of central interest in this study are the ways in which teachers control and develop the 'talk around instructional activities' to support science learning.

Given this focus of the study, the next issue to be considered concerns the theoretical perspective to be drawn upon in exploring and analysing this 'talk around activities'.

1.4 A theoretical perspective

The theoretical view which informs the conceptual and methodological framing of this study and the interpretation of findings is based on Vygotsky's socio-cultural perspective on development and learning and the work of other scholars of the neo-Vygotskian school. So why choose Vygotskian theory?

Over the past ten to fifteen years there has been a major upsurge of interest in the ideas of Lev Semenovich Vygotsky (1896-1934). One major reason for Vygotsky's current appeal in Europe and particularly in North America is his approach which focusses on the social origins of mental processes. In Vygotsky's view, mental functioning in the individual can be understood only by examining the social and cultural processes from which it derives. This perspective calls on the investigator to begin the analysis of mental functioning in the individual by going outside the individual. As one of Vygotsky's students and colleagues, A.R. Luria, puts it:

> In order to explain the highly complex forms of human consciousness one must go beyond the human organism. One must seek the origins of conscious activity... in the external processes of social life (Luria, 1981, p.25).

Thus, in order to gain understanding of the ways in which young people develop personal understandings of scientific conceptual knowledge in school, it is necessary to investigate the social processes of life in the classroom. In the classroom concepts are first rehearsed between teacher and students principally through talk; that talk then provides the cognitive tools for mediation of individual mental functioning. In other words, language provides the tools for personal thought. Vygotsky's emphasis on the social origins of individual mental processes emerges quite clearly in his analysis of the functions of language. Thus he argues that, 'a sign is always originally a means used for social purposes, a means for influencing others, and only later becomes a means of influencing oneself' (Vygotsky 1981, p.157).

This view stands in marked contrast to the strongly individualistic assumptions that have guided the bulk of contemporary Western research in psychology. It is also a theoretical view which holds out promise for analysing the impact of social institutions such as schools on the cognition of individuals. In his introduction to the first English translation of Vygotsky's (1962) *Thought and Language*, Jerome Bruner makes the point that, 'Vygotsky's conception of development is at the same time a theory of education'.

Vygotsky regarded education not only as central to cognitive development but also as the quintessential socio-cultural activity. That is, he considered the capacity to teach and to benefit from instruction a fundamental attribute of human beings. He argued that higher psychological processes, such as the scientific

conceptual knowledge which is of interest in this study, develop in children through enculturation into the practices of society; through the acquisition of society's signs and tools, through education in all its forms. Here then, we have a theoretical perspective which lends itself to the analysis of teaching and learning in school settings.

An important point to be borne in mind, however, in drawing on Vygotsky's theoretical ideas is that his work was prematurely brought to a halt by his death in 1934. In Chapter 6 of *Thinking and Speech* (Vygotsky, 1987) Vygotsky introduces his ideas on how the forms of teacher-student interpsychological functioning encountered in the institutional setting of formal schooling provide a framework for the development of students' conceptual thinking. This work is very close to the interests of the present study, but the point to be aware of is that it was written in the year that Vygotsky died, thus removing the opportunity for any elaboration or development of ideas. The work was also (of course) located in the particular social and cultural context of Soviet schooling in the 1930's. Vygotsky's work therefore cannot, and does not, provide a ready-made and complete theoretical template for analysing the interactions of UK classrooms towards the end of the twentieth century. Vygotsky's theoretical position can be drawn upon to provide a guiding framework for this study but there is clearly room, and need, for further work in operationalising and developing that theoretical position.

The intention in this study is therefore to draw upon Vygotsky's ideas, and those of neo-Vygotskian scholars, in exploring and analysing the ways in which teachers use and guide classroom talk to support students in developing an understanding of scientific conceptual knowledge. A key feature of the analyses developed in this study is that they are based on an extended time line; they focus on sequences of teaching which last for three hours or more and are framed in terms of the ways in which the teacher develops a 'teaching narrative' to introduce the science way of knowing and to support the students in their learning. The teaching narrative is described in terms of four aspects of classroom discourse relating to:

1. The forms of pedagogical intervention
2. The authoritative-dialogic nature of the discourse
3. The content of the discourse
4. The pedagogical interventions in terms of scaffolding

1.5 An overview of the design and methodology of the study

The study presented here has both theoretical and empirical components. The theoretical component involves drawing on aspects of the Vygotskian perspective to develop theoretical tools for exploring and analysing the teaching interactions of the classroom. The empirical part involves taking those theoretical tools and applying them to real classroom situations. It is anticipated that the process of applying the theoretical tools to particular situations will enable an iterative process of further elaboration and development of those tools. In this respect there is close interlinking between theoretical and empirical components of the study; development of the theoretical tools involves putting them to work in practical situations.

The empirical component is based on two case studies. These case studies detail short teaching sequences in which two teachers introduce their classes to particular scientific concepts. The first case involves teaching and learning about chemical change (focussing on the process of rusting) and the second about air pressure. As discussed earlier, the demands of learning particular scientific concepts can be conceptualised in terms of the differences between everyday and scientific views. Here the two science concepts which are the subject of teaching were chosen so as to generate different 'learning demands' for students; the nature of these demands is considered later in the thesis. Both cases involve approximately three hours of teaching and the methodological approach taken is to follow the progress of the lessons in some detail, monitoring and recording all of the interactions between teacher and students and also collecting data to sample the development in reasoning of a small group of students in each class. The detailed transcripts of these interactions provide the data base for analysing the ways in which each teacher guides the classroom talk to support student learning.

The teachers involved in the two cases are both considered to be 'expert practitioners' by their peers. Both are sensitive to children's thinking and are concerned with supporting their students in developing firm understandings of scientific concepts. Both teachers routinely involve their students in talk aimed at exploring meanings and developing understandings. As outlined earlier the purpose of this study is to explore and to develop theoretical tools for describing how the two teachers use and guide the talk of the classroom in supporting students in developing an understanding of scientific conceptual knowledge. It is clear that one would not attempt to address such aims through gathering data in

classrooms where there is little interaction between teacher and students. Hence the involvement of these two particular teachers.

A final point to be made concerns the way in which theoretical ideas are developed through the different parts of the thesis. The reader should be aware that the process of theory elaboration and development referred to earlier is planned to take place throughout the course of the study. This is an iterative process in which the starting point is provided by Vygotskian and neo-Vygotskian principles which are then applied and refined in the context first of Case Study 1 and then of Case Study 2. This approach is reflected in the progressive development of ideas through the chapters of the thesis, culminating in the summary statements of the final chapter.

In summary, the main aim of this thesis is to draw upon Vygotskian theory to develop ways of talking and thinking about language-based pedagogical strategies of science teaching. The hope would be that these ways of talking and thinking about pedagogical strategies might contribute to the professional language of science teaching, providing tools to support further reflection on, and development of, teaching practice.

1.6 Structure of the thesis

This first chapter is intended to provide the reader with an overview of what the study is, and is not, about. The theoretical, empirical and methodological issues raised and briefly discussed here are dealt with in fuller detail in subsequent chapters.

In Chapter 2 the theoretical base of the study is introduced; a comprehensive review and discussion of Vygotskian theory is presented along with other theoretical ideas relevant to this study and developed by neo-Vygotskian scholars. Chapter 3 offers a short review of classroom-based research studies which focus on the role of talk in science teaching and learning. The purpose of this review is not to provide a comprehensive survey of all of the research work which has been carried out in this area; rather the focus is upon locating the present study with regard to other research into talk, teaching and learning in science. This review sets the scene for Chapter 4 in which the design of the present study is presented in detail: aims and research questions are specified; the basic theoretical tools for addressing those questions are outlined; the research methodology is laid out and discussed. In Chapters 5 and 6 detailed case studies relating to each of the

teaching sequences are set out. Chapter 5 focusses on teaching about the conditions required for 'rusting' and Chapter 6 on developing and applying the concept of 'air pressure'. The Vygotskian theoretical ideas drawn upon in examining and analysing the teacher-student interactions in the two case studies are progressively elaborated and developed through application to those cases. In Chapter 7 the main findings and outcomes of the study are presented and evaluated and implications for further study considered.

Chapter 2: Vygotskian and neo-Vygotskian theory: a socio-cultural perspective on learning and teaching

2.1 Introduction

The purpose of this chapter is to introduce and review the theoretical ideas which are drawn upon in framing and implementing this study. These theoretical ideas are taken both from the writings of Vygotsky and scholars of the neo-Vygotskian school who include some of Vygotsky's Russian contemporaries such as Luria, Leontiev and Bakhtin and researchers such as Wertsch, Bruner and Tharp who have contributed to interpreting and developing the Vygotskian position.

In the context of the whole thesis this chapter is of fundamental importance in setting the theoretical backdrop to the study. The chapter is organised in five main sections. In the first three sections Vygotskian perspectives on development and learning, learning science concepts and teaching are presented; the fourth section focusses on further developments and interpretations of the Vygotskian perspective; in the final section the theoretical ideas to be drawn upon in analysing the classroom discourse in this study are presented and reviewed.

2.2 A Vygotskian perspective on development and learning

2.2.1 Vygotsky's genetic approach

Fundamental to Vygotsky's analysis of development is his genetic approach which is based on the view that it is possible to understand aspects of human mental functioning only by considering their origin and the transitions they have undergone:

> We need to concentrate not on the *product* of development but on the very *process* by which higher forms are established....To encompass in research the process of a given thing's development in all its phases and changes, from birth to death, fundamentally means to discover its nature, its essence, for it is only in movement that a body shows what it is (Vygotsky, 1978, pp.64-65).

Vygotsky addressed several genetic domains in his writings. For example, he was interested in how human mental functioning emerges out of its phylogenetic origins and how it changes through sociocultural history. The principal focus for

his research was, however, on development of individuals over a life span, or ontogenesis.

In his analysis of ontogenetic development Vygotsky makes a fundamental distinction between 'elementary' and 'higher' mental functions (Vygotsky, 1978, p.39). Vygotsky's general strategy was to examine how mental functions such as memory, perception and thinking first appear in an elementary form and then are changed into a higher form. In his approach a related distinction is that between the 'natural' and the 'social' or 'cultural' lines of development. Natural development produces functions in their elementary forms, whereas cultural development converts elementary into higher functions. Thus:

> We shall call the first structures *elementary*; they are psychological wholes, conditioned chiefly by biological determinants. The latter structures which emerge in the process of cultural development are called *higher structures*. The initial stage is followed by that first structure's destruction, reconstruction, and transition to structures of higher type. Unlike the direct, reactive processes, these latter structures are constructed on the basis of the use of signs and tools (Vygotsky, 1978, p.124).

The 'higher structures', or 'higher psychological processes', which Vygotsky refers to include 'structures' such as conceptual knowledge and 'processes' such as deductive reasoning. Both are viewed as internalised transformations of socially prevalent patterns of interpersonal interaction. That is, these structures and processes originate as cultural artefacts which initially are developed and sustained through social interactions between people. Vygotsky offers a two-stage transformation to describe the way in which the individual can internalise social experience, this is summarised in his 'General genetic law of cultural development':

> Every function in the child's cultural development appears twice, on two levels. First on the social, and later on the psychological level; first between people as an interpsychological category and then inside the child as an intrapsychological category. This applies equally to voluntary attention, to logical memory and to the formation of concepts. The actual relations between human individuals underlie all higher functions (Vygotsky, 1978, p.128).

The focus of this study is on the ways in which students, through formal schooling, are able to acquire those cultural artefacts which are the conceptual structures and modes of reasoning constituting two specific topics in the physical sciences.

2.2.2 Internalisation, language and the development of thought

Given the Vygotskian position on the social origins of mental functioning, it is evident that development of thought must entail some process of internalisation, a passage from 'without' to 'within'. Vygotsky's formulation of internalisation is based on an analysis of the semiotic mechanisms that mediate social and individual functioning. According to Vygotsky:

> The following can serve as examples of psychological tools and their complex systems: language; various systems of counting; mnemonic techniques; algebraic symbol systems; works of art; writing; schemes, diagrams, maps, and mechanical drawings; all sorts of conventional signs (Vygotsky, 1981, p.137).

These are all examples of mediational means that are the products of socio-cultural evolution and are appropriated by groups or individuals as they carry out mental functioning. In other words, on the interpsychological plane language and other semiotic mechanisms are used to develop and rehearse meanings between individuals and that language then provides the tools or mediational means that enable individual cognition. From this perspective language is absolutely fundamental to thought and learning. It is not the case that language provides the means to communicate internally developed products of cognition; language provides the very means though which personal cognition occurs.

In his analysis of internalisation Vygotsky gave greatest attention to spoken language and indeed it is the role of talk in classroom teaching and learning which is of prime interest in this study. In the following paragraphs Vygotsky's ideas about the ways in which thought and speech are linked and develop through childhood are reviewed.

Vygotsky (1962) draws attention to two forms of children's talk: 'egocentric' and 'socialised' speech. In egocentric speech, the child talks only to itself; he or she does not try to communicate, expects no answers and does not care whether anyone listens. In socialised speech, however, the child does try to communicate with others in asking questions, conveying information, begging, commanding.

According to Vygotsky, the earliest speech of the child is social, supporting communication. The social function of speech is clearly apparent even during the first year; laughter, crying, inarticulate sounds are all means of social contact during the first months of the child's life. At a certain age, the social speech of the child divides into communicative (social) and egocentric speech. Now the child starts conversing with herself as she has been doing with others. Egocentric speech becomes an accompaniment to the child's various activities and gradually takes on a 'planning' or 'analytical' character as the child rehearses, to herself, possible solutions to a problem (Vygotsky, 1978, p.25). In this way egocentric speech becomes an instrument of thought in the sense of seeking and planning solutions to problems. As Vygotsky points out (ibid, 1978, p.26), 'Children solve practical tasks with the help of their speech, as well as their eyes and hands'. The final stage of language development occurs as the prevalence of egocentric speech subsides and is replaced by 'inner speech'. At the age when egocentric speech 'goes underground', children facing difficult situations resort now to egocentric speech, now to silent reflection; inner speech and egocentric speech are thus seen as being functionally equivalent.

In addition to these changes in the ways in which speech is used by children, a critical development occurs when the child recognises the *purpose* of words, that words have a *symbolic* function and that each object has its own name. At this point the child feels the need for words and through questions actively tries to learn the signs attached to objects. The child is no longer restricted to communicating about those objects which are within its immediate environment; through socialised speech, the child can talk to others about remote objects and through inner speech the child now has the means to represent objects and ideas to itself. The child now has the capability for conscious thought.

Vygotsky's scheme for speech development thus passes from social to egocentric to inner forms. Egocentric speech is interpreted as a transitional stage in the evolution from vocal to inner speech; egocentric speech shares the same functions as inner speech - it is speech on its way inward, intimately tied up with ordering the child's behaviour and providing the foundations for conscious thought. For Vygotsky, therefore, the development of thought is determined in large part by language. Essentially the development of inner speech depends on outside factors; the child's intellectual growth is contingent upon mastering the social means of thought, that is language.

In passing it is interesting to compare this scheme with that proposed by Piaget. For Piaget (1962), speech development passes from an initial autistic state, to egocentric speech and then to socialised speech. These changes in speech are accompanied by development in thought in which autism is seen as the earliest form, logic appears relatively late and egocentric thought is the genetic link between them. According to Piaget, egocentric speech simply atrophies as the child develops a desire to communicate with others; it does not provide the basis for inner speech and personal thought which is a central feature to the Vygotskian scheme. The development of thought according to Piaget, is a story of the gradual socialisation of personal autistic mental states. In simple terms, the Piagetian perspective offers a model for the development of thinking which is from the individual to the socialised, whilst Vygotsky sees the true direction as being from the social to the individual.

A final point to make before leaving this section (and a point which is of fundamental relevance to this study) is that semiotic mechanisms, whatever their form, do not in themselves 'carry meaning'. Lemke supports this view in stating:

> A word, or a diagram, or a gesture does not *have* meaning. A meaning has to be *made* for it...different people make different meanings for the same word, the same diagram, the same gesture. People from different communities...tend to have different ways of making meaning. We can only make sense of, and to, one another to the extent that we share the same ways of making meaning (Lemke 1990, p.186).

Similarly, Wertsch (1985a, p.159) argues that 'interlocutors may differ and change in their representations of the same set of objects and events'. He uses the notion of 'situation definition' to argue that, 'although the same concrete objects and events are perceptually available to both adult and child, they are not in the same situation because they do not define these objects and events in the same way'. This perspective is of importance in analysing the talk and activities of classrooms where one cannot assume that teacher and pupils 'see' and understand events in the same way.

2.2.3 Internalisation, transfer and transformation

In the previous sections, the process of learning concepts has been characterised in terms of the internalisation of social structures, a movement from social to psychological planes. A fundamental point to bear in mind here is that

internalisation does *not* involve direct *transfer* of concepts, through social interaction, to the individual. The point is made by Leontiev:

> The process of internalisation is not the transferral of an external activity to a pre-existing, internal 'plane of consciousness': It is the process in which this plane is formed (Leontiev, 1981, p.57).

The issue of importance here is that learners *reorganise* and *reconstruct* experiences of their physical and social environment. The mental plane is not isomorphic with the external plane of action and speech; as the external plane is internalised, transformations in structure and function occur. In this respect Vygotskian theory shares common ground with a Piagetian constructivist perspective in recognising that the child cannot be a passive recipient of knowledge and instruction. Tharp and Gallimore (1988, p.29) point out that the term 'guided reinvention' is used by some developmentalists to acknowledge the inventive role of the child in transforming what is internalised, and suggest that the term captures aspects both of social learning and cognitive reconstructivist arguments. Fischer and Bullock (1984) credit Vygotsky with having best anticipated the guided reinvention perspective which:

> acknowledges the social theorists' insistence that social guidance is ubiquitous. It also acknowledges, however, the Piagetian insight that to understand is to reconstruct. Thus guided reinvention elaborates the theme that normal cognitive development must be understood as a collaborative process involving the child and the environment (Fischer and Bullock, 1984, p.112-113).

2.3 Learning science concepts

In Chapter 1 it was agued that scientific knowledge consists of constructs advanced by the scientific community to interpret nature and that learning science involves being initiated into the ways of talking and knowing of the scientific community; scientific knowledge does not exist to be 'discovered' by the individual learner through personal observation of the natural environment. Learning science therefore involves enculturation through language to the concepts and modes of reasoning of the scientific community. Any individual who wishes to gain access to scientific knowledge can only do so through interaction with those who are familiar with that knowledge.

The point was also made earlier that scientific conceptual knowledge applies to natural phenomena which very often the learner already knows and talks about in 'everyday ways'. The distinction which Vygotsky (1987) makes between *spontaneous* and *scientific* concepts mirrors the relationship between everyday and scientific views.

2.3.1 Spontaneous and scientific concepts

Vygotsky (1987) draws attention to the distinction between spontaneous and scientific concepts in his discussion of the development of scientific concepts in childhood. It should be noted that according to Vygotsky's usage, the term 'scientific' relates to *any* formalised knowledge system of which the natural sciences would be just one example.

Vygotsky maintains that spontaneous concepts are developed through everyday experience and communication and are formed aside from any process aimed specifically at mastering them. Scientific concepts, on the other hand, are developed through instruction: 'the birth of the scientific concept begins not with with an immediate encounter with things but with a mediated relationship to the object' (Vygotsky 1987, p.219). Scientific concepts are located within a network of concepts, 'the very notion of scientific concept implies a certain position in relation to other concepts, ie a place within a system of concepts' (ibid, p.219). In developing scientific concepts, the child is put in the position of consciously regarding and manipulating the objects of instruction, this being in contrast to the spontaneous ways in which everyday concepts are developed.

Learning in the context of the natural sciences gives rise to the three-way relationship, referred to in Chapter 1 (Section 1.2), which exists between a specific phenomenon and spontaneous (everyday) and scientific ways of talking and knowing about that phenomenon. Spontaneous ways of knowing reflect how people talk about aspects of the natural world in day-to-day living. Scientific knowledge, on the other hand, is not often represented in everyday discourse, it is a form of public knowledge which is developed and validated by the scientific community.

An important feature of the three-way relationship between natural phenomena and 'ways of knowing' is that very often there are significant differences in the concepts used to describe particular phenomena from everyday and scientific viewpoints. In science education research a great deal of work has been dedicated to describing and cataloguing students' *alternative conceptions* of natural

phenomena (see, for example, Pfundt and Duit, 1985). These 'alternative conceptions' map onto Vygotsky's notion of 'spontaneous concepts'. Indeed, it might be argued that from a Vygotskian perspective the label 'alternative conception' is misplaced; that it is scientific conceptions which are 'alternative' to prevailing everyday modes of talking and knowing.

In the context of this thesis, Vygotsky's distinction between spontaneous and scientific concepts offers a potentially useful means both for analysing the talk of the interpsychological plane of the classroom and for sampling progress in individual learning on the intrapsychological plane.

2.3.2 Learning outcomes: the principle of heterogeneity

In his analysis of conceptual development Vygotsky stressed the complex interweaving of spontaneous and scientific concepts: 'the scientific concept grows downwards into the domain of the concrete, into the domain of personal experience'. The spontaneous concept follows a reverse course. Initially this type of understanding is very context dependent; over time however, 'it moves toward the higher characteristics of concepts, toward conscious awareness and volition' (Vygotsky, 1987, p. 220).

Vygotsky's descriptions of learning in terms of the 'interweaving' of spontaneous and scientific concepts raises important questions about the nature of individual mental states on completion of learning.

The most prominent metaphor currently being used in science education circles to describe learning is that of 'conceptual change' (Posner et al., 1982). The very notion of conceptual change is open to multiple interpretations but certainly one understanding of the process involves *replacement* of spontaneous views by scientific views. There is a problem with this characterisation of science learning in that learners do not necessarily abandon spontaneous ideas after science instruction; learners might retain *both* viewpoints drawing preferentially upon either one according to particular contexts of application. An alternative perspective on learning which allows for such a co-existence of spontaneous and scientific views has been suggested by Tulviste (1991) and is referred to as the 'Principle of Heterogeneity'. Tulviste maintains that overlapping social networks present a learner with a variety of different types of problems to solve, thus prompting individuals to develop a number of parallel frameworks for thinking. Development of thought can thus take several directions simultaneously.

There is a certain ambivalence in Vygotsky's views on this notion of the heterogeneity in outcomes to learning. In some cases he seems to suggest that heterogeneity does not exist since there is a powerful tendency for later forms of mental functioning to transform and incorporate earlier forms:

> The formal discipline of studying scientific concepts results in the transformation of the child's entire sphere of spontaneous concepts. The major significance of scientific concepts in the history of children's mental development consists of this (Vygotsky, 1982, pp. 280-287).

Elsewhere Vygotsky argues that even with the emergence of scientific concepts, humans continue to have access to everyday concepts and often employ the latter:

> Children who have mastered a higher form of thinking - scientific concepts, by no means leave more elementary forms behind. For a long time these elementary forms remain the quantitatively predominant and leading type of thinking in many areas of children's experience. Even in the case of adults...their thinking often is carried out on the level of complexes, sometimes dropping to still more elementary forms (Vygotsky 1982, p.176).

Of course, this apparent ambivalence may well suggest an intermediate position where either outcome to learning is considered possible: in some learning contexts initial structures are transformed whilst in others initial structures remain intact as alternative perspectives are developed. Such a dual-outcome model may fit quite well to learning in different contexts of the natural sciences. For example, it is likely that coming to understand a fundamental principle such as conservation of mass acts to transform the thinking of the individual. It is unlikely that the learner will consciously revert to being a non-conserver (being prepared to believe, for example, that salt actually does 'disappear' on dissolving). On the other hand, in learning about air pressure it is unlikely that air pressure explanations will replace everyday talk in terms of 'sucking'; here it is quite likely that the individual will move between using the two forms of explanation according to the perceived context of activity and application.

Having considered some fundamental aspects of Vygotsky's perspective on learning and how these relate to learning scientific conceptual knowledge, let us now turn our attention to Vygotsky's conceptualisation of teaching and the role of the teacher.

2.4 A Vygotskian perspective on teaching

The Vygotskian perspective on learning higher mental processes which has been reviewed in the previous sections is clear in emphasising the social origins of that learning. Given this viewpoint then it is evident that the teacher or some other knowledgeable figure has a key role to play in mediating and 'passing on' existing public knowledge to students. Bruner (1985) refers to this role for the teacher as follows:

> Vygotsky's project [is] to find the manner in which aspirant members of a culture learn from their tutors, the vicars of their culture, how to understand the world. That world is a symbolic world in the sense that it consists of conceptually organised, rule-bound belief systems about what exists, about how to get to goals, about what is to be valued. There is no way, none, in which a human being could master that world without the aid and assistance of others for, in fact, that world is others (Bruner, 1985, p.32).

Central to Vygotsky's perspective on teaching is his concept of the 'Zone of Proximal Development' (ZPD) and the notion of teaching as assisted performance.

2.4.1 The zone of proximal development

Assisted performance defines what a child can do with help. For Vygotsky, the contrast between assisted performance and unassisted performance identifies the fundamental nexus of development and learning that he called the Zone of Proximal Development. The ZPD is:

> the distance between the actual developmental 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 capable peers (Vygotsky 1978).

Vygotsky investigated the implications of the ZPD for the organisation of instruction and for the assessment of intelligence. With regard to the former he argued that instruction should be tied more closely to the level of potential development than to the level of actual development. With regard to the latter he suggested that measuring the level of potential development is just as important as measuring the actual development. Vygotsky (Vygotsky, 1978, p.85) used the

following example to illustrate the meaning of ZPD in relation to his ideas about assessment.

Suppose two children enter school, both aged ten years chronologically and both aged eight years in terms of mental development (as might be ascertained by some standardised test). In other words, each child is capable of *independently* dealing with tasks up to the degree of difficulty that has been standardised for the eight year old level. On this basis it might be assumed that the subsequent course of mental development and of school learning for these children will be the same, because it depends on their intellect.

Suppose that the children are shown various ways of dealing with the tasks used to establish their level of mental development. This might involve: running through an entire demonstration and asking the children to repeat it; initiating the task solution and asking the children to complete it; offering a series of 'leading questions'. In short, some way or other is devised so that the children solve the problem *with assistance*. Under these circumstances it turns out that the first child can deal with problems up to a twelve year-old's level, the second up to a nine year old's level. Are these two children mentally the same? The capability of children, with equal levels of mental development, to learn under a teacher's guidance varies to a high degree. In this particular example, it is clear that the two children are not mentally the same and the differences between eight and twelve years and eight and nine years are the respective ZPD's for each child in this particular area of learning.

Vygotsky (1978, p.86) maintained that the child's actual developmental level defines psychological functions that have already matured, these are the end products of development. The ZPD, on the other hand, defines those functions that have not yet matured but are in process of development. The actual developmental level characterises mental development retrospectively, whilst the zone of proximal development characterises mental development prospectively. Distinguishing the proximal zone from the developmental level has profound implications for educational practice. In Vygotskian terms, teaching is only good when it, 'arouses to life those functions which are in a stage of maturing, which lie in the zone of proximal development' (Wertsch and Stone, 1985).

One issue raised through Vygotsky's conceptualisation of the ZPD relates to the question of what *limits* performance in the proximal zone. At first reading it might appear that the notion of the ZPD allows the possibility of any learning

outcome for an individual given appropriate assistance. Vygotsky makes the point clear that this is not the case:

> We said that in collaboration the child can always do more than he can independently. We must add the stipulation that he cannot do infinitely more. What collaboration contributes to the child's performance is restricted to limits which are determined by the state of his development and his intellectual potential (Vygotsky, 1987, p.209).

In other words, and returning to Vygotsky's distinction between 'elementary' (biological) and 'higher' (socially mediated) mental processes (see Section 2.2.1), biological factors fix the range of cognitive potential of a learner's ZPD which then takes shape through the learner's use of socially located mediational tools.

The power of the zone of proximal development as a theoretical structure lies in the fact that it brings together the processes of 'individual learning' and 'instruction'. Moll emphasises this point in suggesting that:

> We should think of the zone of proximal development as a characteristic not solely of the child or of the teaching but of the child engaged in collaborative activity within specific social environments. The focus is on the social system within which we hope children learn, with the understanding that this social system is mutually and actively created by teacher and students (Moll, 1990, p.11).

Tharp and Gallimore (1988, p.33) have developed a model of the ZPD in which they specify the instructional role of the teacher and the corresponding progress in learning of the student at four separate but interlinked stages.

Four stages of the ZPD

Stage 1: where performance is assisted by more capable others.

Initially the child may have a very limited understanding of the task and the goal to be achieved through that task. The teacher offers directions or modelling and the child's response is acquiescent or imitative. When some conception of the overall performance has been acquired through language or other semiotic processes, the child can be assisted by other means: questions, feedback and further cognitive structuring. Posing guiding questions is a form of assistance of performance which has been described as *scaffolding* (Wood, Bruner, Ross, 1976). During Stage 1, a steadily declining plane of adult responsibility for task

performance and a reciprocal increase in the learner's proportion of responsibility is observed. This exchange of responsibilities has been referred to by Bruner (1983) as the 'handover principle'.

Stage 2: where performance is assisted by the self.

In Stage 2 the child carries out a task without assistance from others. This does not, however, mean that the peformance is fully developed or automatized. Control is passed from adult to child but the control function remains and is frequently expressed through overt verbalisation. In other words it is in Stage 2 that the child (or adult for that matter) can often be heard 'talking herself through the task', using ego-centric speech as a means of self-guidance. Very often the level of self-directed speech increases under task circumstances involving particular obstacles and difficulties.

Stage 3: where performance is developed, automatized and 'fossilized'

Once all evidence of self-regulation has vanished, the child has emerged from the ZPD into the developmental stage for that task. The task execution is now smooth, it has been internalised and automatized. In Stage 3, assistance from adult or self is no longer needed, indeed instruction might now be perceived as being disruptive and irritating and self consciousness is likely to be detrimental to performance. Performance is now 'fossilized' in the sense of being distant from the social and mental forces of change.

Stage 4: where de-automatization of performance leads to recursion back through the ZPD.

A most important consideration, and one which is frequently neglected, is that de-automatization and recursion occur so regularly that they constitute a fourth stage of the normal developmental process: what one formerly could do, one can no longer do. After de-automatization, if capability is to be restored then the develomental process must become recursive. This might be achieved in a number of different ways. For example, making inner-speech external is a form of recursion often effective in restoring competence whilst in some cases restitution of other-regulation may be necessary.

According to Tharp and Gallimore, the life-long learning of any individual is made up of these same regulated ZPD sequences. At any point in an individual's life, there will be a mix of other-regulation, self-regulation and automatized processes in different areas of that individual's learning.

Wertsch (1985a, p.162) has identified four levels in the transition from interpsychological to intrapsychological functioning which map onto the transitions in Tharp and Gallimore's model through Stages 1 and 2.

At *Level 1* the child's situation definition is so different from the adult's that communication is very difficult. *Level 2* is generally characterised by the fact that the child is beginning to participate successfully in the task setting, but the child's understanding of the task situation is still far from being in complete agreement with the adult's. At *Level 3*, the child can respond appropriately to other-regulation by making the inferences needed to interpret the adult's directives even when they are non-explicit and rely on an adult-like situation definition (the notion of 'situation definition' was introduced in Section 2.2.2). While the process is still carried out on the interpsychological plane, the fact that the child can make the appropriate inferences indicates that intrapsychological functioning is beginning to account for the child's performance. The adult no longer has to specify all the steps that must be followed in order to interpret a directive since the child can carry these out on the basis of a fairly complete situation definition. Indeed in some cases it seems that the child is functioning independently and that the adult is simply providing reassurances that what the child is doing is correct. At *Level 4*, the child takes complete responsibility for carrying out the goal directed task. Egocentric speech may appear during and shortly after the shift to intrapsychological functioning. At this point there is almost complete intersubjectivity between adult and child on the situation definition, a fact that makes further other-regulation unnecessary.

2.4.2 Scaffolding

Tharp and Gallimore refer to the process of 'scaffolding' by the teacher in outlining their first stage of the ZPD. The scaffolding metaphor was first introduced by Wood, Bruner and Ross (1976) in their analysis of the role of tutoring in problem solving. This seminal study refers to a task in which a tutor seeks to teach children aged 3,4 and 5 years to build a particular three-dimensional structure that requires a degree of skill which is initially beyond them. Wood et al describe the intervention of the tutor as involving:

> a kind of 'scaffolding' process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts. The scaffolding consists essentially of the adult 'controlling' those elements of the task that are initially beyond the learner's capacity, thus permitting him to concentrate upon and complete only those

> elements that are within his range of competence. The task thus proceeds to successful conclusion. We assume, however, that the process can potentially achieve much more for the learner than an assisted completion of the task. It may result, eventually, in development of task competence by the learner at a pace that would far outstrip his unassisted efforts (Wood, Bruner, Ross, 1976, p.90).

In this first specification of scaffolding there are no direct references to the work of Vygotsky, although it is clear that the approach is consistent with Vygotskian theory. Bruner (1985) later makes the link explicit when he refers back to the Wood et al paper, 'a study that I am only beginning to understand' and writes of the implications of 'acting as a support for the child's foray into the zone of proximal development' (Bruner, 1985, p.29).

A key feature for Vygotsky of learning in the ZPD is that it involves a process in which 'consciousness and control appear only at a late stage of development of a function' (Vygotsky, 1934, p.90). Bruner maintains that learning in the ZPD without conscious awareness is made possible by the actions of a tutor or peer who:

> serves the learner as a vicarious form of consciousness until such a time as the learner is able to master his own action through his own consciousness and control (Bruner, 1985, p.24).

When the learner achieves that conscious control over a new function or conceptual system, it is then that they are able to use it as a tool:

> Up to that point, the tutor in effect performs the critical function of 'scaffolding' the learning task to make it possible for the child to internalise external knowledge and convert it into a tool for conscious control (Bruner, 1985, p.25).

Six functions of tutors in the scaffolding process are outlined by Wood et al in their paper:

1. *Recruitment:* enlisting the problem solver's interest in, and adherence to, the requirements of the task.
2. *Reduction in degrees of freedom:* simplifying the task by reducing the number of constituent acts required to reach solution.
3. *Direction maintenance:* keeping the the learners in pursuit of a particular objective.

4. *Marking critical features:* marking or accentuating certain features of the task that are relevant.
5. *Frustration control:* acting to reduce levels of frustration for the learner.
6. *Demonstration:* demonstrating or modelling solutions to a task.

(Wood, Bruner, Ross, 1976)

The concept of scaffolding has been explored in various other areas of informal out-of-school learning, focussing on problems which, through their concrete and repetitive nature, are not dissimilar to the Wood, Bruner and Ross 'pyramid' task. These problems include, for example, weaving a piece of cloth, making a basket or putting away the shopping (Rogoff and Gardner, 1984). Griffin and Cole (1984, p.47) outline the kinds of activities which might be involved in scaffolding and suggest that: 'Sometimes the adult directs attention. At other times the adult holds important information in memory. At still other times the adult offers simple encouragement'. Wood (1986) suggests that scaffolding might involve the teacher in: 'Highlighting crucial features of the task situation; acting as an external source of memory and planning for the child; breaking down a learning goal into a series of less complex sub-goals'. Wood (1986) also offers two simple rules to guide the actions of the teacher in a scaffolding event. Firstly, any failure by a child to bring off an action after a given level of help should be met by an immediate increase in help or control. The second rule dictates that any subsequent instruction should offer less help than that which pre-dated success. In other words, after success the adult should give the child more space for success (and error).

Since the concept of scaffolding has been largely developed in the context of an adult working with an individual child, there are potential problems attached to applying the idea to classroom learning situations where a single teacher might be working with over 20 children. Askew et al (1995), for example, report on a study in which they explored 'what scaffolding might look like in primary classrooms in the contexts of mathematics, science and design and technology teaching' (Askew et al, 1995, p.209). They report that 'despite detailed observation and analysis of some 105 lessons, there was little evidence to support the hypothesis of teachers being intuitive scaffolders' (ibid. p.213). The authors suggest that this lack of teacher activity which might be described as scaffolding is due to fundamental differences between everyday and school settings (principally the adult-child number ratio) and between everyday and school knowledge (in terms of being procedurally-based as opposed to conceptual). They also draw attention to the importance of teachers' subject knowledge in the

scaffolding process: 'if teachers are to scaffold successfully, they must be secure in their own knowledge of the subject' (ibid. p. 215). Lack of detailed subject knowledge by the primary school teachers, in areas such as science and technology, provides a further explanation for the scarcity of scaffolding in the classrooms observed. Askew et al conclude by suggesting that although scaffolding may be useful as a descriptive, post hoc, metaphor for producing accounts of some teaching/learning situations, care must be taken not to over-extend it to the point where it becomes meaningless.

Of those studies which have drawn on the idea of scaffolding in describing teaching and learning in schools, most have tended to focus on teaching procedural knowledge. For example, Edwards and Mercer (1987) describe making a clay pot and setting up a pendulum, whilst Newman et al (1989) focus on learning an algorithm for long multiplication. Maybin et al (1992, p.187) consider that the metaphor of scaffolding is tremendously appealing in principle but at the same time elusive, or at least problematic, in practice. It is clear that there *are* problems attached to using the idea of scaffolding to describe teaching in classroom situations, particularly in the context of teaching and learning about conceptual knowledge which is of primary interest in this thesis. This is an issue which will be addressed in subsequent chapters.

2.5 Expanding the Vygotskian perspective

In this final part of the review of Vygotskian theory ways in which the basic Vygotskian position has been developed and built upon by other scholars are considered and discussed.

2.5.1 The social and cultural contexts of learning

One important critique of the Vygotskian perspective on development and learning is directed towards the lack of detailed analysis of the social and cultural contexts in which the interactions of the interpsychological plane are played out. Thus Wertsch argues that:

> Instead of recognising that interpsychological functioning itself is always situated with regard to cultural, historical and institutional setting, Vygotsky often treated it as if it always occurs in essentially the same form (Wertsch and Toma, 1991).

That is, Vygotsky tended to:

> equate social with interpsychological functioning which amounts to a reduction of the social phenomena one addresses when examining the social origins of individual mental functioning (Wertsch and Toma, 1991).

Wertsch suggests that Vygotsky was attempting to rectify this shortcoming in his later works as he increasingly emphasised that an account of the social origins of children's intrapsychological functioning must take into account consideration of the unique features of adult-child interactions as they occur in a particular institutional context. Wertsch (1991, p.46) further suggests that a richer description of the various kinds of socioculturally situated, interpsychological functioning is needed and has turned to the work of M.M. Bakhtin and Yuri Lotman for the additional tools needed to develop the Vygotskian account.

2.5.2 Bakhtin's perspective on speech communication and meaning making

Unlike many scholars of language, especially those linguists who concern themselves primarily with linguistic form abstracted from the actual conditions of use, Bakhtin (1986) focussed his analytic efforts on the *utterance*, 'the real unit of speech communication'. Thus Bakhtin maintains that:

> Speech can exist in reality only in the form of concrete utterances of individual speaking people, speech subjects. Speech is always cast in the form of an utterance belonging to a particular speaking subject, and outside this form it cannot exist (Bakhtin 1986, p.71).

This perspective is in contrast to those linguistic analyses which focus on words and sentences, which according to Bakhtin:

> ...belong to nobody and are addressed to nobody. Moreover they in themselves are devoid of any kind of relation to the other's utterance, the other's word (Bakhtin 1986, p.99).

In Bakhtin's account the notion of utterance is inherently linked with that of *voice*, or the 'speaking personality, the speaking consciousness'. Throughout his analysis Bakhtin stresses the idea that voices always exist in a social milieu; there is no such thing as a voice that exists in total isolation from other voices. From Bakhtin's treatment of meaning it is evident that he views it as an active process

rather than a static entity. He insists at many points that meaning can come into existence only when two or more voices come into contact; when the voice of a listener responds to the voice of a speaker.

There are several ways in which this view of speech communication manifests itself in Bakhtin's writings. For example, understanding or comprehending an utterance according to Bakhtin involves a process in which other utterances come into contact with and confront it. The point is made by Voloshinov, one of Bakhtin's contemporaries:

> For each word of the utterance that we are in the process of understanding, we, as it were, lay down a set of our own answering words. The greater their number and weight, the deeper and more substantial our understanding will be. Thus each of the distinguishable significative elements of an utterance and the entire utterance as a whole entity are translated in our minds into another active and responsive context....Understanding strives to match the speaker's word with a *counter word* . Any true understanding is dialogic in nature (Voloshinov 1973, p.102).

There are clear links here between Bakhtin and Vygotsky. The Vygotskian concept of internalisation, involving transformation of meaning through the agency of inner speech, is equivalent to the notion of matching the speaker's word with a counter word.

NB

Bakhtin also draws attention to the different modes of discourse which are used in different parts of society and refers to these as *social languages*. For Bakhtin a social language is, 'a discourse peculiar to a specific stratum of society (professional, age group etc) within a given system at a given time' (Holquist and Emerson, 1981, p.430). Thus a social language would include a dialect used in a particular geographical area, or a particular form of professional jargon, or indeed the way of talking about the natural world which is termed *science*. In Bakhtin's view, a speaker necessarily invokes a social language in producing an utterance, and this social language shapes what the speaker's individual voice can say. This process of producing unique utterances by speaking in social languages involves a specific kind of dialogicality or multivoicedness that Bakhtin termed *ventriloquation*, the process whereby one voice speaks through another voice or voice type in a social language:

> The word in language is half someone else's. It becomes one's own only when the speaker populates it with his own intention, his own accent, when he appropriates the word adapting it to his own semantic and expressive intention (Bakhtin, 1981, pp. 293-294).

Bakhtin suggests that users of language 'rent meaning' from words and sentences as they use them and draws attention to the existence of *speech genres* which he sees as being distinct from social languages. According to Bakhtin:

> A speech genre is not a form of language, but a typical form of utterance; as such the genre also includes a certain typical kind of expression that inheres in it. In the genre the word acquires a particular typical expression (Bakhtin 1986, p.87).

Speech genres include: everyday genres of greeting; genres of table conversation; everyday story telling; genres of classroom discourse. Whereas social languages might be identified through their characteristic content, the particular conceptual structures used in each language, a speech genre can be identified through the *form* of the utterances.

Wertsch (1991, pp.93-118) makes use of the Bakhtinian notion of speech genres in discussing the 'Principle of heterogeneity' (referred to earlier in Section 2.3.2 with reference to Tulviste, 1991). Wertsch suggests that mediational means be viewed not as some kind of single undifferentiated whole but rather in terms of the diverse items that make up a *tool kit.* He draws on the concepts of Bakhtinian (1986) 'speech genres' and Wittgensteinian (1972) 'language games' in elaborating the tool kit analogy and argues that:

> When the notion of heterogeneity is coupled with a Bakhtinian approach to meaning, I argue that speech genres are good candidates for the tools in the heterogeneous mediational tool kit.....children do not stop using perspectives grounded in everyday concepts and questions after they master these [scientific] forms of discourse. Different speech genres are suited to to different activity settings or spheres of life (Wertsch, 1991, p.118).

In these terms, the different social languages and speech genres which are rehearsed on the interpsychological plan of the classroom offer the means for developing a range of distinctive modes of personal thought: a whole kit of psychological tools.

Bakhtin's theoretical ideas which have been briefly outlined in this section offer a starting point for addressing the previously identified need for a richer description of interpsychological functioning. An analysis of the discourse of the interpsychological plane based on Bakhtinian ideas can draw on the concepts of utterance, voice, speech genre and social language. In focussing on the representation of different speech genres and social languages on the interpsychological plane one is inevitably reminded that mediational action is inextricably linked to various historical, cultural and institutional settings and that the social origins of interpsychological functioning extend beyond the interactions of the interpsychological plane. Bakhtin's perspective on meaning making draws attention to its dialogic character; that meaning making is a dynamic process which involves the coming together, or interanimation of, different voices. The Bakhtinian perspective also leads to focussing on the representation of different voices in the talk of the interpsychological plane and recognition of the multivoiced nature of specific utterances.

One further aspect of Bakhtinian theory to be considered concerns a distinction made by Bakhtin between the 'authoritative function' of speech on the one hand and the 'internally persuasive' function of speech on the other. Wertsch (1991) couples this approach with the distinction made by Yuri Lotman between the 'univocal' and dialogic' functions of texts.

2.5.3 The authoritative (univocal) and internally persuasive (dialogic) functions of speech

In analysing both spoken and written texts Yuri Lotman has developed an approach which is based on a functional duality. The two basic functions he sees texts fulfilling are 'to convey meanings adequately' and 'to generate new meanings' (Lotman, 1988, p.34). The first of these is very similar to the function assumed by a simple transmission model of communication:

> The first function is fulfilled best when the codes of the speaker and the listener most completely coincide and, consequently when the text has the maximum degree of univocality (Lotman, 1988 p.34).

In contrast, the second function of a text is grounded in the kind of multivoicedness associated with Bakhtin. Wertsch has termed it the 'dialogic' function to contrast it with the univocality Lotman associates with the first function:

> The second function of text is to generate new meanings. In this respect a text ceases to be a passive link in conveying some constant information between input (sender) and output (receiver). Whereas in the first case a difference between the message at the input and that at the output of an information circuit can occur only as a result of a defect in the communications channel....in the second case such a difference is the very essence of a text's function as a *thinking device* (Lotman, 1988, pp.36-37).

In Lotman's view, 'the main structural attribute of a text in this second function is its internal heterogeneity' (Lotman 1988, p.37). This heterogeneity is one of different perspectives or 'voices' giving rise to an event rich in the interanimation of voices:

> In its second function a text is not a passive receptacle or bearer of some content placed in it from without but a generator. The essence of the process of generation is..., to a considerable extent, an interaction between structures. A text of this type is always richer than any particular language and cannot be put together automatically from it. A text is a semiotic space in which languages interact, interfere and organise themselves hierarchically (Lotman, 1988, p.37).

A fundamental point in Lotman's account of functional dualism is that communication is best understood *not* in terms of *either* a univocal or dialogic model in isolation; instead, virtually every text is viewed as involving *both* univocal, transmission aspects and dialogic, thought generating aspects. These ideas about the functional dualism of texts are closely tied to Bakhtin's distinction between 'authoritative' and 'internally persuasive' discourse. In addition to the univocality and dialogicality associated with Lotman's two functions, Bakhtin characterised the difference in terms of the degree to which one voice has the *authority* to come into contact with and interanimate another. In Bakhtin's (1981) view authoritative discourse is based on the assumption that utterances and their meaning are fixed, not modifiable as they come into contact with new voices:

> The authoritative word demands that we acknowledge it, that we make it our own; it binds us, quite independent of any power it might have to persuade us internally; we encounter it with its authority fused to it (Bakhtin, 1981, pp.342-343).

Instead of functioning as a generator of meaning or as a thinking device, an authoritative text 'demands our unconditional allegiance' (ibid, pp.342-343). In contrast to authoritative discourse, 'the internally persuasive word is half-ours and half-someone else's'; it allows dialogic interanimation. Indeed:

> Its creativity and productiveness consist precisely in the fact that such a word awakens new and independent words, that it organises masses of our words from within, and does not remain in an isolated and static condition....the semantic structure of an internally persuasive discourse is open...this discourse is able to reveal ever new ways to mean (ibid, p.345-346).

The distinction between authoritative/univocal and internally persuasive/dialogic texts offers a further means for analysing the talk of the interpsychological plane of the classroom. Bakhtin's ideas introduced earlier provide a basis for analysis of discourse in terms of what is said; this analysis might be in terms of: particular utterances; representation of different voices; different social languages with associated content of scientific and everyday concepts; different speech genres. The authoritative/univocal-internally persuasive/dialogic distinction offers an alternative and complementary means for analysis of discourse in terms of its function or in terms of 'how' things are said. For example, the 'how' of a univocal text might be 'to get over the message' ; the 'how' of a dialogic text might be 'to get students thinking'.

2.6 Review of theoretical elements to be drawn upon in this study

In Chapter 1 the overall aim of this study was outlined in terms of drawing upon and developing Vygotskian theory to explore and analyse the ways in which teachers use and guide classroom talk, over an extended period of time, to support students in developing an understanding of scientific conceptual knowledge. Having reviewed some of the major aspects of Vygotskian theory, the question to be addressed now concerns *which* features of that talk are to be explored and*what* aspects of theory are to be drawn upon in the analysis.

The classroom talk which is of interest here has certain basic attributes: it is enacted in the social and institutional setting of secondary school science classrooms; it consists of the voices of both teacher and students; it is largely controlled by the teacher; it is directed towards meaning making on the interpsychological plane of the classroom; it is directed towards helping students

develop personal understandings of scientific concepts; it is enacted over an extended period of time.

There are clearly many different approaches which might be taken to examining and analysing this talk. The approach taken in this study is to develop an analytical scheme which draws upon, and is guided by, aspects of Vygotskian theory in attempting to capture some of the key features of the talk. In addition the analysis is framed in terms of the concept of a *teaching narrative.*

The notion of the 'teaching narrative' is developed in this thesis in order to capture the ways in which the teacher introduces a specific scientific way of knowing *over an extended period of time.* The teaching narrative can be thought of as an extended teaching 'performance' based on talk and through which new ideas are first introduced and then explored on the interpsychological plane of the classroom. The concept of the teaching narrative draws on the seminal work by Jerome Bruner on the narrative form.

In his influential book 'Acts of Meaning', Bruner makes a case for the central importance of the *narrative form* in enabling the sharing of meanings in the interactions within social communities:

> This method of negotiating and renegotiating meanings by the mediation of narrative interpretation is one of the crowning achievements of human development in the ontogenetic, cultural and phylogenetic senses of that expression (Bruner, 1990, p.67).

It is clear that Bruner's ideas about the narrative form link closely to the basic Vygotskian perspective on development and learning outlined earlier. The narrative constitutes one distinctive form of talk by which meanings can be made and shared between people on the interpsychological plane; put simply, it is a characteristic feature of everyday talk that people spend a lot of time in telling each other stories in order to share meaning over particular events. In Bakhtin's terms the narrative form can be taken as a key example of a speech genre.

Bruner suggests that the principle property of the narrative is its inherent sequentiality:

> A narrative is composed of a unique sequence of events, mental states, happenings involving human beings as characters or actors. These constituents do not have a meaning of their own. Their meaning is given

> by their place in the overall configuration of the sequence as a whole...its plot or fabula (Bruner, 1990, p.43).

Bruner thus makes the point that the narrative form enables people to make sense of particular events or phenomena and that the constituents of the narrative assume meaning through the telling of the narrative. Ogborn et al. make a similar point in the context of science teaching when they suggest that scientific explanations can be thought of as being analagous to stories and that the constituents or 'protagonists' of the stories must be 'talked into existence' (Ogborn et al., 1996, p.14) through the telling of the story to enable sense making by the student or listener.

In this study the teacher talk which extends through a sequence of science lessons is conceptualised as constituting an extended 'teaching narrative' through which the teacher both makes scientific ways of talking and thinking available to students and negotiates their meaning. The question was raised at the beginning of this section about which features of teacher talk are to be focussed upon in this study; this question can now be re-stated as follows: 'how is the teacher talk which constitutes the teaching narrative to be described and analysed?'.

In the following section four features of teacher talk are introduced; these features draw upon the Vygotskian theoretical principles discussed earlier and form the basic theoretical elements for the analysis of teacher talk to be carried out in this study.

2.6.1 Four features of teacher talk to be focussed on in the analysis presented in this study

i. The forms of pedagogical intervention

The first feature focusses on the different types of intervention used by the teacher to support students in developing an understanding of particular scientific concepts. These different forms of intervention will be referred to as the 'Forms of pedagogical intervention'.

Vygotskian theory draws attention to the primacy of the talk of the interpsychological plane in enabling students to develop an understanding of scientific concepts. This first feature relates to how that talk is structured and shaped by the teacher in meaning making and in supporting students in developing understandings. Possible directions for development of this analysis relate to how the talk is shaped by the teacher so that: new scientific concepts can

be introduced and rendered intelligible and plausible for students; scientific concepts can be related to students' spontaneous knowledge; particular conceptual themes can be sustained over the course of a number of lessons; the scientific concepts are made available to *all* of the students in the class.

ii. The authoritative-dialogic nature of the discourse

The second feature concerns the *nature* of the talk of the interpsychological plane and draws on the distinction made by Lotman and Bakhtin between univocal/authoritative and dialogic/internally persuasive texts.

This distinction based on differences in the nature of discourse offers a further potentially fruitful theoretical perspective for analysing classroom discourse. In the classroom, the relationship between teacher and students is clearly subject to an asymmetry in authority with regard to knowledge of subject matter. It is the teacher who is recognised as having responsibility for providing guidance in learning and it is to be expected that this is reflected in the way in which the teacher controls the discourse of the classroom. The authoritative-dialogic distinction offers the means for distinguishing between situations where the teacher approaches this task from an authoritative stance (transmitting knowledge) and where the teacher encourages dialogue (exploring and developing the meaning of knowledge). The authoritative-dialogic dimension offers a theoretical means for monitoring *how* teachers support learning through the discourse of the classroom.

iii. The content of the discourse

The third feature concerns the *content* of the discourse of the interpsychological plane. In both of the case studies presented in this thesis, the instruction has a strong scientific conceptual content and in both cases the instruction focusses on natural phenomena which are open to interpretation from everyday and scientific perspectives.

In situations such as this (where the previously referred to three-way relationship between phenomenon and ways of knowing exists), then it might be expected that both everyday and scientific perspectives will be represented in the discourse. The analysis of the content of the discourse is therefore based on Vygotsky's distinction between spontaneous and scientific concepts and relates to the on-going talk of both teacher and students on the interpsychological plane of the classroom.

iv. The pedagogical interventions in terms of scaffolding

The final element of the proposed analysis involves reviewing interventions made by the teachers in terms of the concept of scaffolding. The point was made earlier (Section 2.4.2) that the idea of scaffolding was first developed in the context of tuition within adult-child diads. Before attempting to analyse classroom teaching in terms of scaffolding, it is therefore necessary first to isolate the characteristic features of scaffolding so that these can be drawn upon in analysing the teacher's interventions in the classroom context. This task is addressed in the next section.

2.6.2 Characteristic features of scaffolding

In addressing the task of identifying characteristic features of scaffolding it is helpful to return to the theoretical basis of scaffolding which, as outlined earlier, is provided by Vygotsky's concept of the Zone of Proximal Development. In the following paragraphs four characteristic features of scaffolding are suggested which are consistent with the theoretical underpinnings of the ZPD and which are also consistent with the principles embodied in Wood et al's (1976) original conceptualisation of scaffolding. Thus for each characteristic feature a fundamental aspect of the ZPD is outlined and this is then applied to the notion of scaffolding. In this way the move is made from ZPD to scaffolding.

1. The concept of ZPD applies to learning some specific competence; the ZPD charts the difference between what the individual learner is capable of achieving with and without assistance, in relation to that particular competence.

- Scaffolding therefore involves interaction between teacher and learner which is focussed on the learner developing *some specific competence* which initially they are unable to achieve alone.

2. Learning in the ZPD involves the teacher in supporting the learner's progress between current and potential levels of performance.

- In interacting with the learner during scaffolding, the teacher is therefore aware of and responsive to existing modes of student thinking and any changes in student thinking, in supporting development of the target competence. That is, the teacher is aware of and responsive to any *differences* between student thinking and the target competence. Thus to scaffold learning, the teacher is able to:

i. monitor present performance of the learner (monitoring)

ii. analyse the nature of any differences between present performance and performance required by target competence (analysing)

iii. respond with an appropriate intervention to address differences in performance (assisting)

Wood et al (1976, p.97) refer to the teacher's need for two 'theoretical models' in scaffolding learning: a theory of the task or problem and how it may be completed and a theory of the performance characteristics of the learner. They argue that without both of these the tutor can neither generate feedback nor devise situations, 'which will be more appropriate for *this* tutee in *this* task at *this* point in task mastery' (ibid, p.97: original emphasis). The analysis set out here might help throw some light on what Wood et al mean by this. It seems that the 'theory of the task' involves the teacher's perception of what the task is about and what constitutes successful completion of the task. The 'theory of the performance characteristics of the learner' involves the changing relationship, referred to above, between the learner's current level of performance and that required by the target competence.

3. In the initial stages of learning in the ZPD, it is likely that the child will have only a limited conscious awareness and understanding of the situation, the task, the target competence to be achieved.

- In scaffolding learning the teacher therefore acts as a 'vicarious form of consciousness' in offering guidance through the learning event and helping the learner to reflect upon, and become consciously aware of learning targets and the progress made towards those targets.

4. As learning progresses in the ZPD there is a steadily declining plane of adult responsibility for task performance and a reciprocal increase in the learner's proportion of responsibility.

- Scaffolding therefore involves a progressive withdrawal of assistance, a gradual 'handover' (Bruner 1983) of responsibility from teacher to learner.

The four characteristic features of scaffolding developed here are offered as general points of principle which follow from consideration of theoretical features of the ZPD. They provide no insight to the range of practical activities which might be drawn upon by teachers in operationalising them. With this point in mind it is instructive to return to Wood et al and their six 'functions of tutors' in the scaffolding process and to consider how those functions map onto the characteristic features identified here. The six functions, outlined earlier in Section 2.4.2, are: recruitment; reduction in degrees of freedom; direction maintenance; marking critical features; frustration control; demonstration.

Of these functions, *recruitment, reduction in degrees of freedom* and *demonstration* all appear to relate to 'assisting' which is part of Feature 2. *Direction maintenance* and *marking critical features* might be taken as part of Feature 2, but they also relate to the role of the teacher in providing guidance through the learning event which is Feature 3. *Frustration control* concerns the need to keep the child motivated (Wood et al refer to 'deployment of zest and sympathy' by the tutor) and relates to *how* the teacher responds to the learner (Feature 2). This function of the tutor is directed towards the affective response of the learner. Although there is no guidance in Vygotsky's formulation of the ZPD about how the teacher should work with the learner, it seems reasonable to suppose that the teacher should be empathetic and supportive in assisting learning. It is interesting that the fourth characteristic feature 'Handover' is not included among the six functions of the tutor in scaffolding. This is surprising, it might be argued that handover of responsibility for performance from teacher to learner is a crucial aspect of the scaffolding process.

2.7 Summary

In the main body of this chapter a review of aspects of Vygotskian and neo-Vygotskian theory has been presented. Drawing on various theoretical perspectives raised in this review, four features of teacher talk (pedagogical interventions; authoritative-dialogic nature; content; interventions in terms of scaffolding) have been identified which will be focussed on in the analyses of teacher talk presented in this study. These analyses of teacher talk are to be framed and developed with reference to the overarching concept of the 'teaching narrative'.

Before considering in detail the design and methodology of this study (which is addressed in Chapter 4) attention is now directed towards a review of other research studies in the field of language, teaching and learning in science.

Chapter 3: A review of studies into the ways in which language mediates science teaching and learning in classroom settings

3.1 Introduction

In the last ten years or so there has been a developing interest by researchers in the role of language in mediating science teaching and learning. This trend has been particularly prominent in science and mathematics education circles in North America and has been prompted in no small part by the rediscovery of Vygotsky and his sociocultural perspective on teaching and learning. In this chapter a brief review of these language-oriented studies on teaching and learning science is presented with the principle aim of locating this thesis within the developing field. First of all, by way of setting the scene, some general issues relating to possible approaches to the analysis of classroom discourse are considered.

3.2 Approaches to the analysis of classroom discourse

Two general approaches can be identified in the more commonly used methods for analysing classroom discourse. The first involves use of 'coding schemes' and the second is based on the 'interpretative analysis of transcribed speech' (Edwards and Westgate, 1987).

Use of coding schemes belongs to the style of research commonly referred to as 'systematic classroom observation' in which observations are made against some pre-determined system of categories and the outcomes of the analysis are reported in terms of the frequency of representation of the different categories of talk. One example of a coding scheme developed for systematic classroom observation in the field of science education is the Science Teaching Observation Schedule, STOS, (Eggleston et al, 1976). This schedule was developed and used to investigate the 'intellectual transactions' generated in Nuffield science teaching and from the frequency of scores recorded in each category three types of teaching style were identified: 'fact acquirers', 'problem solvers' and 'pupil-centred enquirers'.

Various critiques have been made of systematic classroom observation (see, for example, Wegerif and Mercer, in press). As far as this thesis is concerned the technique of systematic observation would enable the researcher to focus on

teacher talk and to represent that talk against a system of categories. What this form of analysis does not offer is the facility to chart the way in which meanings are developed over a period of time through interactions between teacher and students. The central focus of this study is on how each teacher guides the classroom talk in supporting development of students' conceptual understandings in specific concept areas of science. This is rather different from a study which, for example, is investigating different forms of teacher questioning irrespective of content. It would be possible to use a coding scheme to investigate forms of teacher questioning but such a scheme, where isolated judgements are made about specific categories of talk, does not lend itself to monitoring the interactions which underpin development of conceptual understandings over a period of time. The methodological focus taken for this study and for this review is therefore based on interpretative approaches to discourse analysis.

The 'interpretative' label has been used to cover a wide range of classroom studies. According to Edwards and Westgate, this range:

> extends from the loosest to the most rigorous kinds of ethnography, and from discursive commentaries on how teachers control the transmission of knowledge to detailed structural analyses of how turn-taking is organised (Edwards and Westgate, 1987, p.99).

In general terms interpretative approaches to investigating classroom communication involve: observing and making field notes of lessons; recording as much of the interaction as is practicable; transcribing the recordings; closely examining the transcripts to identify any patterning in the discourse; selecting sections of transcript to support final claims. The transcript materials serve to illustrate and to exemplify the claims being made and also provide the reader with some 'feel' for the interactions being described. Douglas Barnes' research (Barnes, 1976; Barnes and Todd 1977, 1995) into the ways in which children develop understandings in the context of small group discussion has been particularly influential in this field of interpretative research.

In the following review all of the studies which are reported can be taken to belong to the 'interpretative analysis' category. The review is set out in two main sections. In the first section research studies which focus principally on the role of language in *whole class* teaching and learning situations are considered; the second section focusses on studies of language use in *small group* contexts. The review is organised in this way simply because there tend to be significant

differences in the patterns of talk and associated research questions for these two contexts.

3.3 Role of language: whole class teaching and learning situations

The research studies reported in this area can be considered in two broad sub-groups. The first group comprises those studies which focus on the use of language in classrooms where the teacher takes the lead in guiding instruction in specific topic areas. These studies might be described as focussing on forms of 'traditional' whole-class teaching. The focus for the second group of studies is on the use of language in classrooms where students are encouraged to take part in the 'authentic practices' (Brown, Collins, Duguid, 1989) of the discipline which is being taught and learning is considered to occur through immersion in the language and activities of those practices. The rationale for this second approach, which has been developed principally in North America, is sometimes presented by making comparisons with the process of language acquisition by young children. Thus just as children are 'apprenticed' to the linguistic practices of their home communities and develop their first language with little apparent conscious effort, so too learners might be apprenticed to 'communities of practice' or 'discourse communities' such that they 'pick up' by immersion the conventions, rules and ways of talking of those communities.

James Gee (1996) suggests that the ideologies underlying these two approaches to instruction constitute a 'debate between progressive and post-progressive pedagogies: a distinction that sometimes turns on arguments about the role and efficacy of explicit instruction in contrast to implicit learning through immersion in rich education environments'. For the purposes of this review the intention is not to analyse the strengths and weaknesses of particular instructional approaches. The distinction between instructional approaches is drawn upon in structuring the review simply because each gives rise to different roles and patterns in the use of language in mediating science teaching and learning; the patterns of language use by teacher and students are different in the contexts of 'explicit instruction' and 'immersion' classrooms.

3.3.1 Studies focussing on the role of language in the context of explicit classroom instruction

In this section attention is focussed principally upon studies by Edwards and Mercer (1987), Lemke (1990) and Ogborn, Kress, Martins and McGillicuddy (1996).

A frequently cited and important study in this area of research is the work of Edwards and Mercer (1987) which is presented in the book 'Common Knowledge'. This research focusses on 8-10 year old pupils and is concerned with, 'the ways in which knowledge is presented, received, shared, controlled, negotiated, understood and misunderstood by teachers and children in the classroom' (Edwards and Mercer, p.1). It is concerned with the ways in which knowledge becomes part of a common or joint understanding between teacher and children in the classroom.

The authors state that the major issue dealt with in the research is, 'the relationship between principles and procedures - between the conceptual understandings at stake in the lessons, and the practical activities and discourse which constituted the lessons themselves' (ibid, p.98). They summarise the overall strategy which they take as being one of, 'identifying the main conceptual principles that the lesson was designed to teach and examining how these were handled during the lesson in terms of what was actually done and said' (ibid, p.99). This approach is realised through detailed analyses of teaching and learning episodes taken from lessons in computer programming, science, handicraft, social studies and mathematics. The analysis draws on the Vygotskian notions of 'ZPD', 'scaffolding' and 'handover' and the authors acknowledge links to the interpretative approach to discourse analysis developed by Barnes (1976).

From their analyses Edwards and Mercer identify the extent to which the teacher controls the teaching and learning events of the classroom maintaining 'a tight definition of what became joint versions of events, and joint understandings of curriculum content' (ibid, p.129) and develop an inventory of the ways in which the teachers involved in the project were able to do this. These features of classroom discourse, cast in terms of the teacher's role in them, include: 'elicitation of pupils' contributions' (where pupils' contributions are directly constrained by teachers' questions); use of 'significance markers' (where expressed knowledge is given special prominence by discursive practices such as special enunciation); offering 'reconstructive recaps' (through paraphrasing what pupils said and through reconstructing what occured in the lesson when recapping later).

Edwards and Mercer conclude that the teaching and learning that they examined was, 'all about the induction of children into the academic world of knowledge and discourse inhabited by the teacher' (ibid, p.155). They suggest that this, 'is necessarily a social and communicative process, and one which has as an inherent

part of it an asymmetry of roles between teacher and learner' (ibid, p.157). In a more recent book, 'The Guided Construction of Knowledge', Mercer (1995) further develops this position, emphasising the central role played by the teacher in making knowledge available to students through discourse. Through this work Edwards and Mercer have given an important lead in demonstrating how careful analysis of classroom talk can lead to insights into the ways in which knowledge is constructed on the social plane of the classroom and is thereby made available to support the development of cognition in individual students.

Jay Lemke's book 'Talking Science: Language, Learning and Values' (1990) has proven to be widely influential in the area of language and learning in science. The basic thesis which Lemke proposes in his book is that learning science means learning to talk science: 'it means learning to communicate in the language of science and act as a member of the community of people who do so' (Lemke, 1990, p.1). The ideas developed in 'Talking Science' are exemplified through data collected in high school classrooms and the basic question which is addressed concerns how students learn to talk science through classroom discourse.

The analysis of classroom discourse is made in terms of two components: an 'activity structure' which demonstrates the organisational patterns of social interaction in the discourse. Lemke refers to one such pattern as 'Triadic dialogue' involving the three steps of teacher question, student response, teacher evaluation (this is the same discourse pattern as the 'initiation-response-feedback' exchange structure identified by Sinclair and Coulthard, 1975). The second component is the 'thematic pattern' of semantic relationships which constitutes the scientific content of the discourse. Lemke describes a thematic pattern as being 'like a network of relationships among the scientific concepts in a field, but described semantically, in terms of how language is used in that field' (ibid, p.12).

Lemke suggests that a large part of the job of science education is to provide students with new ways of talking about scientific topics and that the most essential element in learning to talk science is mastery of the thematic patterns of each science topic. In his analysis of classroom discourse Lemke addresses the question of how teachers communicate thematic patterns and identifies (ibid, p.100) a number of strategies commonly used by teachers to achieve this. These strategies include: 'selecting student answers' (from ongoing classroom discourse); 'modifying student answers' (possibly through extracting part of a student response to link into the thematic pattern which the teacher is trying to develop); 'retroactive recontextualisation of student answers' (...'after an answer

has already been given, which had one meaning in the context of the dialogue that preceded it, the teacher says something to alter the context and make it seem, retroactively, that the answer had quite a different, or additional, meaning', ibid, p.103). There is some overlap between the list of teacher strategies proposed here by Lemke and those identified by Edwards and Mercer; for example, 'retroactive recontextualisation' appears to offer the same pedagogical function as 'reconstructive recaps'.

In his analysis Lemke adopts an anti-mentalist position by arguing (ibid, p.122) that unless we prefer to believe that concepts or meanings have an existence independent of their being made and remade by the social use of language, pictures and other systems of signs, we may as well cut out the 'middleman' of mental concepts and simply analyse conceptual systems in terms of the thematic patterns of language use and other forms of meaningful human action. He emphasises the point that a scientific theory is a thematic pattern of semantic relationships in a subject, one that is reconstructed again and again in nearly the same ways by the members of a community. Consistent with this point of view Lemke suggests that scientific reasoning is learnt, 'by talking to other members of the community, we practice it by talking to others, and we use it in talking to them, in talking to ourselves, and in writing and other forms of more complex activity' (ibid, p.122).

Ogborn, Kress, Martins and McGillicuddy, in a recently published book 'Explaining science in the classroom' (1996), address the issue of how teachers can make scientific knowledge available to students on the social plane of the classroom. The authors present findings from a research project which focusses upon the ways in which high school science teachers construct and present *explanations* in the classroom. The authors offer as the main outcome of the research 'a way of thinking about what explanations are' and present a theoretical framework which has three main components (Ogborn et al., 1996, p.8):

1. Scientific explanations as analagous to 'stories'
2. An account of meaning-making in explanation consisting of four main parts:
    - creating differences
    - constructing entities
    - transforming knowledge
    - putting meaning into matter
3. Variation and styles of teacher explanation.

The idea of scientific explanations being analagous to stories has already been referred to in the previous chapter (Section 2.6) and is one that has been gaining recent support in science education circles (see, for example: Arnold and Millar, 1996; Stinner, 1995; Sutton, 1996). Ogborn et al consider that the vital features of a scientific story are that: firstly there is a cast of protagonists, each of which has its own capabilities which are what makes it what it is (protagonists might include entities such as electric currents, germs, magnetic fields and also mathematical constructions such as harmonic motion and negative feedback); secondly the members of this cast enact one of the many series of events of which they are capable; lastly these events have a consequence which follows from the nature of the protagonists and the events they happen to enact. This notion of scientific explanations as stories based on certain protagonists maps onto to Lemke's perspective of thematic patterns which are developed from networks of relationships among scientific concepts.

Ogborn et al make the point that these worlds of protagonists, which constitute scientific explanations, are often far from everyday common sense and that scientific explanations can make no sense to the learner until they know what the entities involved are supposed to be able to do or have done to them. Thus there is the need for students to 'construct explanatory entities' or as Ogborn et al put it there is the need to 'talk into existence' (Ogborn et al., 1996, p.14) these entities. The process of talking into existence explanatory entities involves transformation of meaning by students. Thus, 'every discussion gives an entity new possibilities and transforms its meaning. The pupil's knowledge is constantly being transformed' (ibid., p.15). The authors cite the narrative form as being one way to transform knowledge and also point to the crucial role of analogy and metaphor in transforming knowledge in the classroom.

The theoretical rationale which underlies this work draws upon current perspectives on realist theories of science (Bhaskar, 1978; Harre, 1985) and work on language and learning in science (Edwards and Mercer, 1987; Lemke, 1990; Sutton, 1992; Halliday and Martin, 1993). In the book each of the three parts of the proposed theoretical framework is exemplified through transcripts of teaching and learning episodes collected in four secondary schools.

All three studies reviewed here, Edwards and Mercer, Lemke and Ogborn et al., share a common approach in focussing attention on the teacher's actions in the classroom and combining detailed observation of talk (and other semiotic mechanisms) in science classrooms with a close attention to the subject matter

being taught. Ogborn et al propose (p.141) that this dual focus on teacher and subject matter constitutes a new perspective in science education research, moving away from the prevailing programmes of work on students' personal understandings. Such a shift in perspective is one which has also been recently promoted and supported by Sutton (1992, 1996) and Solomon (1994) and we shall return to consider these perspectives in the final discussion of Chapter 7.

Recent research studies in this area of explicit classroom instruction includes work by: Mortimer (1995), who investigates, from a social negotiation perspective, how ideas about the particle model of matter develop in a Brazilian classroom (14-15 years); Boulter and Gilbert (1996), who examine the talk of a primary (9-11 years) classroom and propose a framework for analysing teacher and pupil participation in modelling; Watt (1996) who analyses teacher questioning behaviour in constructivist primary science classrooms using a modification of a descriptive system designed by Barnes and Todd (1977).

3.3.2 Studies focussing on language use in the context of implicit classroom instruction through immersion in particular learning environments

In recent years there has been an explosion of research interest in North America in teaching and learning science and mathematics through immersion of students in authentic discourse communities. Put simply, this instructional approach involves students in 'doing' science and mathematics themselves, identifying problems, framing questions and working with their teacher (as consultant) to talk through and to develop arguments leading to possible solutions. Such approaches have been encouraged in schools through current North American curriculum reform recommendations (AAAS, 1989; National Research Council, 1996).

Interestingly, a key influence in this field of research studies has been the previously reviewed work of Jay Lemke and his book 'Talking Science: Language, Learning and Values' (1990). 'Talking Science' provides an analysis of discourse from 'traditional' North American classrooms. Through analysing that empirical data Lemke points to various shortcomings in prevailing approaches to teaching and learning and offers alternative pedagogical strategies. As cited earlier, Lemke suggests that scientific reasoning is learnt 'by talking to other members of the community, we practice it by talking to others, and we use it in talking to them, in talking to ourselves, and in writing and other forms of more complex activity' (ibid, p.122). This general perspective on learning science has been heavily drawn upon in framing and developing instructional practice and

research on teaching and learning through immersion in discourse communities. This research field has also been influenced by Vygotsky's sociocultural perspective, it draws on the principles of situated cognition (see: Brown, Collins and Duguid, 1989; Lave and Wenger, 1991; Rogoff, 1990) and has had considerable impact in both science education (see, for example: Eichinger, Anderson, Palincsar and David, 1991; W-M Roth, 1996; Moje, 1995; Roychoudhury and Roth, 1996) and mathematics education (see, for example: Lampert, 1990; Cobb, Wood and Yackel, 1991).

In all of the studies which are cited here students are directly involved in 'doing' science or 'doing' mathematics. Roychoudhury and Roth (1996), for example, investigate interactions in an 'open-inquiry' physics laboratory involving junior high school students. They describe the 'open-inquiry' laboratory as being one in which, 'the activities are open-ended...there is no recipe-type, step-by-step procedure available for conducting the experiments' (ibid, p.425); the students 'have decision-making power over what to investigate and how to investigate within the constraints of available resources' (ibid, p.426). The purpose of the research study considered here was to find out about the nature of student-student interactions, the nature of the peer group-teacher interactions and the students' views of collaborative work in the context of the open-ended laboratory activities. In their analysis Roychoudhury and Roth develop a categorical scheme for characterising the verbal interactions among students which is based on the degree of participation by the members of the group. Three types of interactions emerge from the data: 'symmetric', 'asymmetric' and 'shifting asymmetric'. These types are not offered as categories in which individual groups can be classified, but as a heuristic for understanding an interaction in a specific context. The teacher in the study is described as acting either as a 'Socratic interlocutor who helped students with guiding questions to construct their own meaning or as a 'coach' who provided scaffolding through explicit explanation in areas that were unfamiliar to the students' (ibid, p.442).

The educational rationales underlying 'inquiry-based' and 'explicit instruction' approaches are fundamentally different and this difference leads to different patterns of classroom discourse. In this respect the observations and descriptions of language-use offered by, for example, Roychoudhury and Roth (1996), where the students work in groups and the teacher acts as coach, are significantly different to those presented by Ogborn et al (1996) where the focus is on teachers working to develop explanations with whole classes of students. The two patterns of language-use exemplify and follow from different approaches to teaching.

3.4 Role of language: small group teaching and learning situations

The distinction which has been made in structuring this review between studies focussing on teaching and learning in whole class situations and those focussing on small group situations does not always hold firm in that 'whole class' studies might often include sections dealing with aspects of group-work and vice-versa (the study by Roychoudhury and Roth (1996) is a case in point). Nevertheless, it is certainly possible to identify a large number of science education studies which are concerned with how the talk of student-student and student-teacher interactions can lead to the development of scientific understandings in exclusively small group situations.

A seminal influence in this area of research into meaning making and the development of understandings in small-group settings is the work of Barnes and Todd, particularly through their book 'Communication and Learning in Small Groups' (1977). In this book Barnes and Todd report on an empirical study of school students (aged 13 years) working in small groups on tasks given to them by their teachers. The aim of the research was to examine the relationship between small-scale aspects of the social interactions of small groups and the cognitive strategies generated in the course of this interaction. In other words, to investigate the interplay between cognitive and communicative functions of speech in contexts planned for learning.

Through this work Barnes and Todd developed a system for describing the interactions between peers in the small groups. This categorical system distinguishes between social and cognitive functions. The social functions identified include, for example, moves made by students to: deal with competition and conflict in groups; offer praise; encourage participation. The cognitive strategies identified include moves made by students to: raise new questions; set up hypotheses; draw on and use evidence. Barnes and Todd have recently published a sequel 'Communication and Learning Revisited' (1995) to their original work. In this book they review the theoretical basis of the original study which was heavily influenced by Piagetian stage theory and retrospectively acknowledge the importance of social context in influencing the course of individual learning and development drawing on the ideas of Vygotsky and Bakhtin.

There is considerable current research activity and interest in the role of discourse in small group teaching and learning situations in science. Recent studies have, for example, focussed on: social processes in small group discourse and scientific knowledge building (Richmond and Striley, 1996); the social interactions and mediation of science learning in small groups of elementary school children (Shepardson, 1996); the analysis of discourse in small groups of students working with computer representations (Kelly and Crawford, 1996; Amigues, 1996); the use of concept maps as conscription devices and tools for social thinking in high school science (W-M Roth and Roychoudhury, 1992).

Shepardson (1996), for example, investigates the effect of teacher-child social interactions on the mediation of children's science learning during small group activity. The analysis which Shepardson presents draws on neo-Vygotskian theory through Wertsch (1991) and is focussed on two assertions developed through an inductive analysis methodology. These assertions are that: first the teacher mediated children's science learning in small group settings through the negotiation of status, actions, and meaning with individual children versus interactions that promote collaboration among children; secondly that the children's small group social interactions did not result in a negotiation of meaning, but instead resulted in a negotiation of actions and the sharing of materials that mediated their science learning. This analytical approach therefore shares the same kind of distinction between cognitive and social functions of interactions as that made by Barnes and Todd (1977) and, indeed, this approach is shared by many of the studies of teaching and learning in small group situations.

3.5 Locating this thesis within current research into the ways in which language mediates teaching and learning science in classroom settings

In the previous sections a brief review of current research into the ways in which language mediates science teaching and learning in classroom situations has been presented along with references to some of the major pieces of work in this area of study. The review has focussed purely on studies based on an interpretative approach to analysis of classroom talk. The ways in which the present study relates to these other studies in this developing field of research are now considered. This task is addressed by taking certain key features of the thesis and considering how each is approached in some of the previously cited research studies, thereby providing the opportunity to identify points of similarity and difference.

The first feature is that this thesis is explicitly grounded in what has been referred to as a Vygotskian and neo-Vygotskian theoretical perspective (as reviewed in Chapter 2) on teaching, learning and development. In many of the studies reviewed above the influence of Vygotskian theory is explicitly acknowledged (as in, for example: Edwards and Mercer, 1987; Barnes and Todd, 1995; Mortimer, 1995; Shepardson 1996). In other studies (such as: Ogborn et al, 1996; Lemke, 1990) no direct reference is made to Vygotsky. The aims of the present study are explicitly based on taking aspects of the Vygotskian theoretical perspective (aspects such as the General Law of Development, the notion of the ZPD, scaffolding, the distinction between authoritative and dialogic discourse) and applying these theoretical tools to classroom teaching and learning situations. This approach of systematically drawing upon aspects of Vygotskian theory to develop theoretical tools for analysing classroom teaching is a key distinguishing feature of the present study.

The main focus of this thesis is on teachers and teaching, on the ways in which teachers make scientific ways of talking and knowing available to their students in whole class settings (which is not to say that the teaching sequences in the two case studies do not involve some small group work). Thus whilst a number of the studies reviewed here focus on student-student interactions in small group settings (for example: Barnes and Todd, 1977, 1995; Kelly and Crawford, 1996), here the emphasis is on teacher-student interactions in whole class situations. Edwards and Mercer (1987) and Lemke (1990) have pointed to some of the strategies which teachers use to develop scientific knowledge on the social plane of the classroom. In the present study such strategies or teaching interventions will be reviewed and systematically developed within a theoretical framework based on Vygotskian principles.

The instructional context of the present study involves mainly whole class contexts where teaching is enacted in an 'explicit' manner rather than involving 'immersion in particular practices'. In this respect the present study shares a common focus and contextual setting with Edwards and Mercer (1987) and Ogborn et al (1996) but not with, for example, Roychoudhury and Roth (1996).

A further key feature of this study is that the analysis is based on investigating the development of meaning on the social plane of the classroom over an *extended* period of time. The two case studies which provide the empirical basis for this study involve lesson sequences which last for up to 3 or 4 hours. The key issue to be addressed is how the teacher develops the talk of the *teaching narrative*, over a

period of time, to support students in developing understandings of scientific concepts. This explicit acknowledgement of the time-line associated with teaching and learning means that the analysis of the classroom talk will include features which follow from that extended time frame. In this respect the present study shares some common ground with the work of Edwards and Mercer (1987). where the notion of 'continuity' in the development of understanding in the classroom is an important aspect of their analysis. This focus on the development of meanings over time is less prominent in other studies. Lemke (1990) and Ogborn et al (1996), for example, report and exemplify their findings through reference to discrete classroom episodes.

Finally, this thesis is concerned with the development of *scientific conceptual knowledge* on the social plane of the classroom. In the studies of 'inquiry-based' classrooms the scientific content of the discourse is often down-played with the main focus being on processes such as how students are able to generate their own questions and then proceed to explore possible solutions. In other studies there is a focus on developing scientific *procedural* knowledge; Edwards and Mercer (1987), for example, focus on pupils manipulating variables in carrying out experiments with a simple pedulum. In this study, in common with Lemke, 1990, (through the 'thematic patterns') and Ogborn et al., 1996, (through the 'scientific stories'),there is a strong focus on how scientific conceptual knowledge is developed and made available to students in the classroom.

In summary the present study might be characterised, through comparison with contemporary studies in language and learning in science, in the following way. This study is:

- grounded in Vygotskian and neo-Vygotskian theory.
- focussed on teachers and teaching interactions.
- contextualised in mainly whole-class teaching situations with an emphasis on explicit instruction.
- focussed on the ways in which teachers support development of meanings and understandings over time, through the teaching narrative.
- focussed on teaching scientific conceptual knowledge.

Chapter 4: Aims, design and methodology

In Chapter 4 three main issues are addressed: firstly the aims of the study are discussed and research questions set out; issues relating to the structure and design of the study are then considered; finally the research methodology is presented and discussed.

4.1 Aims and research questions

As outlined in Chapter 1, this study is focussing on the interactions of the interpsychological plane of the classroom and in particular on the ways in which the teacher guides the talk of the social plane to support students in developing an understanding of scientific conceptual knowledge. The study has three principle aims.

The first aim involves explicating from a perspective informed by Vygotskian socio-cultural theory and framed in terms of the concept of the teaching narrative, how the two teachers in the case study lessons guide the classroom talk, over an extended period of time, to support students in developing an understanding of scientific conceptual knowledge. The second aim involves developing and exemplifying the theoretical features of discourse focussed upon in analysing the classroom talk with a view to formulating *analytical tools* which might be applied to other cases of teaching and learning science. The third aim involves reflecting on the two specific cases of teaching and learning science with a view to considering what *general statements* might be made about teaching and learning scientific conceptual knowledge when viewed from a Vygotskian perspective.

In addressing these aims the study entails both theoretical and empirical components. In Chapter 2 Vygotskian theory was used as a basis for identifying four key features of discourse which are to be taken as a starting point for analysing the teacher talk in this study. The intention is that the first aim, of exploring the ways in which each of the two teachers develops the teaching narrative to support learning, is addressed by drawing on those four features in analysing the classroom discourse. Through the process of analysing the classroom discourse, the key features are reviewed and elaborated to develop the analytical tools referred to in the second aim.

In this way it can be seen that the theoretical and empirical components of the study are closely linked: theory is drawn upon in analysing the classroom talk and through that process the theoretical features of discourse employed are refined and elaborated in developing more generally applicable analytical tools. Development of insights to the ways in which the two case study teachers use talk to support learning (Aim 1) goes hand-in-hand with development of the theoretical tools used to carry out that analysis (Aim 2).

The aims for the study can be reformulated in terms of three research questions:

1. Taken from a Vygotskian socio-cultural perspective and framed in terms of the concept of the teaching narrative, what are the ways in which the two case study teachers use and guide classroom talk to support students in developing an understanding of scientific conceptual knowledge?

2. What analytical tools, based on a Vygotskian socio-cultural perspective and framed in terms of the teaching narrative, can be developed and exemplified in describing and analysing the ways in which the two case study teachers use and guide classroom talk to support students in developing an understanding of scientific conceptual knowledge?

3. What general insights might be developed from this Vygotskian theoretical perspective about what is involved in teaching and learning scientific conceptual knowledge in classroom settings?

4.2 Overall design of the study

In Chapter 2, Section 2.6.1, four key features of discourse were identified as providing a basis for analysing the teacher talk of the classroom. These are:

i. The forms of pedagogical intervention
ii. The authoritative-dialogic nature of the discourse
iii. The content of the discourse
iv. The pedagogical interventions in terms of scaffolding

The intention is to draw upon each of these features in analysing the discourse of the two separate case studies. The two case studies focus on teaching and learning different science topics and serve different functions in the overall development of the thesis. In Case Study 1, the discourse is examined and analysed with

reference to the four key features of discourse. In carrying out the analysis of the discourse of Case Study 1 in terms of the four features, there is the opportunity to elaborate and exemplify each of those features, to develop them as analytical tools. Those elaborated features or analytical tools are then used in analysing the classroom discourse of the second case, enabling further insights into the ways in which the teacher uses talk to support learning and further refinement of the analytical tools.

The two-case structure of the study is represented schematically in Figure 4.1:

Four features of discourse: developed from Vygotskian theory
and framed in terms of the teaching narrative are used
in analysing the teacher talk in:

|

CASE STUDY 1

|

Outcomes to analysis: i. insights to use of talk by teacher
ii. elaborated features of discourse which constitute the...

...Analytical Tools
which are used in analysing the discourse in:

|

CASE STUDY 2

|

Outcomes to study: i. description and analysis of pedagogical interventions in two case studies
ii. generally applicable analytical tools iii. general statements on teaching and learning scientific concepts.

Fig. 4.1 Overall structure of the study

The design which is proposed here is therefore one in which Vygotskian theory provides a starting point for the analysis of classroom discourse in Case Study 1 and the features of discourse (analytical tools) developed are then applied to Case Study 2. The two case format makes possible a reflexive and iterative development of insights into the ways in which the teachers use talk to support learning, first in one context then in another, and enables the theoretical tools developed in the context of the first case to be applied to a second, different

situation. Applying the tools to the second context enables a check to be made on whether the tools are relevant in a different situation and also allows for refinement and further development of those tools. Having access to two contexts also enables comparisons to be made between the patterns of discourse in each classroom, a process which can be helpful in identifying key features in the discourse.

4.3 Framing the study

4.3.1 The science contexts

In Case Study 1 the lessons focus on teaching about the 'rusting' process; the specific aim of the instruction is to introduce the idea that air, water and iron are essential for rusting to occur. The lessons of Case Study 2 offer an introduction to the concept of 'air pressure' and how that concept can be used to explain a range of simple phenomena. The topics of 'rusting' and 'air pressure' were chosen for a number of reasons.

Firstly, the decision was taken to focus the study on teaching and learning about scientific *conceptual* knowledge, rather than developing scientific procedural competence. The conceptual focus was settled upon because of the comparative lack of previous research into the ways in which scientific conceptual knowledge is developed through classroom discourse and made available to students (as outlined in Section 3.5 of the previous chapter). The actual topics 'air pressure' and 'rusting' were selected for a mixture of pragmatic and theoretical reasons.

Firstly the topics were part of the regular science curricula of the two classes to be observed and were being taught at a time which fitted in with the work programme for the research. In addition, and importantly, it was considered that there would be different relationships between the students' spontaneous views and the scientific view for the two topics. In the case of rusting, it was anticipated that there would be some common ground between students' spontaneous understandings of the phenomenon and the scientific view (water being commonly associated with rusting). With air pressure, it was recognised that scientific explanations based on the action of the surrounding air (for example in explaining how one is able to drink through a straw) would have little in common with spontaneous notions (of sucking).

It was therefore anticipated that the gap between everyday and scientific views would be greater for the air pressure case than the rusing case; it was anticipated

that the two topics would provide different kinds of 'learning demand' (see Section 1.2; Leach and Scott, 1995) for the students.

4.3.2 The role of the teachers

The two teachers involved in the case studies had both participated in previous activities with the CLIS Research Group and as such were aware of the body of research into 'childen's learning'. Both teachers are very experienced (having each taught in schools for about twenty years) and are highly regarded as science teachers; both display a genuine interest in and sensitivity towards the thinking of the students in their classes. The purpose of working with 'expert' teachers such as these was to increase the chances of observing classrooms where activities and interactions were deliberately planned and implemented with the aim of supporting learning.

The instructional approaches used in the two cases were planned jointly by researcher and teachers and in broad terms attempted to take into account any differences between students' existing understandings of the phenomenon in question and the scientific view (further details of the instructional approaches taken are set out in chapters 5 and 6). Although the outline of the teaching was worked through collaboratively, the details of implementing that plan was left to each teacher in preparing and teaching the lessons.

The purpose of planning the instruction with the teachers was to enable the researcher and teachers to have some shared understanding of the basic aims and underlying rationale of the teaching approach. By this means the researcher was aware of the details of the instructional approach and could concentrate on interpreting the talk around the instructional activities as events unfolded in each of the classrooms. Such an approach is in contrast to those naturalistic studies where ascertaining the *purposes* of activities in the classroom is part of the interpretative process.

4.4 Analysis of classroom discourse

The issue of how teachers use language to mediate the development of student understanding of scientific concepts in classroom settings is central to this study. Given this focus on language, and in particular on the classroom discourse which underpins development of student understanding, then the question arises as to what approach is to be taken in analysing that classroom talk.

A fundamental issue to be addressed concerns selection of the 'unit of analysis' to be employed in the development of the study. In his work on analysis of discourse Bakhtin focused his efforts on the 'utterance' which he refers to as being 'the real unit of speech communication'. Bakhtin claims that the units of analysis, such as words and sentences, used in linguistics:

> belong to nobody and are addressed to nobody. Moreover, they in themselves are devoid of any kind of relation to the other's utterance, the other's word (Bakhtin, 1986, p.99).

There are parallels between Bakhtin's comparison of analyses based on utterances and those based on linguistic units and a distinction made by Saussure (1959) between language (*langue*) and discourse (*parole*). According to Saussure, language is an abstract system from which, using the input of the lexicon and grammatical rules, sentences can be produced as output. Discourse is the concrete manifestation of this abstract system and is generated in a specific context of time, place, persons present, and their relationships to each other. Speakers combine these circumstances with the linguistic elements of language to produce real utterances. Meaning does not arrive in the same way in language and in discourse. In contrast to the single meanings of words and sentences that are not part of context, utterances can be interpreted, and used, in any number of different ways which arise from the interpretations that may be attributed to an utterance in context.

Given these dual possibilities (of 'langue' and 'parole') on which the analysis of discourse might be focussed, it is perhaps not surprising that the position taken in this study is to follow Bakhtin's path. Here the analysis of classroom talk is based on the 'utterance'; the assumption underlying the analysis is that meaning is indeterminate and open to change, that it is dependent on context, and that it is spread over exchanges of utterances rather than inhering in any one of them. As Barnes and Todd observe:

> Meaning is not something that is owned by one participant in a discussion but something that, developing and changing as it does in the course of a series of contributions by differing participants, is constructed and reconstructed by all of them (Barnes and Todd, 1995, p.141).

This study will focus on the ways in which meanings develop through classroom talk over an extended period of time, during the course of a sequence of lessons.

This approach of focussing on utterances and charting the development of meaning over time is consistent with the 'interpretative methods' of discourse analysis which were outlined in Section 3.2 of the previous chapter.

Research in the interpretative field has not been without its critics. For example Stubbs, in a discussion of Douglas Barnes' work (Barnes, 1976; Barnes and Todd 1977), refers to the 'highly insightful observations' but argues that there is 'no method or guiding principle for those of us who are not so sensitive' (Stubbs, 1984. p.120). A further criticism of interpretative methods concerns the practice of selecting exemplary pieces of transcript to support the analysis without being explicit about the bases on which they are selected. In addition, it might be that no detailed information is given about how frequent or how representative are the kinds of exchanges which are quoted (Edwards and Westgate, 1987, p.106).

Rather than presenting here a detailed review of various critiques of interpretative classroom discourse analysis, these issues will be addressed in the following sections where the detailed methodology for this study is set out. Suffice it to say for the moment that this study's aim of analysing how teachers guide talk to support development of understanding in their students is to be approached through interpretative methods which focus on the classroom talk of two case studies.

4.5 Framing the analysis in this study

4.5.1 Features of classroom discourse

In this section we return to review the four features of discourse identified in Section 2.6.1 of Chapter 2 which are to be used in guiding the analysis of classroom interactions in Case Study 1.

Edwards and Westgate (1987, p.107) draw attention to the tendency in interpretative studies to seize on 'the details of small excerpts torn from their context because they seem intuitively to be interesting or significant, at the expense of a comprehensive examination of whole sequences and the rules which can be shown to have produced them'. This tendency towards an 'opportunist approach' to data collection and analysis is reduced in this study by setting out a clear theoretical base and prescribing in advance of data collection the features of discourse to be attended to. In the following sections each of these four features of discourse are reviewed.

1. Forms of pedagogical intervention

These are the forms of intervention which the teacher uses to develop scientific knowledge on the interpsychological plane of the classroom, making it available to students. The forms of pedagogical intervention constitute the various means used by the teacher to talk through the scientific way of knowing, rendering it intelligible and plausible for students.

It should be noted at the outset that the analysis presented here focusses on the talk on the interpsychological plane which relates to developing and making available scientific knowledge. There are clearly other areas of classroom talk which teachers engage in: relating to administrative, organisational, disciplinary matters and so on. It is also the case that these areas of talk are important in setting the scene and preparing students for the teaching and learning which is the prime focus of the lesson. Having acknowledged this point the focus taken in this study remains on the classroom talk relating to teaching and learning scientific knowledge.

2. The authoritative-dialogic nature of the discourse

The second feature concerns the nature of the classroom discourse which enables development of student understandings. The analysis here is based on the Bakhtin/Lotman distinction between univocal/authoritative discourse on the one hand and dialogic/internally persuasive discourse on the other, and draws attention to the differing purposes of specific sequences of discourse.

Nature of discourse	Authoritative	Dialogic
Function of discourse	to convey meanings	to generate new meanings
Character of discourse	transmissive	internally persuasive

Fig. 4.2: The authoritative and dialogic nature of discourse

The authoritative-dialogic distinction offers the means for distinguishing between situations where the teacher approaches the task of supporting meaning making *largely* from an authoritative stance (transmitting knowledge) and situations where the teacher encourages dialogue (exploring and developing understandings). The point was made earlier, in Chapter 2, that this kind of

analysis is not to be interpreted as implying that particular acts of communication are best understood in terms of *either* an authoritative *or* dialogic model in isolation. Instead, virtually every sequence of discourse is viewed as involving both univocal, transmission aspects and dialogic, thought-generating aspects.

3. The content of the discourse

The point was made earlier in Section 4.3.1 that the focus on the development of scientific *conceptual* knowledge is an important feature in framing this study. The content of the discourse on the interpsychological plane is analysed in terms of the representation of spontaneous (everyday) and scientific concepts. Insights to progress in students' learning is also analysed in relation to the ways in which those students draw on spontaneous and scientific concepts in their talk.

4. The pedagogical interventions as scaffolding

The final feature of discourse to be drawn upon in analysing classroom interactions involves relating the teacher's interventions to the concept of scaffolding. Put simply, can the teacher's interventions in different parts of each instructional sequence be related to, and described in terms of, scaffolding?

In Section 2.6.2 of Chapter 2, four characteristic features of scaffolding were developed by considering the original specification of scaffolding by Wood et al (1976) and relating this to aspects of the ZPD. The characteristic features are as follows:

1. Scaffolding involves interaction between teacher and learner which is focussed on the learner developing *some specific competence* which initially they are unable to achieve alone.
2. In interacting with the learner during scaffolding, the teacher is aware of and responsive to existing modes of student thinking and any changes in student thinking, in supporting development of the target competence. That is, the teacher is aware of and responsive to any *differences* between student thinking and the target competence. Thus to scaffold learning, the teacher:

   i. monitors the present performance of the learner (monitoring)
   ii. analyses the nature of any differences between present performance and the performance required by target competence (analysing)
   iii. responds with an appropriate intervention to address differences in performance (assisting)

3. In scaffolding learning the teacher acts as a 'vicarious form of consciousness' in offering guidance through the learning event and helping the learner to reflect upon, and become consciously aware of, learning targets and the progress made towards those targets.
4. Scaffolding involves a progressive withdrawal of assistance, a gradual 'handover' of responsibility from teacher to learner.

These four characteristic features of scaffolding represent general points of principle which will be drawn upon in analysing pedagogical interventions in terms of scaffolding.

4.5.2 Analysis of teaching: reference to learning

The key facet of this study is the way in which teachers support student learning of conceptual knowledge in the classroom. Student learning and meaning making are taken to be mediated by talk and to take place over a period of time; meanings are not transferred from teacher to student but are constructed and developed through interactions.

Given this perspective on the development of meaning and understanding, then it follows that an important part of the analysis of teaching interventions is provided by insights to the developing understandings of students. Such insights allow the observer to gain some idea of the extent to which specific teaching interventions give rise to shared understandings between teacher and students. The point here is not to find out whether students are achieving 'correct answers' and are thus making progress in learning; rather the issue is one of monitoring the developing ideas of the students in order to assist in the analysis and interpretation of specific teaching interventions. The insights to students' developing understandings provide a crucial backdrop in judging the effectiveness of particular teaching interventions.

In Vygotskian terms, the interactions of the interpsychological plane are to be investigated with reference to students' developing understandings on the intrapsychological plane. The analysis of teaching interventions which is presented in this study will therefore be made with reference to the four features of discourse set out above and also with reference to the development in students' thinking.

4.6 Research methodology

Attention is now turned to the research methods to be employed in the empirical component of the study. In the following sections the research methodology used in each phase of the study is reviewed and discussed.

4.6.1 Data collection

Classroom talk

The essential body of data for this study is all of that talk on the interpsychological plane of the classroom which underpins development of student understandings of scientific concepts; this talk may involve teacher and students working in whole class, small group, or one-to-one situations.

The aim was to capture as much of this talk as possible without disrupting the normal workings of the classroom. In order to achieve this aim each of the teachers in the case study lessons was fitted with a neck microphone which picked up all of their talk and which was also sufficiently sensitive to capture the utterances of students as the teacher interacted with them (in whole class as well as in small group situations). An additional tape recorder was used to pick up any general talk in the room which might not be detected by the teacher's microphone. If the teacher was talking at the front of the room this recorder was placed at the back and vice-versa.

Student understandings

In the previous section the point was made that the analysis of teaching interventions is to be made with reference to students' developing understandings on the intrapsychological plane. By their very 'cognitive' nature, intrapsychological understandings are not open to direct inspection. In fact, some (including Lemke 1990, as outlined in Chapter 3) would therefore argue for an anti-mentalist position in investigating learning.

The position taken in this study, is that students do develop ideas-in-mind as they are exposed to the interactions of the classroom and that those ideas can then be publicly represented in later discourse. It is therefore legitimate to interview students about their ideas and to probe their understandings away from the interpsychological plane of the classroom. What is said in those interviews then allows inferences to be made about the development of individual understandings. It is clear that the interviewer and interviewee themselves constitute an

interpsychological plane in which meanings are developed in the particular context of an interview. The inteviewer therefore needs to maintain as 'neutral' a position in the discourse as is possible, minimising any form of external assistance which might influence or guide the student's comments.

With these points in mind students' developing understandings were monitored in various ways. In both case studies all of the students completed short diagnostic exercises before and after teaching and all of the written work of the students, completed during the lessons, was collected. A small target group of students was also identified in each class (4 students in the first case study; 2 students in the second). The target group in each class was selected on the advice of the class teacher as being a group of students who normally worked together and who would be happy to talk about the lessons to the researcher. The students in the target group were interviewed individually about aspects of the developing scientific themes before, during and after the sequence of lessons; the discourse of the target group was also recorded during any activities in class.

It might be useful to re-emphasise the point that the focus of this study is on teaching and that the monitoring of student learning is only being carried out insofar that it allows for further interpretation of the teaching which is going on.

General approach to data collection

The study was initially conceived of as being naturalistic in that the researcher aimed to act as a 'fly on the wall' in making observations and collecting data. The decision was therefore taken to keep the technology used in data collection as low-key as possible in order not to disrupt the normal working of the classes. In line with this approach video-recording techniques were not used. Even though it is the role of classroom talk in mediating student learning which is of interest in this study, it is recognised that in the classroom meaning making can be influenced by semiotic means which go outside linguistic expression. With this point in mind the collection of data through audio recordings was complemented by detailed field notes focussing on all those aspects of the teacher-student interactions which would not be captured in the talk.

The issue of minimising disruptions to the classes was also addressed through the researcher visiting the classes and sitting in with them ahead of the target lessons. This seemed to work well; in the case study lessons the researcher was largely ignored by the students.

Summary of modes of data collection

Theoretical Focus	Data	Data Source
Discourse of interpsychological plane	• teacher and student talk in whole class.	• Audio recordings in class
	• teacher talk with target groups of students	
Students' developing intrapsychological understandings	• student talk	• Individual interviews with target students outside lessons.
		• Student comments in class
	• student written material.	• Writing in exercise books: classwork & homework.
		• Responses to diagnostic pre & post teaching questions

Fig. 4.3 Summary of modes of data collection

4.6.2 Data analysis

A thorough approach to discourse analysis requires that the entire corpus of recorded talk is systematically categorised in order to evaluate the category scheme being developed. In this way some assurance is offered about the adequacy of the scheme to account for all that was recorded in the given setting. Recurring patterns in the categorised discourse then provide a basis for selecting passages which illustrate simultaneously the scheme itself and the nature of the events.

The first step taken in analysing the data was therefore to transcribe all of the audio tapes of classroom and interview discourse. The complete transcripts for each lesson were then divided into *episodes* which were identified in terms of the different teaching and learning phases of the lesson. Different episodes might involve: 'introductory talk by teacher'; 'reviewing student ideas'; 'student group-work activity'. The principal function of the episodes was to provide convenient chunks of data for analysis and reporting.

As outlined earlier, the data set for each case study was analysed in turn. For Case Study 1, the discourse constituting each of the episodes was worked through systematically, utterance by utterance, focussing upon each of the four features of discourse. Thus, for example, in investigating the 'Forms of pedagogical intervention' each of the teacher utterances was examined and the following kinds of questions posed: 'how (if at all) do these utterances contribute to making scientific knowledge available to all of the students in the class?' 'What are the purposes of these utterances with regard to establishing scientific knowledge on the interpsychological plane?'. By these means a number of different categories of interventions were developed and these were refined and extended through analysis of all of the data of the first case.

This kind of methodology in which categories are developed and elaborated from close inspection of case study data has been referred to as 'single case analytic induction' (Patton, 1990). An important point in the design of this study is that this inductive analytical process was guided by the features of discourse identified from the review of Vygotskian theory. It is not the case that 'anything goes' with regard to the analytical step; the analysis is grounded in, and steered by, Vygotskian theory.

For Case Study 2, the process of analysis was taken one step further as the categories or 'analytical tools' developed in the context of the first case were applied to the new data. Through this process, there was the opportunity to examine the extent to which existing categories could be used to analyse new data and thus to elaborate and develop categories as necessary. The intention was that through application to two cases, the emergent categories become more robust in definition. This methodological approach has been referred to as 'cross-case analytic induction' (Patton, 1990).

A fundamental issue to be addressed with this kind of research methodology concerns the validity of the claims made about the categories which 'emerge' from the data. In Stubbs' (1984) terms, whose 'insightful observations' are we to believe? The issue of validity is addressed in this thesis in a number of different ways.

Firstly, in developing the analyses of transcripts an iterative process of analysis and review was used in which each episode was analysed, the commentaries written up and then left to be reviewed at a later date. This process allowed for

revisiting data and refining interpretations by the researcher; the interpretations were not arrived at through one-off analyses of the text.

In collecting data every effort was made to gain the perspectives of both teacher and students on the events of the lessons. Thus:

- prior to each lesson, the lesson plan was discussed in detail with the teacher so that researcher and teacher had a shared understanding of the aims of the lesson and how the various activities addressed those aims...(what do you hope to do?).
- after each lesson, key events were reviewed and discussed with the teacher...(what was going on there?).
- during the lessons individual students were asked informally (where circumstances allowed) about things said in class...(what do you understand by that?).
- between lessons informal interviews with individual students were used to follow up issues raised in the lessons...(what did you understand by that?).

In addition, each case study teacher was asked to read through their case and to comment, from their point of view, on what had been written. This procedure is a form of 'respondent triangulation' (Denzin, 1970) and it addresses the issue of whether or not the interpretations arrived at by the researcher appear valid from the point of view of the person who actually carried out the teaching. In the event each teacher read through their cases and in subsequent meetings with the researcher talked through points where there was divergence between their view and the account presented. Both teachers were very positive about the nature and content of the account presented in 'their' case study. There have been various critiques of triangulation (Silverman, 1993) and the process of 'taking back' to the participants a provisional account prepared by the observer; questions arise as to whether it is valid to treat the participant's perspective as representing the 'reality of the situation' any more than the observer's account. Whilst understanding the issues underlying such debates, the position taken in this study is that respondent validation is to be valued in confirming that the account has resonances for the teachers both in terms of the 'story told' and the analytical tools used to present that story.

A final point relating to the issue of validity is that all points of interpretation and analysis presented in the thesis are supported by relevant transcript materials. To this extent the reader has the opportunity to review for themselves whether or not the suggested interpretations make sense.

4.6.3 Reporting the case studies

In reporting Case Study 1 an overall account of the three lesson sequence is presented first of all (Section 5.2). This account provides an overview, for the reader, of the various activities in the lessons and focusses on the *content* of the talk of the interpsychological plane and developing student understandings. In subsequent sections each of the remaining three features of discourse (pedagogical interventions, authoritative-dialogic nature, interventions as scaffolding) is developed and exemplified through data taken from all parts of the lesson sequence.

A different approach is taken with Case Study 2 in Chapter 6. Here, rather than drawing on data from all parts of the lesson sequence, to exemplify specific features of discourse, the 'theoretical tools' developed in the first case are applied to analysing of the classroom discourse of the full air pressure lesson sequence. That is, an analytical account of the teaching sequence is presented which follows the time-line of the actual lessons and which is based on the theoretical tools developed in the context of the first case.

4.6.4 Ethical issues

As stated earlier both teachers read through their case study and both agreed to the accounts being published. Neither teacher was concerned about anonymising their identity. The headteachers of both schools were aware and supportive of the research being carried out; since it would add nothing to the accounts, the identities of the two schools have not been revealed. The children's names which are referred to in the case studies have been changed.

4.7 Summary

In this chapter the aims and research questions have been set out and the design and methodology of the study introduced. The following two chapters take us into the classroom with the presentation of the two case studies. Here the four features of discourse which have been identified through consideration of Vygotskian theory are used in analysing the teacher talk in both cases.

Chapter 5: Case Study 1: Teaching and learning about the conditions essential for rusting to occur.

5.1 Introduction

In this chapter the theoretical ideas developed in Chapters 2 and 4 are applied to the first of the two case studies which focusses on teaching and learning about the conditions essential for rusting to occur. This is a lengthy chapter whose major part is taken up with reviewing, elaborating and exemplifying the four features of discourse identified earlier through reference to the data of this case.

First of all in the following Section 5.2 an account of the instructional sequence is presented outlining the events and activities of the lessons and monitoring the way in which the *content* of the discourse of the interpsychological plane of the classroom and students' individual understandings change during the course of the lessons. Both the discourse of the interpsychological plane and developing intrapsychological understandings are described in terms of the spontaneous and scientific concepts represented. The account given in Section 5.2 provides a backdrop to the analyses of discourse presented in the following sections. Put simply, the account in Section 5.2 tells the reader 'what happened' in the lessons both in terms of the events and the conceptual content. In subsequent sections each of the key features of discourse is focussed upon in turn in analysing the teacher talk of those lessons.

In Section 5.3 the concept of the 'teaching narrative' is discussed and developed in relation to the data of the first case. Section 5.4 focusses on the 'forms of pedagogical intervention' used by the teacher in developing the teaching narrative. In Section 5.5 the nature of the classroom discourse is analysed with reference to the 'authoritative-dialogic' dimension. Section 5.6 focusses upon an analysis of the pedagogical interventions in terms of 'scaffolding'.

5.1.1 Background to the case

The school

This case study took place in a comprehensive school in a large city in the North of England. The school is situated in an inner-city area which is rather down-at-the-heel and shows many of the signs of urban decay, with empty shops and derelict waste ground alongside new mid-rise housing developments. The pupils attending the school are almost entirely from working class households in which

unemployment and various social problems are common. At the time of the study the school had just completed a substantial development programme to change its status from an 11-16 boys secondary school to an 11-18 mixed school.

The class

The class focussed on in the study was a mixed-ability Year 8 group in which there were 27 pupils (12 boys and 15 girls) aged 13-14 years. The case study lessons were taught in November of the Autumn term and because of the on-going school re-organisation the pupils in the class had just arrived in school 3 months previously in September. The general level of attainment of the class was rated as being average for the school year group; the class included a wide spread of pupil abilities with a significant skew towards the lower ability end. It would be fair to say that the majority of children in the class would fall on or below the national average of ability and that a significant number of pupils were very limited in academic ability. As regards behaviour, the class had a reputation in the school for being 'lively'. Many of the pupils had very limited attention spans and were prone to chattering and other diversions from classwork. Pupil attendance was generally sporadic with patterns of missed lessons here and there being quite common. An inexperienced teacher would undoubtedly find this group a handful.

All Year 8 classes in the school had two double lessons (each lasting 70 minutes) of science each week. The first double lesson was timetabled for the last two periods on a Monday afternoon; the second for the first two periods on Thursday afternoon. There proved to be a tremendous difference in the pupils' ability to settle to work on the two days. On the Monday afternoon the pupils tended to arrive at the lab. over a period of time (up to 10 minutes after the bell) and were generally very boisterous and excitable. A much calmer atmosphere tended to prevail during the Thursday lessons.

As outlined earlier in Section 4.5.2, the analysis of teaching interventions in this study is made with reference to the development in students' thinking. In the first case study two pairs of students were selected to follow through the lessons; these students are Claire and Jill, Matthew and Ajay. Each of these pairs of students worked together in class. In the report of the case study which follows, the views of all four students are not represented in full throughout the case. This is partially due to the practical problems attached to gaining access to pupils in schools (before, during and after lessons) but also reflects the underlying principle that references are only made to development in student thinking insofar as they contribute to the analysis and interpretation of the ongoing teaching interventions.

The teacher

Lynne, the science teacher for the lessons was a Senior Teacher in the school having major areas of responsibility outside the science department. Lynne had close to twenty years teaching experience and this had all been gained in demanding inner-city schools. By any standards Lynne would be regarded as being a very good teacher indeed; her relationship with the pupils was characterised by a calm, interested and very caring approach. In class she consistently offered encouragement and praise to the pupils whilst at the same time laying down clear and firm expectations about their behaviour. Lynne demonstrated her respect for the pupils and expected that this would be reciprocated both towards herself and between pupils within the class.

At the time of the case study lessons Lynne was studying part-time for a Masters degree in education. She had been involved in a major curriculum development project with the Children's Learning in Science Research Group during the preceding two years and thus had been exposed to the literature on children's alternative conceptions in science. This area of research was of considerable interest to Lynne who interpreted it as complementing her generally 'child-centred' philosophy of education. Lynne's relationship with the case-study class was very good; although she regarded them as being 'hard work' she enjoyed teaching them.

All of the case-study lessons were taught in a laboratory which was set out in a traditional format with the teacher's demonstration bench at the front of a long rectangular room and the pupils sitting on stools behind 5 ranks of benches facing the front. The laboratory was clean and tidy with students' work being prominently displayed on the walls.

The instructional approach

Lynne agreed to participate in the research exercise in July of the previous academic year. At this time she and the researcher reviewed topics normally covered in the Year 8 school science curriculum and decided to focus attention on 'rusting' which was part of an existing unit of work on 'Chemical Reactions'. The topic 'rusting' was chosen because it seemed to be an area in which pupils would have existing, everyday understandings and Lynne was keen to have a go at putting into practice the educational dictum of 'starting where the students are at'.

The work on rusting was scheduled near the start of the unit on Chemical Reactions and Lynne wanted to use the context to begin to establish the general 'rule' that new substances are formed when chemical changes occur. The study of rusting was intended to contribute to a developing understanding of chemical change and two learning goals were identified for the teaching:

i. to appreciate that air (oxygen), iron and water are necessary for rusting to occur.

ii. to appreciate that rust is a 'new substance' formed at the surface of iron.

In the event, the case study lessons focussed entirely on the first learning goal, the second goal was addressed in subsequent lessons.

Prior to the lessons, Lynne and the researcher talked through an instructional approach which involved each student taking an iron nail home, three weeks prior to the first lesson, and placing it in a location where they thought it would go rusty. The nails would then be returned and each mounted on a sheet of paper with information from the pupil about where the nail had been placed and why it had been placed there. A display would then be set up with the nails placed in sequence from least to most rusty along the laboratory wall. The 'nails display' was to be used as a reference point in identifying the conditions necessary for rusting. Firstly the students were to review all of the different places where they had placed their nails and compile a list of what it was about those places which had caused rusting. Further activities were then planned to help the students isolate any factors which were present in *all* of the cases of rusting, hence identifying the conditions which are essential for rusting to occur. As a follow up to this, the students were then to design and carry out test-tube experiments to verify that these were, in fact, the essential conditions. The teaching was planned to extend over three lessons. The researcher talked through this instructional approach in outline with Lynne, who then developed detailed plans for the lessons.

In the accounts which follow, the overall sequence of lessons is broken down into episodes which are referred to as follows:

Lesson 1: Thursday

Episode 1: Reviewing the 'Nails activity' *(5 minutes)*

Episode 2: Setting the talking agenda *(10 minutes)*

Episode 3: Decontextualising the water condition *(10 minutes)*

Episode 4: A shift in perspective: from suggested conditions to essential factors *(5 minutes)*

Episode 5: Identifying essential conditions *(30 minutes)*

Lesson 2: Monday

Episode 1: Homework review *(10 minutes)*

Episode 2: The 'cold' condition *(5 minutes)*

Episode 3: Scientific experiments *(25 minutes)*

Episode 4: Setting up the experiments *(15 minutes)*

Lesson 3: Thursday

Episode 1: Just to remind you: the story so far *(5 minutes)*

Episode 2: What do the experiments tell us? *(10 minutes)*

Episode 3: Writing up *(10 minutes)*

Episode 4: Introduction: applying the scientific view *(5 minutes)*

Episode 5: Applying the scientific view *(30 minutes)*

5.2 An account of Case Study 1: the content of the discourse of the interpsychological plane and developing individual understandings

5.2.1 Introduction

In this section an account of the case study lessons is presented which outlines the activities and events of those lessons and focusses on the content of the discourse of the interpsychological plane and insights into the developing understandings of individual students.

At the start of the teaching all of the students in the class 'knew' about rusting; all of them were able to identify rust on a piece of iron and all of them had some idea about where to place a nail so that it would go rusty. In Vygotskian terms this knowledge can be referred to as the students' *spontaneous* knowledge about rusting in that none of them had received any previous formal instruction in this area. The teaching approach taken in the lessons involved eliciting the students' spontaneous knowledge through the 'Nails activity', and using that as a starting point for developing the *scientific* concept of rusting.

The distinction, made by Vygotsky, between spontaneous and scientific knowledge was reviewed earlier in Chapter 2 (Section 2.3.1). Vygotsky argued that, 'the first and most decisive distinction between spontaneous and scientific concepts is the absence of a system in the former' (Vygotsky, 1934, p.194, in Wertsch, 1985a, p.103). In the case of spontaneous concepts, the child's attention is 'always centred on the object being represented and not on the act of thought that grasps it'. In contrast, 'scientific concepts, with their quite different relationship to an object, are mediated through other concepts with their internal hierarchical system of inter-relationships'. With scientific concepts, Vygotsky proposed that the concept involves, 'simultaneously a relationship to an object and a relationship to another concept, that is, the intitial elements of a system of concepts' (ibid., p 196). In the development of scientific concepts, the emphasis is therefore shifted away from those aspects of linguistic organisation that involve contextualisation, to the capacity of linguistic signs to enter into decontextualised relationships, that is relationships which are constant across contexts of use. Scientific concepts are what make it possible for humans to carry out mental activity in a way that is independent of the concrete context.

With reference to this perspective, the instructional approach taken in the case study lessons involved a shift from a contextualised, spontaneous way of knowing about rusting to a scientific perspective which is not dependent upon any single example of rusting and can be applied to any context. Such a shift in forms of knowledge has been referred to as 'decontextualisation of mediational means' (Wertsch 1991, p.39). This concept of the decontextualisation of mediational means is drawn upon in framing the following account of the case study lessons.

5.2.2 The 'iron nails' activity: students' spontaneous reasoning about rusting

Three weeks prior to the first of the lessons, each of the students in the class was given an iron nail and asked to take it home and put it in a place where they thought it would 'go very rusty'. The students were required to write down in their science book where they had placed their nail and what it was about that place which made them put it there.

According to Vygotsky's account of spontaneous reasoning, one might expect the students' initial reasoning to have certain qualities, that it would: draw upon a range of everyday sources of knowledge about rusting; tend to relate to specific examples of rusting rather than to generalisable schemes for talking and thinking about rusting; tend to be spontaneous rather than consciously reflective. All of these qualities were, in fact, represented in the talk of students interviewed individually by the researcher prior to the first lesson (and after they had recovered 'their nail' from its 'rusting location').

One of the students, Claire, placed her nail out-of-doors 'near the garage'. She put it there:

> 'Because I thought - sometimes water will come in 'cos of the rain - so it'll get water and it'll be - it's quite draughty in there, so it'll get quite a lot of cold - and sun's there when it's sunny. And it's not a very nice place - the leaves all cover it an' things like that'.

Claire had previous experience of rusting:

> 'Well, I've got a bike you see. I haven't been using it lately and it's starting to go all rusty on the handlebars. And Mum and Dad tried to get it off, you know...and I thought well if I left that [*the nail*] out then, and now that I've put it [*the nail*] outside and I've left it outside, its gone rusty'.

Claire has experience of her bicycle handlebars rusting and uses this as a *prototypical* reference point in her thinking about rusting. Put simply, she is arguing that if her bicycle rusts when left outside then so too should the nail. Her knowledge of rusting is contextualised in this kind of way.

Jill placed her nail in the cellar, 'because most other things have gone rusty there'. Ajay placed his nail in a bowl of water, in the kitchen, 'because I know that rust forms round the wet substance'. Ajay knew this because, 'sometimes when I'm on my bike and stuff, I go in puddles and it rusts up'. Ajay also claimed that he had 'never really thought about it before'.

Matthew placed his nail in a bucket of water with salt in, under a plant pot, in the garden. Whe asked why he put it there he replied:

> 'cos that's where t'dampest place is - cos it's always covered - like, I mean, sun gets to it and air gets to it and cold gets to it - and I put salt in as well'.

In his exercise book he wrote:

> 'My nail started to rust when I took the nail out of the bucket of water and into the damp part of the garden and waited. Then when the cold and air got to the nail it really started to rust'.

Ideas such as these was repeated throughout the inteviews: the students drew upon a range of prototypical events and everyday knowledge about rusting in framing and talking about their ideas on rusting and as would be expected none of the students considered generally applicable conditions for rusting in placing their nail (although all of them knew that water was needed). Most of the students claimed that they 'never really thought about it before'; they 'knew' about the phenomenon but had never consciously reflected on it.

5.2.3 A transformation of knowledge: from spontaneous to scientific ways of knowing

The contextualised nature of the students' spontaneous reasoning about rusting has been described and exemplified in the previous section. The instructional approach taken in the three lessons started with these spontaneous ideas. Attention is now focussed on the talk and activities of the three lessons which enabled the transformation from everyday to scientific ways of knowing.

The following account of the lessons is structured around the episodes listed in the previous section. The episodes which are focussed upon were selected as

containing events which are significant in making the scientfic view of rusting available on the interpsychological plane of the classroom. In presenting the episodes attention is paid both to the talk and actions of the teacher and to the developing understandings of the students.

Setting the talking agenda (Episode 1.2)

At the start of the first lesson Lynne recounts where students had left their nails:

Teacher: You put them in some really interesting places. The sort of places you put them - Dawn put hers on a slope outside in the garden, and Matthew, Andrew and Louise also put theirs outside in the garden...Now, er, Barry put his in a cement hole outside in a wall. Clare put hers near the garage. Jill put hers in a cellar. Now all of those went rusty.

Lynne then collects ideas from the students on what it was about the places selected that made their nails go rusty:

Teacher: So - what I want to do - put on the board, is put down your ideas of what it was about the places that made your nail go rusty. What do you think it was - thinking about the places - that made your nail go rusty? Haley?

Haley: Damp

Teacher: Damp. Now, we'll put things up first of all, then we'll have a think about them in a minute. Right, so, damp [*Lynne writes it on the board*]. Yes, Cheryl?

Cheryl: Moisture

Teacher: Moisture [*writes it on board*]. Damp, moisture. Anything else? Gavin?

Gavin: I put mine in some mud in the garden.

Teacher: What was it about that mud that you think made yours go rusty?

Gavin: 'Cos it were all wet and all boggy.

Teacher: Wet - so it was wet again. Wet [*writes it on board*]. Right, wet. Any other ideas, Matthew?

Matthew: Air

Teacher: Air - right you think air could actually, right [*writes it on board*]. Air could make it go rusty. Fiona?

Fiona: Condensation might.

Teacher: Condensation, right [*writes it on the board*]. Dawn?

Dawn: Could it be like - climate like - if it's hot or cold?

Teacher: Hot or cold. Do some other people think that hot or cold might be something significant, in making something go rusty? Hot or cold - is that an idea - yeah? Hot. Which? Both of them or just one?
Dawn: Both
Teacher: Haley's saying perhaps cold. Cold? [*students mutter*] Well, is there anybody who put theirs in a hot place and it went rusty? [*mutters*] Don't forget you're thinking about where you put your nail - what it was - what things in that place - were making it go rusty. Yes?
Student: Cold.
Teacher: Right, have we got anything else it could have been? Anyone that hasn't given me an answer yet? No? Andrew then.
Andrew: On me bike - if I scrape me bike and leave it out in the rain, it goes rusty.
Teacher: So, what are you saying is making it go rusty then? Which of these things, which is causing it to go..
Andrew: [*interrupting*] ..rain

The full list of ideas on the chalkboard now reads: **Rain, Damp, Moisture, Wet, Salt, Vinegar, Air, Condensation, Cold, Dark.**

This initial sequence of discourse is critical in setting the agenda for the activities and discussion to come. The initial focus for the students was on *places* where rusting occured, the teacher now guides the classroom talk towards the *conditions* existing in those places. Lynne asks for ideas ('your ideas') from the students and they contribute suggestions enthusiastically; in Bakhtin's terms many voices are represented in the discourse.

During the discourse Lynne helps students clarify their suggestions: she differentiates between conditions (hot and cold); she helps a student to identify the conditions present in a muddy garden; she initiates an exchange about what makes a scratched bike go rusty when left out in the rain; she reflects some issues back to the class for discussion (hot or cold?). In addition, Lynne also carries out a preliminary sorting or filtering of suggestions. In some cases student ideas are accepted without comment (air, damp); at other times Lynne selects part of a student answer (wet...not boggy) which is then listed. In this way Lynne has control over what appears on the chalkboard; the chalkboard itself is a powerful device for drawing attention to and publicly logging particular ideas. The list on the board is available to all of the students, it acts as a form of 'shared memory' on the interpsychological plane of the classroom.

Decontextualising the water condition (Episode 1.3)

Lynne now invites the students to examine the suggestions on the board to see whether they have anything in common:

> **Teacher:** Now - what I'd like you to do first of all is to look at these suggestions, because - is there anything that some of them actually have in common - have we actually repeated ourselves with any of the things that we've got on the board at the moment?

After discussion, teacher and students agree that rain, damp, moisture, wet and condensation are all 'forms of water'. These conditions which initially were offered by students as descriptions of particular *places* (for example: a damp shed; condensation under the window) are now recast by Lynne as 'water' a 'key thing' which was present in all of those different places. The teacher uses the term 'water' which is not tied to any particular location; in doing so she continues the process of transforming the language used to describe the process of rusting. The list on the board now includes 7 items and reads: **water, salt, vinegar, air, cold, dark, dry.**

A shift in perspective: from suggested conditions to essential factors (Episode 1.4)

Lynne reviews progress:

> **Teacher:** Right, OK, fine. Think what we've done now. What we've actually done is try to draw together the reasons why you think your nails have gone rusty. And we've actually tried to tease out what are the main factors.

In this review, Lynne makes a subtle retrospective shift in describing what has been done. From the students' point of view, they had been engaged in describing the conditions in the places where their nails rusted. Lynne now refers *not* to describing conditions in particular situations *but* to identifying the 'reasons' and 'main factors' which lead to rusting. Lynne continues:

> **Teacher:** Maybe, even within this list here [*water, salt, vinegar, air, cold, dark, dry*], it's just perhaps one or two of those that are the really essential things - the real things that we need for something to rust.

The idea of 'essential conditions' is thus introduced to the discourse. A scientific view of rusting involves knowing not only that iron, air and water are involved but also that they are the *essential* conditions. The notion of 'essential conditions'

provides a particular epistemological framing for the scientific knowledge about conditions for rusting. Other conditions (such as presence of salt) may affect the rate of rusting but water, air and iron are essential for that process.

During these opening sequences of discourse the teacher has introduced a shift in 'referential perspective' (Wertsch, 1985, p.167) from 'places where things rust' to 'conditions in those places' to 'essential conditions'. This is a shift from describing rusting events in terms of contextualised everyday knowledge towards developing one generalisable scientific explanation for all of those events.

Identifying essential conditions (Episode 1.5)

The students are now set an activity, working in small groups, in which they consider the locations where nails rusted and decide whether each of the listed 7 conditions existed in that place. Any conditions existing in *all* places might then be 'essential' for rusting.

One group finishes the activity and seeks Lynne's attention:

Student: We're finished, Miss.

Teacher: You've finished the whole lot? Right, let's have a look. So, now. Looking at everything you've done. Are there particular columns where you've ticked everything? So therefore you think it must be that.

Student: Cold?

Teacher: So let me have a look. Well, cold, so it looks like cold could be something.

Student: Air?

Teacher: Air, air.

Student: Vinegar, vinegar's got..

Teacher: ..vinegar's all crosses so we can discount vinegar, can't we? Right, OK.

Student: Salt's just two.

Teacher: Salt. So perhaps we could discount salt. They're not essential factors.

Student: Miss, water.

By carrying out the activity the students are able to identify possible essential conditions. The activity serves to mediate *what is meant* by 'essential conditions' (those conditions for which there are ticks in all locations) and the 'talk around the activity' is in terms of conditions present in all locations. When all groups have completed the activity, Lynne collects the groups' proposals for essential conditions.

During the activity there was much debate in the groups about whether certain conditions exist in particular locations (for example, is a shed cold?). A number of groups therefore suggested conditions which were present in *most* but *not all* locations (maybe because there was still uncertainty about some of these) and these were accepted by Lynne. An ambiguity in meaning of 'essential conditions' was thereby created and this became apparent in comments made by students when asked about the *purpose* of the group activity. Jill, for example, suggested that it was, 'to see what mainly made the nails rusty'; Fiona stated that the conditions with most ticks are 'the most common things to make the nails go rusty'; Matthew talked about, 'the main things what you need to rust'. The students' talk echoes what was said and done in the activity; it does *not* reflect the scientific meaning of 'essential conditions'.

After the report back from the activity is complete, Lynne provides a summary:

> 'So, water is everywhere where rusting is taking place and air is also an essential factor. What we have done is to narrow things down to definitely air and water, but it looks as though cold and dark need further testing'.

The list on the board reads: **air, water, cold, dark.**

The 'dark' condition is interesting in that only three out of the six groups nominated it. Lynne took the decision that it should be retained as a possible essential condition (maybe because there had been debate in certain groups about whether dark or light conditions prevailed in particular locations). 'Air' is also interesting in that it has become a prominent feature in the discourse without ever having been discussed or questionned by teacher or students. First introduced by Matthew and implicitly accepted by Lynne, it has come through the group activity without being challenged (because air is everywhere, even in water).

Student reasoning about the conditions for rusting

At this point in the lesson sequence, the researcher asks one of the students, Ajay, about the conditions for rusting:

Researcher: Do these things [*the listed conditions*] make much sense to you? What about the water? Does it make sense to you that it is needed for rusting?
Ajay: Yes. Yes.
Researcher: What about the air?
Ajay: Not too sure about it. I think there might be different chemicals in the air and they could help rust.
Researcher: Right. And what about the cold? What do you think?
Ajay: Think - that might have chemicals in it as well - if it's right cold it could like freeze or summat and go cold and the other chemicals go like onto it.

The researcher also talks with Matthew:

Matthew: Air - air dries the water, so it makes it damp, then damp gets in and rusts.
Researcher: And what about the cold?
Matthew: Cold freezes it - so when cold - so when air dries, when air and water come it sort of rusts, like, it starts at end and it works into the middle.

The interviews with Matthew and Ajay offer insights to the kinds of ideas which each constructs to enable them to make personal sense of the talk about 'conditions' enacted on the interpsychological plane. The group activity led to the identification of possible essential conditions but provided no underlying model or reasons to enable students to make sense of those conditions. The responses from Ajay and Matthew suggest that there is a problem for the students in generating plausible warrants for accepting the conditions. It is obvious that water is needed for rusting (this is part of personal and social experience) but why should air and cold be needed?

Bakhtin refers to the 'dialogic nature' of meaning making in which two or more voices come into contact and understanding develops through 'striving to match the speaker's word with a counter word' (Voloshinov 1973, p.102 in Wertsch 1991, p.52). Bakhtin further reminds us that:

> the word in language is half someone else's. It becomes 'one's own' only when the speaker populates it with his own intention, his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention (Bakhtin, 1981, p.293).

Here we have examples of Matthew and Ajay taking some of the ideas raised in the lesson and adapting them to their own knowledge frameworks in different and personal ways. Both boys have made the intellectual effort to 'interweave' new ideas with their existing frameworks; in doing so they have developed notions ('air acting to dry the water'; 'chemicals existing in air') which are not in accord with the scientific view. The teacher can control, to some extent, the actions and talk of the interpsychological plane but she cannot direct the way in which individuals will interact with those events and bring personal voices to bear in making sense of them. As outlined earlier (Section 2.2.3) internalisation does not involve simple transfer of ideas from interpsychological to intrapsychological planes, there must also be an element of personal reorganisation and reconstruction.

The cold condition (Episode 2.2)

At the start of the second lesson, Lynne draws attention back to the list on the board: **water, air, cold and dark.** The idea that 'cold is needed for rusting' has become established in the classroom discourse (and, as we have seen, in the personal understandings of students such as Ajay and Matthew). This is not part of the scientific 'story' and Lynne now challenges this notion by referring to holidays in hot places:

> **Teacher:** Right, if we want to check ...that cold, air, water and dark are needed. Now - I thought about this and I was thinking about the first one - the cold, because people were talking about cold. And I suddenly thought about going on holiday somewhere hot, right? Now, how many of you might have been abroad, somewhere very hot, like Greece or Spain - places like that? [*about 7 students raise their hands*]. Right, quite a lot of you. Right, put your hands down. Now, thinking about this I suddenly thought of all the places I'd been to, and I thought, well they're not cold at all, so does that mean that in these places abroad nothing ever goes rusty?

Lynne continues:

> **Teacher:** Cos if you think about it - if we're saying it's cold that makes things go rusty, then the logic of that is that if you're somewhere hot things will never go rusty. Anyone got any comments about that, just put your hand up. Gavin?
>
> **Gavin:** It can rust without cold.

Teacher: Cold. It can rust without cold, right. 'Cos d'you get what I'm - getting at, Nicola, what does that mean? Gavin is saying that things can rust without cold - should we then have cold in our list? Is cold essential for rusting then?
Students: [*chorus*] No.

Teacher: It's not, is it? No. I even went back and looked through some of my holiday snaps to see if I could prove this right. And I got some wonderful photos of some brilliant rusty railings - yes, you can pass them round. These are pictures from an island in Greece called Santorini - and there's a picture there of some wonderful rusty railings - there's also a picture here of a boat and the end you can see has got a lot of rust on it. That seems to me like pretty good proof therefore, that cold - we can cut it out really because it's not absolutely essential for rusting.

Lynne thus provides 'proof' for removing cold from the list of possible essential conditions. Lynne's anecdotal account and photographs offer strong imagery of railings and boats turning 'wonderfully' rusty in the very hot weather and Lynne draws on these images in presenting a compelling case to suggest that cold is not essential for rusting. From a scientific point of view a number of questions are not addressed: what is meant by 'hot' as opposed to 'cold' conditions? the conditions in Greece are not 'controlled', might rusting have occurred during the cool of the evening? Nevertheless, it appears from the students' responses that they find Lynne's arguments plausible and nobody objects when 'cold' is removed from the list.

In developing the argument relating to the cold condition, Lynne refers to the notion of 'essential conditions': things can rust without cold, cold is not essential for rusting. In this way the meaning of 'essential condition' is rehearsed once again on the interpsychological plane. It has become a feature represented in the ongoing talk of these lessons and each time the concept of 'essential conditions' is referred to students have the opportunity to redefine and transform their understanding of it.

Scientific experiments (Episode 2.3)

Removing 'cold' from the list, Lynne reviews progress and looks ahead to the next step:

Teacher: Now that means that we're left with air, water and dark, and what we've got to try and do is to see if we can actually prove whether it is air on its

> own, perhaps even water on its own, perhaps dark on its own, or a combination of the three which is going to make things go rusty. Now, no matter what you think, doesn't matter what you think, what your ideas are - the point of this afternoon is that we're going to set up an investigation to test that. Right!

Lynne's words here provide a clear indicator that the discourse is now firmly located in the scientific domain. Whereas at the beginning of the lessons students' views were elicited and dialogue encouraged, Lynne now states that, 'it doesn't matter what you think', scientific experiment, 'an investigation', will provide the basis on which knowledge claims are to be judged. Lynne talks through the design of experiments to test whether the three conditions taken separately and in combination lead to rusting. The talk focusses on the scientific logic and practicalities of how variables can be controlled to test each condition and groups of students set up experiments with iron nails in conditions of: air alone (water removed with a drying agent); water alone (air removed throough boiling); air and water. Half of these experiments were then left in the dark and half in illuminated conditions. The controlled conditions operating in these experiments contrast markedly with the real-life situations used in the initial 'Iron Nail activity', a further indicator of progress towards establishing scientific knowledge.

Just to remind you: the story so far (Episode 3.1)

At the start of the final lesson, Lynne reviews the activities of the previous two lessons:

> **Teacher:** Just to remind you. We were trying to narrow down all the factors we were thinking about that caused rusting, to the absolute, vital ones that were absolutely essential. And we'd started to narrow it down by doing the work on the posters - which had left us with four things that we thought were essential - we were left with air, water, ...dark and cold. But we eliminated cold because we realised that if you live in a hot country you still have lots of things around you that go rusty. So that left us with these three things, air, water and dark. So you set up your experiments last week. Now today - we need to look at these results and see if we have narrowed it down any further to the absolute essential things that are needed for rusting.

The review is presented as though it is a summary of established 'shared knowledge'. Lynne makes abbreviated references to key arguments presented

earlier ('the work on the posters', 'things go rusty in a hot country') and refers to essential conditions as 'the absolute vital ones'.

What do the experiments tell us? (Episode 3.2)

Lynne invites the class to examine their own experiments and firstly directs attention to the test tubes which contained only air. All agree that no rusting of iron had occured in these tubes. Lynne next turns to the tubes which contained only water and these show no rusting, apart from Rebecca's:

Teacher: Can I just borrow that tube then, Rebecca, and see if we can think of perhaps why - in this particular tube - we might have had something go rusty. Think about this carefully. Right, anyone got any ideas, Clare?

Clare: Maybe not enough oil, some air might have got in.

Teacher: Right - so one point might have been that there - in fact it is quite a thin layer of oil - but it still seems to cover it quite well. So it's a good point, but I think, looking at it - what d'you think, Matthew? Do you think there's enough oil on there to stop air getting back?

Matthew: No.

Teacher: No, well actually Matthew says perhaps there isn't quite enough, so that might have been one point, right? Is there another reason though, Rebecca, can you think about your own experiment then, and think why?

Rebecca: Miss, when I spilt it all out - a lot of it flew out.

Teacher: Right, right . So, you put the boiled water in here, and then you dropped the tube and it. No?

Rebecca: The oil Miss..

Teacher: ..you spilt the oil - it dropped out - so that could have been - did any water get out as well?

Rebecca: Yeah, it went all over..

Teacher: ..so it was all around. Can anyone think why that might have affected Rebecca's experiment then? Right - Philip do you want to give me an answer?

Philip: Y'know when she spilt it? It could have cooled down and let air in.

Teacher: Right, I think that's a very good point - and I heard somebody down here - was it Dean? - say the same thing. Perhaps when it spilt - the air got in.

Rebecca's result is not what was expected and Lynne asks the students for their ideas about what has happened. Clare tentatively suggests 'Maybe not enough oil'. It is clear that Lynne is not convinced by Clare's idea and she turns to Matthew, possibly expecting him to voice *her* reservations. In fact Matthew offers support to Clare, and Lynne leaves the issue open, 'well actually Matthew says perhaps there isn't quite enough'. Lynne turns to Rebecca and it becomes apparent that there are very good reasons for the nail rusting! Even now Lynne draws other students into the dialogue to talk through how Rebecca's accident would affect her nail, Philip makes a suggestion which Lynne takes and repeats to the whole class. In this short sequence there is genuine exploration of meaning by teacher and students; the sequence demonstrates how Lynne is able to encourage dialogue and use it as a basis for reaching the scientific point of view.

Finally the tubes with air and water present are examined and all of these show rusting; Lynne focusses on these nails and asks what this means:

Teacher: So in fact everyone's got their hand up, telling me that with air and water then the nail has gone very rusty. Right, now then. Is that telling us something very important, d'you think? Have we narrowed this information down any more? Dawn?

Dawn: Well, it means that, means, er, you have to have them both together for the nail to go rusty.

Teacher: Right. I think that is an excellent point - and I think it's an excellent way of saying it too. Listen carefully and I'll just re... - can you just repeat for everyone what you just said?

Dawn: Erm, if, if you've got air and water mixed together it's the only time when the nail will go rusty.

Teacher: Excellent. You have to have - what you actually said the first time was this - you have to have air and water together to make the iron go rusty, and I think that's an excellent way of describing this. Let's just think back again. At the start, you were suggesting that it was cold, it was warm, it was dark, it was light, it was acids, or it was, water and air. All those things that were causing rust. That's what we started off thinking. And what we've done now - we've now come to the point where you've decided and you've proved in fact that it's just two things, with the iron.

The transformation of knowledge, *as enacted on the interpsychological plane*, is now complete. Lynne signals this end point by asking Dawn to repeat her statement, 'you have to have them both together for the nail to go rusty'. She then takes Dawn's words and arrives at the general decontextualised rule that, 'air and water together are needed to make the iron go rusty' (Lynne omits reference to the nail in 'repeating' what Dawn said). Lynne finally refers back to the student thinking at the start of the lessons and draws attention to the difference between the scientific view and that initial spontaneous thinking.

Applying the scientific view: Group Work (Episode 3.5)

The final activity of the lesson involved the students working in groups to decide whether objects left in certain situations would or would not rust. The group exercise provided the opportunity for students to apply their knowledge of the conditions needed for rusting to a variety of situations. Over the whole of the class, the responses to the different situations presented in the exercise showed little variation and were in accord with the scientific view.

The following transcripts are taken from a group which consisted of Jill, Claire, Fiona, Katie and Joanne. It is not possible to differentiate between voices of pupils which are therefore all denoted '**Student**'. As the groups worked through the cards Lynne circulated making occasional comments. The group's decision for each case [will rust, will not rust] is given in square brackets after the transcript.

Iron railing

Student: [*reading card*] Iron railings next to the sea.

Student: It will rust, there's air and water and it'll all rust.

Student: Yes, there's air, there's water - yes it would.

Student: So iron gates will rust.

[Will rust]

Lunar rocket

Student: [*reading card*] Part of a lunar rocket module left on the surface of the moon.

Student: No, 'cos there's no gravity up there.

Student: And there's no air..

Student: ..no air up there.

Teacher: If there's no air it can't go rusty..

Student: ..just write rocket.

Teacher: I don't suppose there's any rain there either, is there?

Student: No.

[Not rust]

Handlebars

Student: [*reading card*] The handlebar of an old bike with the chrome flaked off.

Students: Yeah, it would, yeah, it would.

Student: Mine's gone rusty.

[Will rust]

Ship's bell

Student: [*reading card*] An iron bell lost from a ship into the bottom of the deepest part of the Pacific Ocean.

Student: Yeah.

Student: Yeah, definitely.

Student: 'Cos if you've ever seen, right, them Jaws films, owt like that - you see all metal, all rusty..

Student: ..it will rust..

Student: ..it will rust because there's air and how do you think the fishes breathe?

Student: Exactly!

[Will rust] Perceptual images (from 'them Jaws films') have a strong influence over the decision, although there is also reference to the presence of air. The argument 'how do you think fishes breathe?' echoes talk from earlier in the lesson.

5.2.4 Summary

In this section, an account has been presented which charts the way in which the teacher guides the talk of the interpsychological plane from a starting point which is focussed upon the students' spontaneous notions about rusting towards the final statement and application of the decontextualised scientific perspective. The account is framed in terms of a gradual decontextualisation of mediational means.

In the following sections the talk and events of the case study are revisited and analysed with reference to the theoretical features of: the teaching narrative, the forms of pedagogical intervention, the authoritative and dialogic nature of the discourse, the pedagogical interventions in terms of scaffolding.

5.3 The teaching narrative

The concept of the teaching narrative was introduced in Section 2.6 (making links to Bruner's work on the narrative form) as a theoretical device to help describe how teacher talk, through an extended sequence of lessons, can be used to make scientific ways of talking and thinking available to students and to negotiate their meaning. In this section the concept of the teaching narrative is returned to and elaborated in the context of the talk and events of the first case study.

In actually observing and starting to analyse the lessons of Case Study 1 it became clear that teacher and students were involved in acting out a particular form of social event or 'public performance'. This performance took place in the school science laboratory and lasted for three to four hours, extending over three different lessons, on different days and in different weeks. The performance was directed by the teacher but also involved the students in a variety of different ways.

The performance was largely based on talk but involved other activities which the students became engaged in. Definite themes emerged in the talk and these became increasingly familiar as they were subsequently referred to and practiced by both teacher and students. Although the performance was enacted over different days, the teacher sustained a sense of continuity through picking up previously rehearsed themes in order that they might be further explored and developed. Central to the performance was the gradual unfolding and 'talking around' of the scientific view of rusting. The performance resembled the enactment of a story: the rehearsal of a narrative which gradually unfolded under the direction of the teacher, a *teaching narrative* to make the science way of knowing available to students.

That teaching should be thought of in terms of the performance of an extended narrative is perhaps not so unusual when one considers the ubiquitous presence of story-telling in day-to-day interactions. Just as people use stories as a means of sharing ideas and offering explanations in everyday situations, then the idea which is developed here is that some forms of science instruction might be conceptualised in terms of a teaching narrative through which students are 'talked into' the particular modes of expression of specific 'scientific stories'. What then is the nature of the teaching narrative as it applies to this context?

The first point to be made is that the performance of the teaching narrative is to a varying extent interactive. There are comparisons which can be made here between the interactions of the classroom and performances in the theatre. In the theatre the storyline is carried principally by the dialogue between players; in Vygotskian terms the interpsychological plane is laid out literally on the stage, in front of the audience, and each member of the audience makes sense of (or internalises) the performance in their own terms. The situation in the classroom is similar, but different. Here the students both take part in, and are an audience to, the performance. The teacher who is sensitive to students' thinking will respond to their ideas as the performance of the narrative progresses; students' comments and questions can alter the way in which the narrative develops. Individual students take their place on the stage from time to time, to contribute to the developing narrative; the teacher guides and controls these interactions so that the performance retains its coherence and leads to the portrayal of the science way of knowing. The narrative which is performed on the interpsychological plane of the classroom carries the seeds from which students' personal (or intrapsychological) understandings can grow.

The teaching narrative is introduced to the analytical scheme which is being developed in this study as an over-arching theoretical construct. The idea of the teaching narrative is introduced to help capture the way in which the 'scientific story' is talked into existence over the course of an extended period of time, with conceptual themes emerging, disappearing and re-emerging. The performance of the teaching narrative is controlled and guided by the teacher; the teaching narrative consists of the various forms of pedagogical intervention made by the teacher in developing the scientific way of knowing on the interpsychological plane of the classroom and making it available to students. These forms of pedagogical intervention which constitute the narrative are developed and exemplified in the following section.

5.4 The forms of pedagogical intervention

The forms of pedagogical intervention are the various interventions which the teacher uses to develop scientific knowledge on the interpsychological plane of the classroom. Through analysis of the transcripts from Case Study 1 five different forms or categories of pedagogical intervention, which constitute the teaching narrative, have been identified. These are referred to as:

1. Developing the conceptual line
2. Developing the epistemological line
3. Promoting shared meaning
4. Checking student understanding
5. Maintaining the narrative

In the following sections each of these forms of pedagogical intervention is reviewed and exempified in turn.

5.4.1 Developing the conceptual line

Central to the teaching narrative is the portrayal or public enactment of the science way of knowing or the 'science story' on the interpsychological plane of the classroom. It is through this public enactment of the science story that the science way of knowing is made available to students; this is the first step in the process of development which leads from interpsychological to intrapsychological planes.

The conceptual line of the teaching narrative is concerned with all of those teacher interventions which contribute to the portrayal of the science way of knowing on the interpsychological plane of the classroom. Based on the observations of Case Study 1, it has been possible to identify a number of different ways in which the teacher guides development of the conceptual line of the narrative. These are presented in three sub-categories:

i. Shaping ideas
ii. Selecting ideas
iii. Marking key ideas

Developing the conceptual line: shaping ideas

These are the interventions made by the teacher to shape the presentation and development of the concepts which constitute the scientific perspective. The

various forms of intervention, from Case Study 1, which involve 'shaping ideas' are introduced and exemplified in the following paragraphs.

The reader should note that the origin of each illustrative example from the lesson sequence is identified by means of reference to the appropriate *episode* (see Section 5.1). For example, Episode 2.3 means: Lesson 2, Episode 3.

a. Teacher introduces a new term or idea

If it is accepted that science offers a way of knowing about the world which is often different to everyday understandings, then it is clear that teaching science must, at some stage, involve introducing new terms and ideas. One might anticipate that there would be many examples of introducing new ideas where the teacher, 'just tells them....a fact'. In the first case study there were, in fact, few (if any) instances of this kind of presentational delivery. New ideas and terms were introduced in a variety of ways which often involved the teacher in trying to create some kind of shared context (Edwards and Mercer 1987) to enable student understanding of the ideas.

For example in Episode 2.3, in talking through the design of the scientific experiments with the students, Lynne introduced the idea that there is water in air by referring to a familiar physical phenomenon:

> **Teacher:** Right, well, there's one quite - there's one very good way of checking that - d'you want to just breathe on that for me, Dean? Right, Dean's just breathed on to a mirror, right, now there's air - so he's breathing out some sort of air - but also, what else has appeared on the mirror - someone mentioned that word.
>
> **Students:** Steam, condensation.
>
> **Teacher:** Condensation, right. So if we just simply take this test-tube, right, and put the nail in, put the nail in and we just put the lid on - what've we got in there? Have we <u>just</u> got air or have we got air and some water?
>
> **Students:** No - water...

Lynne knew ahead of time that she wanted to introduce the idea that there is water in air and had the mirror ready for this simple demonstration. The mirror served to 'capture the invisible'; there was no water to be seen in Philip's tube but by using the mirror Lynne was able to offer evidence of its existence and make plausible the idea that water can exist in air.

A little later (Episode 2.3), Lynne is attempting to introduce the idea that the process of boiling water removes the air from it. She approaches this by recounting an anecdote about Mr Scott and his goldfish:

> **Teacher:** In fact, Mr Scott told me this story about when he was little - he was saying how when he was little his Mother bought him his first ever goldfish and he was so thrilled to have this goldfish that he wanted to do everything the best of it he possibly could - so he wanted everything to be really clean and perfect for this goldfish. So, what he did was - he thought - well, it better have really, really, really clean water - so what do you think he did to the water?

Lynne developed the anecdote and used it to introduce and make plausible the idea that boiling takes the air out of water. This strategy of using anecdotes to introduce new ideas has been identified in other research studies (see Ogborn et al 1996). In the context of the developing conceptual line of the teaching narrative, the 'goldfish anecdote' can be seen as a 'story within the developing science story'.

One final example of a new idea being introduced is to be found in Episode 2.2 where Lynne is attempting to establish the point that the condition of 'coldness' is not needed for rusting to occur:

> **Teacher:** Now, how many of you might have been abroad, somewhere very hot, like Greece or Spain - places like that? Right, quite a lot of you. Right, put your hands down. Now, thinking about this I suddenly thought of all the places I'd been to, and I thought, well they're not cold at all - so does that mean that in these places abroad nothing ever goes rusty?

Lynne might have included a control for temperature in the scientific experiments which were designed with the class; instead she decided to make the point that cold is not an essential condition for rusting by referring to circumstantial evidence taken from common experiences of holidays in hot places.

In each of these three examples the teacher offers a warrant for believing the new idea. The warrant takes different forms (physical evidence, an anecdote, common experience) in the three examples but serves, in each case, to render the new idea plausible for students.

The other forms of intervention to 'shape' ideas do not involve introduction of new ideas; they all focus on ways in which the teacher shapes ideas which are already represented in the discourse of the interpsychological plane.

b. Teacher guides students through the steps of an argument or explanation by means of a series of key questions.

Teachers use questions for a range of purposes during classroom teaching. At one moment a question might be used as a disciplinary device at another as a means for gaining a student's attention. Here the focus is on the teacher's use of questions insofar as they contribute to the development of the conceptual line of the narrative.

In Episode 2.3, there is a sequence in which Lynne is talking with the class about how they might prove experimentally that air by itself can cause rusting:

> **Teacher:** ...now, how're we going to do this though - if we're trying to prove that it's just air - how can we do this? Any ideas? Right - sh, sh - Philip first of all.
>
> **Philip:** Miss, get - put some of metal in one of them boiling tubes and just let some air in and leave it out..
>
> **Lynne:** ..right , good idea - let's start with that, shall we? First of all we get a boiling tube, and, Philip's suggesting that inside there we put a piece of iron, like another smaller nail perhaps - we could use a smaller nail - and that in there if you've got air - then that means that we're testing out whether there's air affecting rusting, right, is there anybody can see any problem with that at the moment? Can I just ask somebody else first? Is that fine, or is there any problem with that, yes, Dawn?

Lynne starts by asking an open question, 'any ideas?' and Philip's response includes no attempt to control conditions. Lynne nevertheless praises Philip's suggestion and places a nail in a tube asking, 'is there anybody can actually see any problem with that at the moment?' Through the intonation of her voice and the directness of the question Lynne clearly signals that there are problems with Philip's approach. She then repeats the question to emphasise the point, 'Is that fine, or is there any problem with that?'

Dawn makes a suggestion which relates to the issue of light and dark and Lynne refocusses the talk:

Teacher: ...that's a good idea, so can we come back to dark and light in a minute? 'Cos at the moment - let's keep thinking about the air. If you've got air in here - if we just put a cork on - have you only got air in here?

Lynne now develops her initial question and focusses it more sharply: 'is there any problem with that?' becomes, 'Have you only got air in here?' Her intonation and emphasis on 'only' indicates very clearly to the pupils that there is more than just air in the tube.

Students: No, no.

Teacher: Have we got rid of the other - have we got rid of water?

Students: Yeah, yeah, no, no. [*clamour of no's*]

Teacher: Well, sh, hang on, whoever's saying no, can you put your hand up to see if we can have some explanations about this, right, Kelly?

Kelly: 'Cos - if air is cold - then it sort a ...

[*others join in - the talk is not clear - but water is mentioned*]

Teacher: I think Haley's hit on the right thing actually - in that tube - is there water in air, is there water in air?

Students: Yeah, yeah.

Lynne's questionning becomes even more directed: 'have you only got air in here?' becomes 'have we got rid of water?'

In this sequence, it is very clear that the teacher is using questionning to guide the talk towards the idea that there is water in the air in the tube. The style of Lynne's questions changes from the initial open invitation for students' ideas to progressively more closed questions which are heavily cued by the teacher's delivery. Lynne uses questions to focus the attention of the students on particular issues and so guides the line of development of the classroom talk.

c. Teacher paraphrases student ideas

There are instances where the teacher repeats a student response and in doing so elaborates upon, or paraphrases, what the student actually said. The elaboration might include points of detail which were left implicit by the student; it might include additional points which were never intended by the student but which the teacher judges to be helpful in developing the conceptual line of the narrative.

In Episode 2.1 Lynne asks Fiona to read out what she has written for homework in describing what she did with her nail:

Fiona: [*reading*]...I put it into water which is cold, dark and wet and I put it in water because iron rusts when it's wet or damp. I think other objects might go rusty if you leave them in a place for a long time. If it gets cold, dark or wet they sometimes go rusty.

Teacher: Right, now in a way, Fiona has sort of picked up the idea best in that - she thought about her nail, she thought back to where she'd actually put it originally and she thought to the four things [*air, water, cold, dark*] that we're now thinking about and thought 'right well in the place that I put my nail - I think it must have been' - what did you say?

Fiona: Cold, dark and wet

Teacher: So those things it was the cold, dark and wet that actually really affected my nail.

Fiona reads out her homework and Lynne uses reported speech 'she thought about her nail...' to paraphrase what Fiona has said. In doing so she reconstructs Fiona's words and meaning, now including inferences about the pattern of thought underlying what Fiona said. In going back to what Fiona actually said, the reader will see that Lynne's reconstruction, 'it was the cold, dark and wet that actually really affected my nail' cannot be justified. In this short piece of reported speech there is interanimation of voices in which the reporting voice penetrates and extends what has been said originally (Voloshinov 1973). By means of this device Lynne is able to model the kind of reasoning which she considers is appropriate in answering the original homework question

d. Teacher differentiates ideas

During the lessons there are instances of students making comments or suggestions in which a number of different ideas are mixed up together. Here the teacher clarifies the situation by drawing attention to and separating out the different ideas.

In Episode 1.2, for example, Lynne helps Andrew to differentiate between the effects of certain conditions on his bike:

Andrew: ...if I scrape me bike and leave it out in the rain, it goes rusty.

Teacher: So, what are you saying? Are you saying it's the - what are you saying is making it go rusty then? Ssh, which of these things, which is causing it to go..

Andrew: ..rain

In Episode 2.3 Gavin poses a question:

Gavin: Can I say something?

Teacher: Yes, Gavin, you can.

Gavin: It's just - say if somebody had a big nail and somebody had a small nail - it could rust a lot quicker wi' t'small one 'cos there's not as much metal to rust.

Teacher: Right, you've got a good point there - but I think what we're testing at the moment is: 'is it actually going to rust at all?', aren't we? Is that fair enough?

Gavin: Yeah, yeah.

Teacher: Is it going to rust? Is it going to rust at all? And how much? We might come onto later.

Gavin raises a valid issue and Lynne responds by differentiating between the questions 'Is it going to rust?' and 'how much will it rust?'

e. Teacher offers a direct choice between ideas.

There are instances in the development of the conceptual line where Lynne offers a straight choice between two ideas. Thus in Episode 2.3 there has been a lot of talk about whether or not there is water in air. Lynne sets up a public resolution of this issue by posing the direct question:

Teacher: So if we just simply take this test-tube, right, and put the nail in, put the nail in and we just put the lid on - what've we got in there? Have we just got air, or have we got air and some water?

Students: No... water...

Teacher: Right, so, what we have to do is make sure we get rid of water.

The intonation of Lynne's voice as she articulates the word 'just' provides a clear marker to the correct answer. Students agree that there must be air and water in the tube and the narrative proceeds.

Summary

The following are the major forms of pedagogical intervention used by Lynne in *shaping* the presentation and development of those ideas which constitute the conceptual line of the narrative:

a. Teacher introduces a new term or idea (using devices such as: anecdotes, links to physical evidence, links to common experience)
b. Teacher guides students through the steps of an argument or explanation by means of a series of key questions.
c. Teacher paraphrases student ideas
d. Teacher differentiates ideas
e. Teacher offers a direct choice between ideas.

The shaping moves include the teacher in both introducing new ideas to the discourse of the interpsychological plane and working on existing ideas.

The conceptual line: selecting ideas

The analysis of Case Study 1 demonstrates that the students raised a large number of ideas and suggestions in classroom talk. Some of those ideas were in line with the development of the narrative (towards the science way of knowing) and others were not. In maintaining the development of the conceptual line of the narrative the teacher therefore needed to act as a *filter* to ideas: some ideas were selected and maintained in the discourse whilst others were discarded. The various forms of pedagogical intervention involved with selecting ideas in the case study are introduced and exemplified below.

a. Teacher selects a student response, or focusses on part of a student response

In Episode 1.2, Lynne is asking the students what it was about the places where they put their nails which made them go rusty:

Cheryl: Moisture
Teacher: Moisture [*writes it on board*]. Damp, moisture. Anything else? Gavin?
Gavin: I put mine in some mud in t'garden.
Teacher: What was it about that mud that you think made yours go rusty?
Gavin: 'Cos it were all wet and all boggy.
Teacher: Wet, so it was wet again. Wet [*writes it on board*]. Right, wet. Any other ideas, Kevin?

When Gavin states that he put his nail in some mud in t'garden, Lynne focusses on the conditions prevailing by asking 'what was it about that mud...'. Gavin offers 'all wet and boggy' as the conditions in his place. Lynne selects part of the response, emphasising the wet condition , 'Wet, so it was wet again. Wet. Right wet'. 'Boggy' is not referred to further.

In Episode 1.3, Lynne is asking the class whether any of the conditions listed on the board have been repeated:

Teacher: Have we actually repeated ourselves with any of the things that we've got on the board at the moment?...Kevin, first of all then - what d'you think we've repeated ourselves with?

Kevin: Erm, rain, damp, then cold.

Teacher: Rain, damp

Lynne is aiming to establish that a number of the listed conditions can be replaced by 'water'. Thus when Kevin responds she accepts 'rain, damp' and ignores 'cold'. A number of pupils call out 'and cold, and condensation'. Lynne selects from these student responses 'condensation'. At this point moisture, condensation, rain, damp, and wet are all underlined on the board and Lynne asks what they have in common.

b. Teacher implicitly accepts a student idea

In some situations the teacher selects a particular student idea with minimal explicit marking of the event. The idea becomes part of the ongoing discourse of the narrative almost by default, with little or no questioning or discussion.

In Episode 1.2, students are suggesting various conditions which might accompany rusting:

Student: like acid rain could..

Teacher: ..but - I mean - did you put..

Student: ..no I didn't..

Teacher: ..you didn't - but you're thinking that it could be - something like acid - that seems to have jogged somebody's memory up here. Matthew?

Matthew: Air

Teacher: Air - right you think air could actually, right...[*writes it on board*]. Air could make it go rusty. Fiona?

At this stage of the lessons, the teacher is acting as a filter for pupil ideas; only if the conditions are accepted by the teacher are they listed on the board. Matthew's suggestion of 'air' is the first time that it has been mentioned in open class talk. Lynne's response is interesting. Even though air is far from being an obvious condition for rusting (it was referred to by only one pupil in the nails activity), it is listed on the board without comment, thereby gaining implicit validation or acceptance from the teacher. In this way, 'air' becomes a condition for further

consideration in the continuing discourse of these lessons; it has become part of the developing narrative.

c. Teacher retrospectively elicits a student response

Here the teacher refers to a student response which has been made at some earlier time, possibly in such a way that it could not be clearly heard by the rest of the class. The teacher returns to select the idea and to register its place in the discourse.

In Episode 2.3, the teacher is raising the question of whether or not there is water in air:

> **Teacher:** Well, shh, hang on - whoever's saying no, can you put your hand up to see if we can have some explanations about this, right, Kelly?
>
> **Kelly:** 'Cos, if air is cold - then it sort a ...
>
> [*others join in - the talk is not clear - but water is mentioned*]
>
> **Teacher:** I think Haley's hit on the right thing actually - in that tube - is there water in air, is there water in air?
>
> **Students:** Yeah, yeah

As Kelly responds 'Cos - if the air is cold', Haley can be heard calling out in the background that there is water in the air. Lynne overlooks what Kelly has said and makes retrospective reference to what Haley is saying.

d. Teacher overlooks a student response

The previous example (Episode 2.3) provides an instance where Lynne overlooks what Kelly has to say. A little later in the same episode teacher and class are talking about designing an experiment to test whether 'dark' is essential for rusting:

> **Teacher:** Right - so let's come back to our experiment now, hang on - now Peter, have you got an idea then?
>
> **Peter:** Miss, I put mine in my pencil case and it went..
>
> **Teacher:** ..you did, yes, people have been trying lots of places. That's right. So - now then, how can we, sh, sh - I think you've stopped thinking, haven't you? Come on, right, go on Cheryl, sh sh.

Lynne responds to Peter's response but overlooks it as she aims to arrive at an acceptable experimental design.

Summary

The following are the major forms of pedagogical intervention used by Lynne in *selecting* for presentation and development those ideas which constitute the conceptual line of the narrative:

a. Teacher selects a student response, or focusses on part of a student response
b. Teacher implicitly accepts a student idea
c. Teacher retrospectively elicits a student response
d. Teacher overlooks a student response

In some cases selection is made explicitly, at other times what the student suggests is taken to be the case and is thus implicitly accepted. The teacher might refer back to an idea introduced at some point earlier in the lessons and use that idea to enable development of the conceptual line. In discussion, some students' ideas are simply overlooked, whilst others may be challenged and over-ruled. All of these moves relate to the process of selecting ideas and thereby contribute to developing the conceptual line of the narrative.

Developing the conceptual line: marking key ideas

A further issue for consideration in analysing the development of the conceptual line of the narrative concerns the ways in which the teacher acts to draw attention to those points in the narrative which are key to its development. Given the amount of talk which occurs on the interpsychological plane of the classroom, then this is an important issue. What does the teacher actually do to mark out those ideas which the students are to pay special attention to and which are to be prioritised in this and future discourse?

a. Teacher repeats an idea

Perhaps the most common single strategy used by Lynne to emphasise a key idea was simply to repeat it. In Episode 2.3 the students are sitting around the front bench and Lynne is setting the scene for the lesson:

> **Teacher:** Now , what I really want to do while you're round the front is to think about how we're going to set this up, right - <u>how</u> we're going to do this investigation. We've got to use things that are in the laboratory, so we can actually use some boiling tubes to put our nails in. Now, how're we going to

do this though - if we're trying to prove that it's just air - how can we do this? Any ideas? Right, sh, sh - Philip first of all.

As Lynne introduces the lesson she repeats the aim of thinking about 'how we're going to set this up' four times with only minor rephrasing. The purpose of the lesson could hardly be made more clear.

b. Teacher asks a student to repeat an idea

In some situations, Lynne asks a student to repeat an idea which the student has suggested. In Episode 3.2, Dawn states that both air and water are needed for rusting to occur:

Dawn: Well, it means that, means, er, you have to have them both together for the nail to go rusty.

Teacher: Right. I think that is an excellent point - and I think it's an excellent way of saying it too. Listen carefully and I'll just re- can you just repeat for everyone what you just said?

Dawn: Erm, if, if you've got air and water mixed together it's the only time when the nail will go rusty.

Teacher: Excellent. You have to have - what you actually said the first time was this - you have to have air and water together to make the iron go rusty - and I think that's excellent - that's an excellent way of describing this.

Dawn offers a good answer to which Lynne reponds very positively: 'that is an excellent point'. Lynne then asks Dawn to repeat what she has said. Dawn does so and Lynne herself repeats the statement once more. This is the conceptual nexus of the three lessons, the teaching narrative has reached its conclusion and Lynne marks the point very clearly through repetition.

c. Teacher enacts a confirmatory exchange with a student

A confirmatory exchange is a brief interaction in which the teacher: states that 'X' is the case; asks a student if 'X' is the case; confirms to all that the student is correct and that 'X' is indeed the case.

For example, in Episode 1.3 it has been established that water is the common factor in a number of conditions (damp, condensation...) identified for rusting locations:

Teacher: Water? So is that the key thing? Ketan what do you think? Is water the key thing here that's linking all of these?
Ketan: Yes
Teacher: You've said rain, damp, moisture, wet, oh - condensation and what I'm asking you is 'what do you mean by that?' So what is the common link perhaps?
Ketan: S'all different forms of water..
Teacher: ..water. Yeah? Anyone disagree with that? That sound reasonable? OK, so we've all of those things we can link up and say that water is important.

When 'water' is suggested, Lynne seizes the word and initiates a confirmatory exchange with Ketan. The form of the exchange is worth examining. Lynne start with a rhetorical question, in which she stresses water as being the key thing linking the others. Ketan agrees that water is the key thing but Lynne continues and reformulates the question before asking Ketan again. Ketan once more offers an acceptable response and Lynne checks consensus within the class.

d. Teacher poses a rhetorical question

In some situations the teacher poses a rhetorical question about an issue after the issue has apparently been resolved. This device allows the teacher to re-rehearse the idea with the class thus emphasising its importance.

In Episode 3.2 Lynne asks all those whose nails went rusty in conditions of air and water to put their hands up:

Teacher: So in fact everyone's got their hand up, telling me that with air and water then the nail has gone very rusty. Right, now then. Is that telling us something very, very important, d'you think? Have we narrowed this information down any more? Right - Dawn?

Lynne draws attention to the weight of support in the class and reiterates the result 'telling me...air and water...very rusty'. Lynne then poses a rhetorical question in emphasising the importance of the finding, 'Is that telling us something very, very important, d'you think?'

e. Teacher uses a particular intonation of the voice:
Throughout the three lessons, Lynne used her voice to signal important ideas. In most cases she achieved this by demanding attention from all of the students and talking in a quiet, careful and very deliberate way.

Summary

The following are the major forms of pedagogical intervention used by Lynne in *marking* those key ideas which constitute the conceptual line of the narrative:

a. Teacher repeats an idea
b. Teacher asks a student to repeat an idea
c. Teacher enacts a confirmatory exchange with a student
d. Teacher poses a rhetorical question
e. Teacher uses a particular intonation of the voice

Of these various pedagogical interventions Lynne used repetition of key ideas a great deal in the lessons observed. Thus she might state an idea, repeat the statement, rephrase and repeat the statement, prompt students to repeat the statement and so on. Lynne also used the intonation of her voice to mark, very effectively, the relative importance of particular sections of talk.

5.4.2 Developing the epistemological line

In analysing the transcripts of the case study lessons one issue which has become apparent is that teaching and learning scientific conceptual knowledge is likely to involve both conceptual and epistemological components.

The epistemological line of the narrative consists of all of those teacher interventions which relate to the nature or framing of scientific knowledge. The different types of interventions observed in Case Study 1 which contribute to the development of the epistemological line are considered below.

a. Teacher introduces a specific epistemological feature

Just as the teacher introduces new conceptual ideas to the discourse then there are occasions when epistemological issues are raised. In Episode 1.4, Lynne refers to the idea of 'essential conditions' for the first time:

> **Teacher:** Maybe, even within this list here [*Water, Salt, Vinegar, Air, Cold, Dark, Dry*] at the bottom, it's just perhaps one or two of <u>those</u> that are the really <u>essential</u> things - the real things that we need for something to rust. Now that's what were going to try and think about now - we're going to try and narrow down, even more...

The notion of 'essential conditions' is thus introduced to the discourse. A scientific view of rusting involves knowing not only that iron, air and water are needed but also that they are the *essential* conditions. The notion of 'essential conditions' provides a particular framing for the scientific knowledge about conditions for rusting and as such can be regarded as an epistemological feature. Other prevailing conditions (such as presence of salt) may affect the rate of rusting but water, air and iron are essential for that process.

b. Teacher refers to the validation of scientific knowledge

During the rusting lessons Lynne presented a range of different warrants to justify and support the development of specific arguments. She argued, for example, that cold cannot be essential for rusting because iron rusts in countries with hot climates. In Episode 2.3 she refers to a different way for making judgements about knowledge:

> **Teacher:** Now that means that we're left with air, water and dark, and what we've got to try and do is to see if we can actually prove whether it is air on its own, perhaps even water on its own, perhaps dark on its own, or a combination of the three which is going to make things go rusty. Now, no matter what you think, doesn't matter what you think, what you're ideas are. The point of this afternoon is that we're going to set up an investigation to test that. Right!

The point could not be made more clearly. A scientific investigation is to be used as the means for judging which conditions or combination of conditions cause rusting to occur. Here personal opinions carry no weight.

In Episode 3.4, Lynne refers once more to the use of scientific experiments in validating knowledge claims. The situation arises when Lynne is stopped by Matthew who has finally been proven to be correct about his hunch that the condition of darkness is not essential for rusting:

> **Matthew:** Miss, Miss, I knew I were right.
>
> **Teacher:** Yes, I knew you were right too - but sometimes with science you just have to prove these things...it's the same process we've been through - there will be people who won't necessarily believe what you're saying perhaps, so you have to go through the process of experiments to try and prove what you're saying is true - which is exactly what you've done, well done.

c. Teacher makes a distinction between different kinds of knowledge

In Epsode 3.2, Lynne draws attention to the difference between the ways of knowing at the start and at the end of the lessons:

> **Teacher:** Let's just think back again. At the start, you were suggesting that it was cold, it was warm, it was dark, it was light, it was acids, or it was, erm, water and air. All those things that were causing rust. That's what we started off thinking. And what we've done now by a process of working it through and doing experiments - we've now come to the point where you've decided and you've proved in fact that it's just two things, with the iron. So there are three things in all which cause rust to happen. Air, water and iron - and I think that is just excellent.

Lynne distinguishes between 'what we started off thinking' and the final idea, arrived at by process of doing experiments, that air, iron and water are needed. In this way Lynne distinguishes between the students' initial spontaneous views and the final scientific view.

The point in the lessons where Lynne explicitly moves away from spontaneous ideas to focus on developing the scientific view point is captured in the piece of transcript used earlier (Episode 2.3):

> **Teacher:** Now, no matter what you think, doesn't matter what you think, what you're ideas are - the point of this afternoon is that we're going to set up an investigation to test that. Right!

Personal, everyday views are no longer of any consequence, the focus now is upon the outcomes of scientific investigations.

Summary

The following are the major forms of pedagogical intervention used by Lynne in developing the *epistemological* line of the narrative:

a. Teacher introduces a specific epistemological feature
b. Teacher refers to the validation of scientific knowledge
c. Teacher makes a distinction between different kinds of knowledge

Two general points can be made about the pedagogical interventions of Case Study 1 relating to epistemological issues. The first is that there were not many of them and the second that they were not prominent in the discourse. More often than not points were left implicit in the talk rather than being addressed directly.

Thus, for example, the notion of 'essential conditions' was raised by the teacher and rehearsed through the small group activity of lesson 1 (Episode 1.4). However, as was outlined in Section 5.2, what is meant by essential conditions was not directly addressed by Lynne and this gave rise to ambiguities in meaning and consequent problems for student understanding.

The impression gained is that in this context of teaching and learning about the conditions needed for rusting the epistemological framing of that knowledge (in terms of essential conditions) is fundamental to understanding the scientific viewpoint but was represented in sporadic threads passing through the narrative.

5.4.3 Promoting shared meaning

The goal of establishing shared meaning within a whole class of students is, even under the most favourable of conditions, an ambitious one. Experiences of talking with just one other person so often provide evidence of the difficulties involved in establishing shared meanings through discourse. It is one matter to negotiate a shared understanding with one other person, how can teachers hope to achieve this with around 30 other people?

Wertsch (1985, p 159) uses the notion of 'situation definition' (see Chapter 2, Section 2.2.2) to draw attention to the fundamental problem which is inherent in establishing shared meanings. He defines situation definition as the way in which objects and events in a situation are represented or defined by individuals. Wertsch makes the point that although the same concrete objects and events may be perceptually available to both teacher and students, they may not 'be in the same situation' because they do not define these objects and events in the same way. The extent to which individuals share the same situation definition is a measure of the 'intersubjectivity', which exists between them.

What steps, then, can teachers take to promote a high level of intersubjectivity between themselves and their students? It seems that there are two parts to this issue. The first is concerned with making the science story available to all of the students or *promoting shared meaning* and the second focuses on clarifying meanings and checking the extent to which intersubjectivity exists, that is *checking student understanding*.

The pedagogical interventions to 'check student understanding' are addressed in the next section (5.4.4). The ways in which the teacher acts to make the 'science

story' available to the whole of the class and to thereby 'promote shared meaning' between teacher and students are considered below.

a. Teacher presents ideas to the whole class

This is the most obvious and common way in which the teacher makes ideas available to all students.

b. Teacher shares the experiences of individual students with the whole class:

In Episode 1.1 Lynne refers to the locations where individual students in the class placed their nails:

> **Teacher:** Now, I went through - you put them in some really interesting places as well. The sort of places you put them like - Dawn put hers on a slope outside in the garden, and Matthew, Andrew and Louise also put theirs outside in the garden. Now, er - Barry put *his* in a cement hole outside in a wall. Claire put hers in a grate. Jill put hers in a cellar. Erm, now all of those went rusty. The following people didn't necessarily put theirs outside but they did put them in...

By means of this review, Lynne shares information with the whole class. At the start of the lesson individual students knew what happened with their nail but largely didn't know what happened with others in the class; here the teacher shares the experiences of individual pupils.

c. Teacher shares group findings with the whole class

In Epsode 3.2, Lynne is seeking feedback on the group experiments with the nail in air and water:

> **Teacher:** Now then, let's think about the last one. Hands up all those people with the air and the water who've got nails that have gone rusty.
>
> **Student:** Ours did have, till he shook it around.
>
> **Teacher:** It's all there though, it's all in the water. Well, that's interesting, that's really, really interesting, because in fact the whole class - I can't see anybody, apart from the people who weren't here to do this who've not got their hands in the air. So in fact everyone's got their hand up, telling me that with air and water then the nail has gone very rusty.

Lynne invites all those in the class whose nails went rusty to put up their hands, a highly visual and effective way of sharing findings. Lynne draws attention to the level of agreement in the class and how this supports the finding that with air and water the nail goes very rusty.

d. Teacher repeats a student idea/response to the whole class

Here the teacher makes an individual student's response available to the whole class by repeating it. In Episode 2.3, Philip suggests an experimental design for testing the 'air' condition:

> **Philip:** Miss, get - put some of metal in one of them boiling tubes and just let some air in and leave it out.
> **Lynne:** Right, good idea, let's start with that, shall we? First of all we get a boiling tube, and - Philip's suggesting that inside there we put a piece of iron, like another smaller nail perhaps - we could use a smaller nail - and that in there if you've got air - then that means that we're testing out whether there's air affecting rusting, right - is there anybody can see any problem with that at the moment?

Lynne repeats Philip's idea making it available to the whole class and asks for comments.

In Episode 2.2 Lynne is making the point that things do go rusty in non-cold conditions:

> **Teacher:** Right. Anyone got any comments about that, just put your hand up, Gavin?
>
> **Gavin:** It can rust without cold.
>
> **Teacher:** It can rust without..
>
> **Gavin:** ..cold
>
> **Teacher:** ..cold. It can rust without cold, right. 'Cos d'you get what I'm, d'you get what I'm getting at? Nicola, what does that mean? Gavin is saying that things can rust without cold - should we then have cold in our list? Is cold essential for rusting then?

Lynne draws attention to and repeats what Gavin has said as she develops the argument that cold is not essential for rusting.

e. Teacher jointly reviews an idea with a student in front of the whole class

Here the teacher reviews an idea which has already been suggested by jointly talking it through with another student.

In Episode 2.3, Cheryl has just suggested how the dark/light condition might be incorporated in the experimental design ('set all of 'em up twice and put one lot in the dark'). Lynne calls on Gavin to re-rehearse the argument:

> **Teacher:** Right, I think we're getting there - I think Gavin's even cracked it finally. Come on, what we're going to do? Put them all..
>
> **Gavin:** ..put them all in the dark.
>
> **Teacher:** Right - if you put them <u>all</u> in the dark , we've got to have some that are..?
>
> **Gavin:** ..in light.
>
> **Teacher:** Right. OK. That's it - what we can do.

Cheryl's original response was made to Lynne. Lynne now takes that idea and makes it available to the whole class by re-rehearsing it with Gavin.

f. Teacher uses the 'collective we' form in making a statement to the class

Throughout the lessons Lynne uses the 'collective we' expression in referring to what has been done, said and thought. In Episode 1.4, Lynne is reviewing progress in the lesson thus far:

> **Teacher:** Right, OK, fine. Think what we've done now. What we've actually <u>done</u> is try to draw together the reasons why you think your nails have gone rusty. And we've actually tried to tease out what are the <u>main</u> factors. Now, what we can do now - I think we've probably teased out some of the main ones here, but like you're all just saying, maybe it's not <u>all</u> of these.

Edwards and Mercer (1987, p.141) also draw attention to this use of 'we' and see the shift from using 'I' to 'we' as, 'an overt expression of the teacher's communicative purpose to establish certain observations and interpretations as joint'. It is a mode of intervention to promote shared understanding.

Summary

The following are the major forms of pedagogical intervention used by Lynne in making the science story available to all of the students and thereby *promoting shared meaning:*

a. Teacher presents ideas to the whole class
b. Teacher shares the experiences of individual students with the whole class
c. Teacher shares group findings with the whole class
d. Teacher repeats a student idea/response to the whole class
e. Teacher jointly reviews an idea with a student in front of the whole class
f. Teacher uses the 'collective we' form in making a statement to the class

All of these forms of pedagogical intervention relate to the function of making ideas publicly available in the classroom. In example 'a' the source of the ideas is the teacher but in all of the other examples the ideas originate with students. The teacher's general role in this kind of intervention is to take each idea and re-represent it on the interpsychological plane of the classroom. In the earlier example Philip makes a suggestion about an experimental design. As Philip makes this suggestion he is talking directly to Lynne; Lynne then takes his idea and relays it to the rest of the class making it available to all of the students.

5.4.4 Checking student understanding

This part of the narrative concerns all of those interventions made by the teacher to check on the level of intersubjectivity between herself and the students.

a. Teacher asks for clarification of student ideas

The teacher checks on what a student actually means by a particular statement. In Episode 3.2, Lynne is trying to establish just what had happened to Rebecca's boiling tube:

Rebecca: Miss, when I spilt it all out - a lot of it flew out.

Teacher: Right, right . So, you put the boiled water in here, and then you dropped the tube and it - no..

Rebecca: ..the oil Miss...

Teacher: ..you spilt the oil - it dropped out - so that could have been - did any water get out as well?

Rebecca: Yeah, it were all over..

Teacher: ..so it was all around.

b. Teacher checks student understanding of particular ideas

In Episode 2.3, Lynne introduces calcium chloride as a substance that will absorb water and then checks student understanding of the effect that it will have in the experiment :

Teacher: Sh, let me just show you what to do, 'cos you may not know this. There is a substance actually which we've put in the bottom which is called calcium chloride, and that will absorb water from the air. So, in other words, if we now put the top onto that boiling tube with the calcium chloride in the bottom, right, then it'll take all the water out, and what's the only thing we're left with?

Students: Air, air

Teacher: Air, right, so that means that in this test-tube here if that's what we do, put a little thing in with our calcium chloride at the bottom, right - then all we're going to have in there, in that test-tube, is air. Right? OK.

Lynne outlines that calcium chloride 'will absorb water from the air' and then checks that the students understand its effect, 'what's the only thing we're left with?'

c. Teacher checks consensus in the class about certain ideas.

In Episode 2.2, Lynne is trying to establish that the cold condition is not essential for rusting:

Teacher: ...Anyone got any comments about that? Just put your hand up. Gavin?

Gavin: It can rust without cold.

Teacher: It can rust without..

Gavin: ..cold..

Teacher: ..cold. It can rust without cold - right. 'Cos d'you get what I'm - d'you get what I'm getting at, sh, Nicola - what does that mean? Gavin is saying that things can rust without cold - should we then have cold in our list? Is cold essential for rusting then?

Students: [*chorus*] No.

Teacher: Is there anybody still unsure about that? Clare? Shh, listen carefully.

Lynne initially asks for comments and Gavin confirms that things 'can rust without cold'. Lynne checks with the whole class that they are following the argument, 'Do you get what I'm getting at?' Having put forward an important argument it seems that Lynne is keen to check that the students are following her line of reasoning. Lynne reiterates what has been said 'Gavin is saying that things can rust without cold' and asks 'should we then have cold in our list, is cold essential for rusting?' Despite the chorus of 'No's' from the class, Lynne probes to see if there are still any doupts as she checks consensus in the class: 'Is there anybody that still would not agree with that'.

Summary

The following are the major forms of pedagogical intervention used by Lynne in *checking student understanding* of the developing science story:

a. Teacher asks for clarification of student ideas
b. Teacher checks student understanding of particular ideas
c. Teacher checks consensus in the class about certain ideas.

The three forms of intervention identified here cover three different kinds of situation. In the first the teacher is asking the student: 'what do you mean by that?'; in the second the teacher is asking: 'do you understand what I mean?'; in the third the teacher is asking: 'do we all agree about this?' Each of these three kinds of intervention is aimed at checking the level of intersubjectivity between teacher and students.

5.4.5 Maintaining the narrative

This final form of pedagogical intervention which constitutes the narrative concerns the ways in which the teacher takes action to sustain its form and direction. Here the teacher is involved in talking *about* the narrative, rather than 'talking the narrative'. In Case Study 1 Lynne used a number of different interventions to sustain the form and direction of the narrative.

a. Teacher declares intentions/ states aims:

Throughout the lessons Lynne stated the aims of particular activies and reminded the students of what they were attempting to do as they were engaged in those activities. In Episode 1.2, Lynne states what is to be done next in the lesson:

Teacher: So, what I want to do - put on the board, is put down your ideas of what it was about the places that made your nail go rusty.

A little later on Lynne reminds the class:

Teacher: Haley's saying perhaps cold. Cold? [*mutters*] Well, is there anybody who put there's in a hot place and it went rusty? [*mutters*] Don't forget you're thinking about where you put your nail - what it was - what factors - what things in that place - were making it go rusty. Yes?

Through interventions such as these Lynne offers a 'commentary' on the work in hand: 'so - what I want to do', 'don't forget you're thinking about where you put your nail'. She is talking about the work in hand and offering a reminder to the students of 'where things are up to' in the evolving narrative.

b. Teacher refocusses discussion/ maintains focus

The teacher has a clear perspective on the direction in which she wishes the narrative to develop and intervenes from time to time to keep the narrative on track. In Episode 2.3 Dawn brings up the issue of dark and light conditions:

Teacher: Right, so we need to put..?

Dawn: ..put a light.

Teacher: Right - put a light on one all the time.

Dawn: Put cloth round it..

Teacher: ..or put one in the dark all the time - that's a good idea, so can we come back to dark and light in a minute - 'cos at the moment - let's keep thinking about the air.

Dawn makes suggestions relating to dark and light and Lynne steers the talk back to earlier unresolved questions.

c. Teacher rehearses/anticipates possible outcomes

There are instances where the teacher intervenes to maintain the direction of the narrative by anticipating what happens next. In this way the teacher prepares the ground for the students and sensitises them to what is likely to occur (and what they should look out for or aim for). In Episode 1.5, Lynne is talking to a small group as they work on the task, 'Narrowing down to essential factors':

Teacher: Right, how're you doing? Well done! [*on seeing the progress made*] The idea is that when you've done all of this at the end, we'll probably end up with one or two or three columns that have got all ticks in them and that's how you're beginning to sort out exactly which thing it is, yeah?

Students: Yeah.

Teacher: OK, well done.

In this brief exchange Lynne anticipates the outcome in suggesting that, 'We'll probably end up with one or two or three columns that have got all ticks in them'. In this way she gives a clear indication to the students of how she expects the exercise will turn out and therefore what they should be aiming for.

d. Teacher reviews the progress of the narrative

Throughout the teaching there are instances where the teacher reviews with the class the findings, thoughts and decisions arrived at. At the start of Lesson 3, Lynne presents a major review:

> **Teacher:** ...just to remind you, right, just to remind you. We were trying to narrow down all the factors we were thinking about that caused rusting - to the absolute vital ones that were absolutely essential. And we'd started to narrow it down by doing the work on the posters - which had left us with four things that we thought were essential - we were left with air, water, light and dark - well cold, sorry, dark and cold, wasn't it for your group? But we eliminated cold because we realised that if you live in a hot country you still have lots of things around you that go rusty, so we thought - well if, therefore - heat - warmth and cold doesn't have any effect. So that left us with these three things - air, water and dark. So you set up your experiments last week and you wrote up the method and drew your diagrams. Now today, we need to look at these results and see if we have narrowed it down any further to the absolute essential things that are needed for rusting.

In talking through the review Lynne stresses the aim of the teaching, 'narrowing down factors to the absolutely vital or essential ones' and also reminds the class of some of the key arguments rehearsed in previous lessons. Thus 'we eliminated cold...because in a hot country...things go rusty'; the argument is presented in an abbreviated form and acts as a common reference point for teacher and class. Throughout, Lynne uses the 'collective we' form and offers no opportunity for students to speak; Lynne is presenting the review as though it is established shared knowledge. Finally Lynne repeats the the aim for today's lesson: 'to narrow down to the absolutely essential things'. In this way Lynne includes elements of both looking forwards and backwards in presenting this commentary on the narrative.

Summary

The following are the major forms of pedagogical intervention used by Lynne in *maintaining the narrative:*

a. Teacher declares intentions/ states aims
b. Teacher refocusses discussion/ maintains focus
c. Teacher rehearses/anticipates possible outcomes
d. Teacher reviews the progress of the narrative

These are the strategies used by the teacher to maintain the form and direction of the narrative. At different times the teacher talks through and reminds students of aims; refocuses classroom discussion ; looks forward to possible conclusions and outcomes; reviews and summarises intermediate and end points.

5.4.6 Summary: The forms of pedagogical intervention

In this section the five different forms or categories of pedagogical intervention which constitute the teaching narrative have been set out and exemplified. The full range of interventions identified in the first case study is as listed below:

1. Developing the conceptual line

Shaping Ideas

a. Teacher introduces a new term or idea (using devices such as: anecdotes; links to physical evidence; links to common experience)
b. Teacher guides students through the steps of an argument or explanation by means of a series of key questions.
c. Teacher paraphrases student ideas
d. Teacher differentiates ideas
e. Teacher offers a direct choice between ideas.

Selecting Ideas

a. Teacher selects a student response, or focusses on part of a student response
b. Teacher implicitly accepts a student idea
c. Teacher retrospectively elicits a student response
d. Teacher overlooks a student response

Marking Key Ideas

a. Teacher repeats an idea
b. Teacher asks a student to repeat an idea
c. Teacher enacts a confirmatory exchange with a student
d. Teacher poses a rhetorical question
e. Teacher uses a particular intonation of the voice

2. *Developing the Epistemological Line*
   a. Teacher introduces a specific epistemological feature
   b. Teacher refers to the validation of scientific knowledge
   c. Teacher makes a distinction between different kinds of knowledge

3. *Promoting Shared Meaning*
   a. Teacher presents ideas to the whole class
   b. Teacher shares the experiences of individual students with the whole class
   c. Teacher shares group findings with the whole class
   d. Teacher repeats a student idea/response to the whole class
   e. Teacher jointly reviews an idea with a student in front of the whole class
   f. Teacher uses the 'collective we' form in making a statement to the class

4. *Checking Student Understanding*
   a. Teacher asks for clarification of student ideas
   b. Teacher checks student understanding of particular ideas
   c. Teacher checks consensus in the class about certain ideas.

5. *Maintaining the Narrative*
   a. Teacher declares intentions/ states aims
   b. Teacher refocusses discussion/ maintains focus
   c. Teacher rehearses/anticipates possible outcomes
   d. Teacher reviews the progress of the narrative

5.5 The authoritative and dialogic nature of the discourse on the interpsychological plane

In the previous section a detailed analysis of the various forms of pedagogical intervention which constitute the teaching narrative has been presented. In this section the *nature* of the classroom discourse is examined in terms of its authoritative and dialogic qualities.

The analysis which follows is based on the Lotman/Bakhtin notions of the authoritative (univocal) and dialogic (internally persuasive) functions of text which were introduced in Section 2.5.3 of Chapter 2. Briefly, Lotman has identified a functional duality of texts (both spoken and written) in which univocal texts serve the function of conveying meanings adequately whilst dialogic texts serve the function of generating new meanings. Bakhtin has characterised the difference between these forms of text in terms of the authority relations associated with each. According to Bakhtin authoritative (univocal) discourse is based on the assumption that utterances and their meanings are fixed, whilst internally persuasive discourse (dialogic) allows dialogic interanimation of voices through which new meanings can be generated. These ideas were summarised earlier in Figure 4.2.

The analysis which follows has two main components. The first involves taking sequences of discourse from the case study lessons and analysing them in terms of the authoritative-dialogic dimension. The second component of the analysis involves developing a characterisation of authoritative and dialogic discourse based on the patterns of classroom talk in the case study.

5.5.1 Analysis of discourse: authoritative and dialogic qualities

In this section, sequences of text (a sequence might include up to three episodes) are taken and examined in relation to their authoritative and dialogic qualities. The analysis focusses first of all on the discourse of the opening episodes of Lesson 1, further sequences of discourse from the remaining lessons are then considered.

In addressing issues relating to the function of the classroom talk, the analysis is based on questions such as: What is the function of this sequence of discourse with regard to meaning making? What function does this sequence of talk serve within the context of the developing teaching narrative? The interpretations

developed here are therefore based on the discourse as it was enacted rather than on any attempt to establish the intended function of the discourse (What was the teacher trying to do here?).

Sequence 1: What was it about those places that made the nails go rusty?

Right at the start of the lessons the students had carried out the 'Rusty Nail' task and the classroom talk focussed on where the nails had been placed and the conditions prevailing in those places. One striking feature of the discourse of the opening episodes concerns the number of 'voices' which are represented either directly or indirectly. Thus in reviewing where students had placed their nails (Episode 1.1), Lynne reports on the ideas of twelve different students:

> **Teacher:** Now, I went through - you put them in some really interesting places as well. The sort of places you put them like - Dawn put hers on a slope outside in the garden, and Matthew, Andrew and Louise also put theirs outside in the garden...Now - er - Barry put <u>his</u> in a cement hole outside in a wall. Claire put hers in a grate. Jill put hers in a cellar. Erm - now all of those went rusty. The following people didn't necessarily put theirs ...

A further nine students then contributed ideas on 'what it was about the places that made the nails go rusty' (Episode 1.2):

> **Teacher:** So - what I want to do - put on the board, is perhaps put down your ideas of what it was about the places that made your nail go rusty. What do you think it was - thinking about the places - that made your nail go rusty?...
> **Fiona:** Condensation might.
> **Teacher:** Condensation - right [writes it on the board]. Dawn?
> **Dawn:** Could it be like - climate like - if it's hot or cold?
> **Teacher:** Hot or cold. Do some other people think that hot or cold might be something significant, in making something go rusty? Hot or cold - is that an idea - yeah? Hot. Which? Both of them or just one?
> **Dawn:** Both
> **Teacher:** Haley's saying perhaps cold.

Lynne's first question here is an open invitation to the class to offer their ideas. The question is framed in such a way that it encourages students to articulate their own thoughts, 'What do you think it was...?' The students respond accordingly and present their ideas as possibilities rather than as necessarily 'correct answers'. Thus Fiona suggests that 'condensation might'; Dawn tentatively suggests, 'Could

it be like - climate like - if it's hot or cold?' Even as Dawn makes her suggestion she invites comment; in the words of Barnes and Todd (1995, p.161), she offers a suggestion which 'carries within it the grounds of its own challenge'. Lynne takes this further in asking for other opinions 'Do some other people think?' and drawing attention to individual views, 'Haley's saying perhaps cold...'.

One student offers 'acid rain' as a possible condition for rusting to occur. Lynne questions whether the nail was actually left in acid rain conditions (it was not):

Teacher: ...OK, anything else? Anything else about the place..
Student: ..like acid rain could..
Teacher: ..but - I mean - did you put..
Student: ..no I didn't..
Teacher: ..you didn't - but you're thinking that it could be - something like acid...

The abbreviated and overlapping form of this exchange is worthy of note. The student suggests, 'like acid rain could..'. Lynne challenges this '..but - I mean - did you put..'. The pupil admits '..no I didn't'. The brevity and overlapping of the utterances indicates how each anticipates the meaning of the other, as the exchange proceeds.

Lynne continues by seeking the views of other members of the class:

Teacher: Right, have we got anything else here it could have been? Anyone that hasn't given me an answer yet? No? Andrew then.
Andrew: On me bike - if I scrape me bike and leave it out in the rain, it goes rusty.
Teacher: So - what are you saying? Are you saying it's the - what are you saying is making it go rusty then? Ssh...which of these things, which is causing it to go...
Andrew: [inaudible]
Teacher: Pardon?...You said, it's when your bike's in the rain and when you scratch it - which of these things is causing it to go rusty, d'you think?
Student: Rain
Teacher: Well, someone's suggesting it's the rain rather than the..
Student: ..yes..
Teacher: ..rather than the scratch you mean..
Students: ..yeah, yeah

Andrew offers a suggestion about his bike. Lynne checks his meaning, 'So - what are you saying?' A different student offers an answer and there is an exchange in which the abbreviated utterances of teacher and student overlap, 'Well, someone's suggesting it's the rain rather than the'..'yes'..'rather than the scratch you mean?'..'yeah, yeah'. There is close interanimation of voices as Andrew first of all makes a suggestion whose meaning is probed by Lynne and then other students in the class become involved in talking through the issue. Lynne tries to move on but another student wishes to say something about the rusting bike and the effect of the rain:

Student: Erm - it's - when it's raining it's not that one which - it's when it's dry it goes rusty. When it's raining, don't do much - when it's dry it goes rusty.

Teacher: Right, so does it, does it need - are you saying it needs the rain?

Student: It's got to rain and then it's got to dry to go rusty.

Teacher: So rain and dry. OK.

Once again a student spontaneously makes a suggestion (that rusting occurs 'when it's dry'). Lynne checks what the student means and then moves on.

This whole sequence includes a number of interesting features. First of all, the discourse is multi-voiced in involving a number of different speakers and including reports of other students' ideas. At different times the teacher invites ideas through open questions and attempts to clarify meanings through asking follow-up questions. The students make spontaneous contributions to the discourse and often articulate their ideas in a tentative, provisional way rather than present them as 'finished thoughts'. Many of the students' contributions are fashioned in whole phrases and sentences rather than in single words. At different times in the discourse there is overlap of contributions, abbreviated utterances and interanimation of ideas between teacher and students. The contribution of one student might be taken up and commented upon by others, taking the discourse in directions which could not have been anticipated. Ideas are offered and received as 'generators of meaning' or 'thinking devices' rather than as 'fixed truths'. This particular sequence of discourse is located towards the *dialogic* end of the authoritative-dialogic continuum and, of course, this is consistent with the teacher's intention of sharing experiences and generating ideas with her students.

The very next sequence of discourse (Episode 1.3) is rather different in nature as the teacher encourages the class to examine the list of conditions which has been written down on the chalkboard.

Sequence 2: Have we repeated ourselves with any of the conditions?

Lynne (Episode 1.3) is referring to the list of suggested conditions on the chalkboard:

Teacher: Right we've got a lot of things at the top here. Now - what I'd like you to do first of all is to look at these suggestions - because - is there anything that some of them actually have in common - have we actually repeated ourselves with any of the things that we've got on the board at the moment?...Kevin, first of all then - what d'you think we've repeated ourselves with?

Kevin: Erm - rain, damp...then cold.

Teacher: Rain, damp.

When Kevin suggests 'rain, damp...then cold' Lynne ignores 'cold' and selects 'rain and damp'; a number of students call out 'and cold, and condensation' and Lynne selects from these responses 'condensation'. At this point moisture, condensation, rain, damp, and wet are all underlined on the board and Lynne asks what they have in common. She is searching for the term 'water'.

Teacher: ...what have we got in common perhaps with all the things we've underlined. What is it Kevin?

Kevin: They're all wet.

Teacher: Well - they're all wet - so what do we mean by wet then. Is there something else about wet?

Students: No - wet [other mutters]

Teacher: What is wet perhaps?

Student: [chorus] Water!! [laughter]

Teacher: Water? So is that the key thing? Ketan what do you think? Is water the key thing here that's linking all of these...

Ketan: Yes.

Teacher: You've said rain, damp, moisture, wet, oh...condensation and what I'm asking you is 'what do you mean by that?' So what is the common link perhaps?

Ketan: S'all different forms of water.

Teacher: Water. Yeah? Anyone disagree with that? That sound reasonable? OK, so we've all of those things we can link up and say that water is important.

In contrast to the previous sequence, Lynne starts here by asking the kind of instructional question ('what have we got in common perhaps with all the things we've underlined') to which she already knows the answer ('water'). This leads to brief exchanges in which the students are required to 'guess what teacher is thinking' and the students find it amusing when somebody eventually hits upon the acceptable answer. When 'water' is suggested, Lynne seizes the word and initiates a confirmatory exchange with Ketan.

In this brief sequence the teacher has the clear aim of reformulating 'condensation', 'moisture' and the other terms as 'water'. In a bid to achieve this aim, the teacher: selects from student responses; poses a series of instructional questions; initiates a confirmatory exchange with a student. Each of these interventions draws heavily upon the teacher's authority and it is the teacher who dominates the discourse; the students' responses tend to be in single words. In Bakhtin's (1981) words, this is an authoritative text which allows 'no play with its borders'. Although, a number of different voices are represented in the sequence (both directly through the contributions of Kevin and Ketan, and indirectly through the voices represented in the words 'moisture', 'condensation', 'rain' etc) it is clear that the discourse is heavily controlled by the teacher who limits the extent to which interanimation of ideas is allowed to occur. This sequence of discourse is located towards the authoritative end of the authoritative-dialogic dimension.

Just as Lynne is completing her exchange with Ketan, Matthew can be heard asking the question, of no-one in particular, 'How can the dark make the nail go rusty?' Lynne offers Matthew the opportunity to state his view.

Sequence 3: How can the dark make the nail go rusty?

Teacher: ...Matthew are you - is there something you <u>don't</u> agree with then?

Matthew: Wit' dark - put in the dark - wouldn't go rusty.

Teacher: ...Sean, then, go on tell me a bit more about that.

Sean: Dark, it's just in't dark and it won't do nowt to t'nail.

Teacher: So like we've talked about damp and moisture really being water, what is dark to do with? Shh! - Shh! What is the <u>dark</u> to do with then? Kevin?

Kevin: Miss - dry and air can go together. They're both dry and they don't contain water.

Teacher: Is dry and dark the same?

Students: No - no

Teacher: No?
Student: No because if it's dark it's damp and wet.
Teacher: Right so we've still got two different things. Dawn!
Dawn: Well. When it's - it's like when it's dark there's no sunlight so there's no warmth - so like that's linked to cold.
Andrew: If it was dark in here, everything would go rusty.
Students: [everybody is talking now]
Teacher: Right, OK. Shh! Have we got dark down? We have. Right - OK - fine. Think what we've done now. What we've actually done is try to draw together the reasons why you think your nails have gone rusty...

This is an interesting (and confusing!) sequence which is initiated by Matthew's spontaneous comment. Matthew is challenging the idea raised by Gavin that darkness causes rusting and Sean joins in to support him. Lynne appears to 'misread' their meaning because she continues with the pattern established with the water issue, of trying to identify any duplicate features on the list. 'What is dark to do with?' Some interesting responses arise from this. Kevin suggests that 'dry and air can go together, they're both dry and they don't contain water'. Lynne overlooks Kevin's suggestion and asks whether dry and dark are the same. There is a chorus of 'no's' and Dawn explains that, 'when it's dark there's no sunlight, so there's no warmth, so that's linked to cold'. Dawn is responding in terms of a *situation* which she has in mind; a situation where dark and cold go together. Whereas the scientific view would see dark and cold as being completely separate conditions, Dawn is able to link them through a particular context. The sequence ends with Lynne checking to see whether dark is listed on the board, 'We have. Right - OK - fine', which is interesting given that the dialogue was initially prompted by Matthew questioning why the darkness factor was listed!

This short sequence of discourse vividly exemplifies authentic dialogue in which a number of students make spontaneous contributions, wanting their point of view to be heard. There is a genuine struggle to reach common meaning and in the event this struggle is *not* resolved before the teacher signals that it is time to move on by presenting a review of ideas:

Teacher: Right - OK - fine. Think what we've done now. What we've actually done is try to draw together the reasons why you think your nails have gone rusty. And we've actually tried to tease out what are the main factors. Now - what we can do now - I think we've probably teased out some

of the main ones here, but like you're all just saying - maybe it's not all of these.

This review is presented in such a way that it would be very difficult for students to interrupt. Lynne's voice takes on a formal air and as she speaks she looks around and raises a finger to indicate that she does not want to be interrupted. The students recognise the authoritative nature of the statement and remain quiet, the time for dialogue has passed.

The 'rhythm' of the discourse in the teaching narrative

In the analysis of discourse set out above, a picture is presented in which the discourse shifts between authoritative and dialogic forms. In the first sequence the teacher encourages the students to make contributions about the conditions for rusting and largely accepts all that is offered. One outcome of this approach is that there is a duplication of terms based on 'water'. The teacher recognises this and addresses the issue in the second sequence through a series of closed questions which contrasts markedly in style and function with the first sequence. The authority-based approach of the second sequence is interrupted when Matthew mutters his question and prompts further genuine dialogue. This dialogue, in turn, is brought to a close when the teacher intervenes to present an authoritative summary of progress to date.

Such shifting, to and fro, between authoritative and dialogic discourse is repeated throughout the three lessons, where now the teacher enables dialogic exchanges and then follows these up with more authoritative, univocal interventions. The classroom discourse is, at one moment, 'opened up' for discussion as ideas are traded and meanings explored, and then 'closed down' once more as the teacher takes back the initiative and makes a summarising statement or moves onto the next issue. This shifting between functions constitutes a kind of pattern in the discourse; this pattern is referred to here as the *rhythm of the discourse* in the teaching narrative. It is clear that the rhythm of the discourse is under the control of the teacher and here we have evidence of Lynne moving between dialogic and authoritative functions; other teachers might focus almost exclusively on an authoritative approach and the fluctuating nature of the rhythm would be less pronounced.

One inescapable feature of teaching science is that the learning goals are fixed in terms of the accepted scientific view. Given the fact that there are these fixed goals to work towards then one might expect that authoritative discourse would

predominate in most science teaching. The analysis presented above demonstrates, however, the way in which the discourse might shift between authoritative and dialogic functions. The impression gained from reviewing the whole performance of the three lessons, is one of the teacher closely controlling the development of the teaching narrative (towards the specific learning goals) through her position of authority, but also allowing and supporting dialogic interludes as particular issues are taken up and discussed. It is in this way, with dialogic interludes punctuating authoritative discourse, that a rhythm in the discourse can be said to exist throughout this particular teaching performance.

These ideas are now considered further as they are applied to a final pair of sequences taken from Lessons 2 and 3. The sequence from Lesson 2, in which teacher and class talk through the design of the scientific experiment to establish conditions essential for rusting (Episode 2.3), is interesting for the way in which the teacher apparently involves the students in the discourse, but maintains such close control that it is clear that the discourse is essentially authoritative in nature:

Sequence 4: Designing the scientific experiments (air alone condition)

Teacher: Now - what I really want to do while you're round the front is to think about how we're going to set this up - right - how we're going to do this investigation... Any ideas? Right - sh, sh - Philip first of all.

Philip: Miss - get - put some of metal in one of them boiling tubes and just let some air in and leave it out...

Lynne: Right - good idea - let's start with that, shall we? First of all we get a boiling tube - and - Philip's suggesting that inside there we put a piece of iron, like another smaller nail perhaps - we could use a smaller nail - and that in there if you've got air - then that means that we're testing out whether there's air affecting rusting - right - is there anybody can see any problem with that at the moment? Can I just ask somebody else first? Is that fine, or is there any problem with that - yes - Dawn?

Dawn: Well if - if like you've just got air in it - well what about at night-time when it gets dark.. [Pupil continues but teacher interrupts]

Teacher: ..right - so we need to put..

Dawn: ..put a light.

Teacher: Right - put a light on one all the time.

Dawn: Put cloth round it..

Teacher: ..or put one in the dark all the time - that's a good idea, so can we come back to dark and light in a minute - 'cos at the moment - let's keep thinking about the air. If you've got air in here - if we just put a cork on - have you only got air in here?

Students: No, no.

Teacher: Have we got rid of the other - have we got rid of water?

Students: Yeah, yeah, no, no. [Clamour of no's]

Teacher: Well, sh - hang on - whoever's saying no, can you put your hand up to see if we can have some explanations about this - right - Kelly?

Kelly: 'Cos - if air is cold - then it sort of...

[Others join in - the talk is not clear - but water is mentioned.]

Teacher: I think Haley's hit on the right thing actually - in that tube - is there water in air - is there water in air?

Students: Yeah, yeah.

Teacher: Right - well - there's one quite - right - sh, sh - that's what I thought - there's one very good way of checking that - d'you want to just breathe on that for me, Dean? Right - Dean's just breathed on to a mirror - right - now there's air - so he's breathing out some sort of air - but also, what else has appeared on the mirror - someone mentioned that word.

Students: Steam, condensation.

Teacher: Condensation - right. So if we just simply take this test-tube, right, and put the nail in, put the nail in and we just put the lid on - what've we got in there? Have we just got air or have we got air and some water?

Students: No... water...

Although a number of different voices are represented in this text, it is clear that Lynne is closely controlling the development of the discourse. Lynne's sole intention is to arrive at an acceptable experimental design to test whether air alone can cause rusting. To achieve this she directs the discourse through a series of instructional questions and employs further authoritative interventions: she indicates that there is a 'problem' with Philip's initial suggestion; refocusses

attention on the air issue after Dawn introduces ideas about dark and light; draws attention to the problem of water in air; overlooks Kelly's suggestion about 'cold'; retrospectively elicits Haley's suggestion of 'water'. Reading back through the text it is possible to string together the teacher's individual utterances and see that they constitute what is essentially a continuous univocal delivery.

The final sequence taken from the case study is selected to demonstrate that even when the teacher has a specific teaching goal in mind it is possible to achieve this goal through dialogue, rather than through the kind of univocal delivery exemplified in the previous sequence. This example is taken from Lesson 3 and focusses on the review of the experiments. Rebecca's nail which was placed in a test-tube containing boiled water covered in oil has gone rusty. This is not what the teacher expected.

Sequence 5: Review of experimental findings for 'no-air' condition

Lynne asks the class to examine the tubes containing boiled water (with no air) and Rebecca signals that there is rust in her tube. Hers is the only one which contains any rust.

Teacher: ...Right - for the majority of people then in the class - we've actually found that if you just have water and no air then again, we haven't got any rust. Now the thing is, when you're doing experiments - sometimes, if you do get a situation and you have an odd one out if you like - you have to think about why you've got an odd one out... anyone got any ideas - Claire?

Claire: Maybe not enough oil, some air might have got in.

Teacher: Right - so one point might have been that there - in fact it is quite a thin layer of air - of oil - but it still seems to cover it quite well. So it's a good point, but I think, looking at it- what d'you think, Matthew? Do you think there's enough oil on there to stop air getting back?

Matthew: No.

Teacher: No - well actually Matthew says perhaps there isn't quite enough, so that might have been one point - right? Is there another reason though - Rebecca - can you think about your own experiment then, and think why?

Rebecca: Miss, when I spilt it all out - a lot of it flew out.

Teacher: Right - right. So - you put the boiled water in here, and then you dropped the tube and it - no?

Rebecca: The oil Miss..

Teacher: ..you spilt the oil - it dropped out - so that could have been - did any water get out as well?

Rebecca: Yeah, it were all over..

Teacher: ..so it was all around. Can anyone think why that might have affected Rebecca's experiment then? Katy?

Katy: Miss, it - she might have tipped it up.

Teacher: Right - Philip do want to give me another answer?

Philip: Y'know when she spilt it..

Teacher: ..yes..

Philip: ..it could have cooled down and let air in.

Teacher: Right - I think that's a very good point - and I heard somebody down here - was it Dean? - say the same thing. Perhaps when it spilt - the air got in and I think that's quite an important factor...

The sequence starts with Lynne asking for ideas about why the nail has gone rusty. Claire tentatively suggests, 'Maybe not enough oil, some air might have got in'; it is clear that Lynne is not convinced by Claire's idea and she turns to Matthew, possibly expecting him to voice her reservations. In fact Matthew offers support to Claire and Lynne leaves the issue open, 'well actually Matthew says perhaps there isn't quite enough, so that might have been one point - right?' Lynne turns to Rebecca and it becomes apparent that there are very good reasons for the nail rusting! Even now Lynne draws other students into the dialogue to talk through the way in which Rebecca's accident would affect her nail. Katy and Philip make contributions to the developing explanation which Lynne finally summarises.

Here the teacher has been able to support a sequence of dialogic discourse which bears many of the characteristics outlined earlier. The teacher encourages contributions through open questions, does not immediately 'close down' issues which are contrary to her own thinking and sustains the dialogue so that the issues are fully dealt with. The students, on the other hand, respond with spontaneous suggestions and ideas, which are made in a tentative way enabling responses from others.

5.5.2 Characteristic features of authoritative and dialogic discourse

Through analysing the discourse of this case study as exemplified in the preceding sections it has been possible to start to develop a characterisation of both authoritative and dialogic discourse. The characterisation is presented below in three parts relating to: general features of the discourse; the nature of teacher utterances; the nature of student utterances.

General features of discourse

Authoritative discourse	Dialogic discourse
• focussed principally on the 'information transmitting' voice	• involving several voices
• low internal heterogeneity: interanimation of voices limited	• high internal heterogeneity: rich in interanimation of voices
• closed: new voices not acknowledged, unless supporting the message to be transmitted	• open: new voices contribute to the act of developing meaning
• fixed intent: outcome controlled	• generative: outcome may not be anticipated.

Nature of teacher utterances

Authoritative discourse	Dialogic discourse
• 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'
• often based on instructional questions: where the teacher already has the answer	• often based on open or genuine questions: where the answer is not obvious
• often involving formal review or factual statements which offer few 'invitations' to dialogue	• directed towards sustaining dialogue
• selectively drawing on other voices	• representing a range of other voices

Nature of student utterances

Authoritative discourse	Dialogic discourse
• often made in response to teacher question	• often spontaneously offered (not elicited by teacher) and triggered by comments from other students.
• often consisting of single, detached words interspersed in teacher delivery	• often consisting of ideas expressed in phrases and in the context of on-going dialogue
• often direct assertions	• often tentative suggestions open to interpretation and development by others

In interpreting the positions represented in each of these columns it is worth remembering the point made by Wertsch (1991, p. 79) that 'for any text the univocal and dialogic functions are best thought of as being in a kind of dynamic tension. There is always an element of univocality as envisioned in the transmission model and an element of response and retort as envisioned by Bakhtin'.

The two columns therefore represent forms of discourse which lie at extreme points on a continuous dimension and it is likely that real discourse will contain elements of both. Furthermore, and as is apparent within the data presented here, there can be rapid movement between points along this dimension as the rhythm of the teaching performance takes hold.

5.6 The pedagogical interventions in terms of scaffolding

In this section the pedagogical interventions of the first case study are examined with reference to the concept of scaffolding. A detailed analysis of pedagogical interventions has already been presented in Section 5.4 and various categories of intervention identified. The analysis presented here can be regarded as adding to and complementing this earlier work; having identified the various forms of pedagogical intervention which constitute the teaching narrative, attention is now turned to considering whether those teacher interventions can be described and analysed in terms of scaffolding.

Given the point made earlier that scaffolding was first developed in the context of individual tutoring, then it is clear that a careful treatment of the concept is needed if it is to be used in classroom situations whilst remaining consistent with the original specification. At present, in science education circles, the term 'scaffolding' tends to be used in an indiscriminate way in referring to any instruction or assistance which a teacher might offer. Through this study an attempt is made to introduce greater clarity to this situation.

The starting point to the analysis presented here is provided by the four characteristic features of scaffolding developed in Section 2.6.2 of Chapter 2. These features offer a theoretically grounded guide to the concept of scaffolding in being derived from the original studies of individual tutoring and the concept of the Zone of Proximal Development. The approach taken is to consider each of the characteristic features in turn and to explore how they might apply to classroom situations in general and to the situation of the present case study in particular. Thus for each characteristic feature two questions are considered:

- What are the issues involved in applying this feature, which was developed in the context of individual tutoring, to classroom teaching and learning situations?
- Can this feature be exemplified and illustrated through the data of this case study?

5.6.1 The characteristic features of scaffolding: scaffolding learning in the classroom

Feature 1

Scaffolding involves interactions between teacher and learner which are focussed on the learner developing some specific competence which initially they are unable to achieve alone.

A key aspect of this feature is the notion of developing *some specific competence.* As outlined in Chapter 2 the original research into scaffolding focussed on tutoring tasks which were procedurally based, involving exercises such as assisting a child to build a pyramid from blocks (Wood, Bruner and Ross, 1976) or to complete a jig-saw puzzle. In such cases the target competence to be achieved is clearly defined and involves mastering a limited number of moves and ideas which can be talked through and demonstrated by the tutor. The target competence for this case study is somewhat different with the focus being on the *conceptual knowledge* involved in developing an understanding of rusting. Vygotsky (1962, p.93) draws attention to an important feature of conceptual knowledge when he states that: 'the very notion of scientific concept implies a certain position in relation to other concepts, that is a place within a system of concepts'. In other words, learning a scientific concept entails making links to other parts of a conceptual framework. For example, in this case study developing the idea that there is water in air relies on the child being able to conceptualise air as being 'something' which can hold water; understanding the target concept (that water vapour can be found in air) is linked to understanding another concept (that air is substantial).

This feature of making links between concepts is a fundamental part of learning scientific conceptual knowledge and contributes to the complexity of teaching and learning that knowledge. Thus whilst a jig-saw puzzle, or some similar procedural task, might be worked on and completed in a single session and involves a limited number of skills and ideas, the lessons on rusting extended for over three hours and involved addressing a disparate range of conceptual themes and sub-themes. In Lesson 2, for example, a number of issues were addressed in quick succession: whether cold is essential for rusting to occur; whether air is present in water (and how it might be removed); whether water is present in air (and how it might be removed).

For the case study lessons as a whole there was a specific teaching aim (for students to know and to be able to apply the conditions essential for rusting) but that overall aim was addressed through many different teaching interventions, each addressing different conceptual goals. Opportunites for scaffolding are therefore *distributed* throughout the teaching narrative and are *varied* in nature and purpose according to the goal being addressed.

Feature 2.

In interacting with the learner during scaffolding, the teacher is aware of and responsive to existing modes of student thinking and any changes in student thinking, in supporting development of the target competence. That is, the teacher is aware of and responsive to any differences between student thinking and the target competence. Thus to scaffold learning, the teacher is able to:

i. monitor present performance of the learner (monitoring)

ii. analyse the nature of any differences between present performance and performance required by target competence (analysing)

iii. respond with an appropriate intervention to address differences in performance (assisting)

These three actions of 'monitoring', 'analysing' and 'assisting' together constitute what is meant here by the teacher being *responsive* to students' ongoing learning. This responsiveness lies at the very heart of scaffolding. Earlier, in Section 5.4.4, the notion of pedagogical interventions to 'check student understanding' was introduced and exemplified. Such interventions to check student understanding map onto the first of the three actions considered here, 'monitoring', and therefore provide just the first element of what is required to demonstrate the responsiveness which is central to scaffolding.

In the context of individual tutoring of procedural competences such teacher responsiveness demands skill and sensitivity but is helped by two factors. The first is that the tutor's full attention can be given to the individual tutee and the second that the level of student performance is apparent from the student's actions (in carrying out the procedural task). Monitoring, analysing and assisting are practicable in this context.

In the classroom the situation is quite different. An obvious feature of classroom life which militates against the teacher being able to be responsive to student learning is simply the number of students involved; rather than the tutor working with one tutee we have the teacher working with 25 students. The obvious

question is whether the teacher can monitor the progress of individual students, analyse the nature of the 'gaps' in individual ZPD's and then provide the assistance needed for each student to progress towards the target competence. The possibility of the teacher achieving the responsiveness to individual students which is essential for effective scaffolding must be in inverse relationship to the number of students involved. The problem of numbers is exacerbated when teaching conceptual knowledge because of the difficulties involved in monitoring the changing understandings of individual students.

Of course teachers do not work in whole-class formats all of the time. The possibility for scaffolding is enhanced when the teacher is working with small groups or individuals rather than with the whole class. Indeed there are instances in the case study where Lynne is interacting with small groups of students and where it is possible to argue that she is demonstrating the responsiveness to students' thinking which is part of scaffolding. One such example occurs in Episode 1.5.

A group of students is engaged in the small-group activity 'Identifying essential conditions' and is considering whether or not there is air in water when Lynne appears:

Student: Miss, do you get air in water?

Teacher: What do you think? You say yes, Andrew. What makes you say yes?

Andrew: I don't know.

Teacher: Well think about it.

Student: Miss, it were in a bowl of water.

Teacher: Well... in water.

Student: Well, no - because... not around it - but air, some sort of air will be there, but not air that we breathe, like this atmosphere.

Teacher: Right.

Student: So [pause]

Teacher: We, we live in this atmosphere but there are also things living in water, so do you think therefore that air <u>is</u> in water..

Student: ..yeah..

Teacher: ..if things are living in it..

Student: ..yeah.

Teacher: Yeah, so there is air in water. Yes there is.

The initial question, 'Miss, do you get air in water?' comes from a student and the teacher responds by focussing on the student's ideas, 'What do you think?' Andrew replies that there is air in water, Lynne asks for his reasoning but Andrew is uncertain. One pupil suggests, not at all clearly, that 'air, some sort of air will be there, but not air that we breathe, like this atmosphere'. Lynne takes up this idea of the 'air that we breathe' and introduces the line of argument: we are living things and need air; living things exist in water; therefore there must be air in water. As the teacher rehearses this argument it is clear from the way in which the students respond (...punctuating the teacher's words with nods of approval and making overlapping comments..'yeah') that they find it plausible.

In this brief exchange, Lynne has checked initial understanding, offered a way of allowing the students to progress with the question (a way which makes links to ideas that the students already have) and thus enables the students to answer the question to their own (and her) satisfaction. On this basis it can be argued that Lynne has scaffolded (monitoring, analysing, assisting) the students in developing the idea that there is air in water. The key step is where Lynne makes the link to 'living things in water'; by doing so she provides a *warrant* for believing that it is possible for air to exist in water. The warrant provides the means by which the students are able to progress between current and intended levels of performance (in their own ZPD's); it offers the means by which the students are able to integrate new concepts with existing ones.

As Lynne subsequently moved around other groups she used the same argument:

Student: Miss, we're not sure if there's any air in water.

Teacher: There might be you know. I was just thinking about fishes..

Student: ..oh, yeah..

Student: ..but they use their gills.

Teacher: Do they get air through their gills though?

Student: Yeah..

Teacher: ..yeah I think they do..

Student: ..yeah, they go like that [impersonation of fish] and get air in their gills..

Teacher: ..yeah, they do. That's a good fish impersonation [chuckles]..

Student: ..they sort of like breathe with their gills.

In the next lesson (Episode 2.3) the issue of whether or not there is air in water was raised again, this time in the whole-class discussion focussing on the design of the scientific experiments. Here Lynne is asking whether there is air in water contained in a test-tube:

Teacher: Is there still going to be air there? Somebody who perhaps hasn't answered yet? Katy - sh, sh, hang on - Katy? Air's everywhere - so - do you mean air's also going to be in the water?

Katy: Yeah.

Teacher: Right, OK, fine. Right - there must be air in water then - is that right?

Student: Guppies - they seem to..

Teacher: ..have you got things living in water..

Students: ..yeah... fish... fish... tadpoles..

Teacher: ..fish, right. In fact, Mr Scott told me this story...

Lynne once again provides the opportunity for students to think through the idea that there is air in water. Initially she states quite unequivocally that 'air's everywhere' and enacts a 'confirmatory exchange' with Katy arriving at the conclusion that 'there must be air in water'. A student then refers to 'guppies' and Lynne returns to the warrant introduced earlier that things living in water need air. She extends this by telling Mr Scott's story (about a goldfish dying in de-oxygenated water) and thus further scaffolds introduction of the idea that there is air in water.

In this way the scaffolding offered by the teacher to support development of this particular concept is returned to during the teaching narrative. There is 'continuity' (Mercer, 1995) in the way in which this particular scaffolding is used. There is also evidence of students using the 'living things in water' warrant later on in the lessons. In Episode 3.5 a group of girls is discussing whether or not a ship's bell will rust and one of them argues, 'it will rust because there's air and how do you think the fishes breathe'. To this extent the scaffolding has served its function of providing a warrant for believing that there is air in water. Furthermore the teacher has been able to use that warrant in scaffolding learning in both small group and whole class situations.

In the preceding paragraphs the notion of teacher responsiveness has been explored and put forward as being central to scaffolding. The problems of achieving such responsiveness in the classroom have been linked to both the numbers of students involved and the difficulties involved in monitoring development of student understanding. The key issue is that scaffolding (if the concept is to be consistent with the original intended meaning) involves support to *individual* learning; in Vygotskian terms, it involves providing assistance to help the learner progress in their ZPD from current to goal levels of performance. If the teacher is able to achieve this with individuals, small groups or whole classes then they are displaying the responsiveness which is central to scaffolding. In the examples of scaffolding set out above there is some evidence of the teacher's interventions enabling progress in individual learning, although, of course, this becomes more problematic in the context of whole class teaching.

Feature 3.

In scaffolding learning the teacher acts as a 'vicarious form of consciousness' in offering guidance through the learning event and helping the learner to reflect upon, and become consciously aware, of learning targets and the progress made towards those targets.

In most teaching and learning situations in science the teacher knows ahead of time what is to be taught and how the teaching will be conducted, whilst the learner inevitably has a limited awareness of purposes, goals and progress made towards those goals. In this situation the teacher can act as a 'vicarious form of consciousness' in providing some form of *guidance* through the learning event. The notion of teacher acting as a vicarious form of consciousness comes from Bruner (1985) who states that:

> If the child is enabled to advance by being under the tutelage of an adult or a more competent peer, then the tutor or the aiding peer serves the learner as a vicarious form of consciousness until such a time as the learner is able to master his own action through his own consciousness and control. When the child achieves that conscious control over a new function or conceptual system, it is then he is able to use it as a tool. Up to that point, the tutor in effect performs the critical function of scaffolding the learning task (Bruner 1985, p.24).

Guidance through the learning event might be achieved in a number of different ways. The teacher might: specify and review learning aims; direct attention to crucial features of the task situation; review progress through the learning task. Through such interventions the teacher provides a commentary which serves to make students consciously aware of matters relating to the state of progress through the learning event. In the analysis of the teaching narrative set out earlier in Section 5.4.5, attention was drawn to a category of teacher interventions directed towards 'Maintaining the narrative'. The interventions to maintain the narrative involve the teacher in: declaring aims; refocussing classroom discussion; anticipating and rehearsing possible outcomes; reviewing progress of the narrative. There is clearly an overlap between these interventions and the teacher actions which follow from this third feature of scaffolding. Both involve the teacher in providing a commentary (both retrospective and prospective) aimed at helping each student to recognise and understand 'where they are up to' and 'where they are headed' in the particular teaching sequence.

In the case study there are many such instances of Lynne providing a commentary to the narrative. In Episode 2.3, for example, she reviews a particular point and sets a goal for what is to be done next:

> **Teacher:** Now that means that we're left with air, water and dark, and what we've got to try and do is to <u>see</u> if we can actually prove whether it is <u>air</u> on its own, perhaps even <u>water</u> on its own, perhaps dark on its own, or a combination of the three which is going to make things go rusty.

In this way Lynne provides a set of 'signposts' through the teaching sequence, helping to raise student awareness of what they are doing.

A further way in which the teacher can raise the conscious awareness of students is in signalling those points in the teaching narrative which are central to its development. Wood et al (1976) refer to this as 'marking critical features'. An example of this is enacted in Episode 3.2 when Dawn suggests that both air and water are needed for rusting to occur:

> **Dawn:** Well, it means that, means, er, you have to have them both together for the nail to go rusty.
>
> **Teacher:** Right. I think that is an excellent point - and I think it's an excellent way of saying it too. Listen carefully and I'll just re.. - can you just repeat for everyone what you just said?

Dawn: Erm, if, if you've got air and water mixed together it's the only time when the nail will go rusty.

Teacher: Excellent. You have to have - what you actually said the first time was this - you have to have air and water <u>together</u> to make the iron go rusty - and I think that's excellent - that's an excellent way of describing this. And that's - you've actually worked to a really good point.

In this exchange Dawn states that both air and water are needed. The teacher strongly validates Dawn's statement, asks her to repeat it and then rephrases and repeats it herself. In the preceding lessons a great deal of talk about a whole range of different issues has occured. Lynne wants to establish with some certainty that the pupils are aware that they have arrived at the end of these deliberations and uses these linguistic devices to clearly mark the point. This kind of teacher intervention was identified in Section 5.4.1 as a way of developing the conceptual line through 'marking key ideas'.

In each of these examples the teacher encourages conscious reflection by the students on the conceptual line of the teaching narrative by explicitly reviewing progress, discussing the nature of current problems and considering the directions to be taken in the evolving performance of the science story. This feature of scaffolding does not involve taking the conceptual line of the teaching narrative forward in substantive terms. Rather it involves encouraging conscious reflection by the students, so that as the conceptual line of the narrative proceeds they have an enhanced awareness of the learning that they are engaged in.

In summary, it has been argued here that an important part of scaffolding involves helping students to become consciously aware of their own learning by attending to aims, key ideas and lines of argument along the way. Examples have been taken from the case study to show how the teacher might make such interventions in the context of classroom teaching.

Feature 4.

Scaffolding involves a progressive withdrawal of assistance, a gradual 'handover' of responsibility from teacher to learner.

This final feature of scaffolding focusses on the way in which the support of the teacher is gradually withdrawn as teaching and learning progress, giving the

learner the opportunity to take responsibility for practising or using their newly learnt competence.

In the case of individual tutoring such *handover* of responsibility might be achieved simply through the teacher progressively offering less verbal support, allowing the tutee to make key decisions unaided. In the context of the case study it can be argued that 'handover' is made possible through the final activity of the instructional sequence in Episode 3.5. Here the students worked in small groups to apply the conditions essential for rusting to various given situations whilst Lynne moved around the groups offering support as needed. One group is considering whether or not an iron pan left in a deep freeze will rust:

Teacher: [reading from the card] An iron cooking pan left in a deep freeze.

Student: Iron, iron.

Teacher: Well, you've got the iron there.

Student: No it won't, 'cos it's not wet, it's not wet.

Student: Though some irons do go rusty [misunderstanding about 'iron' here]

Student: Yeah they do.

Student: It won't be getting wet, it won't be getting wet and there's no air.

Teacher: Why are we saying no?

Student: 'Cos it won't get wet and it won't go rusty.

Teacher: 'Cos all of the water's frozen in a deep freeze.

Here Lynne gently underlines the key points as they are made by the students: 'Well you've got the iron there'....'Why are we saying no?'. Her final statement 'Cos all of the water's frozen in a deep freeze' slightly extends what the girls have said in making explicit why there is no water in the deep freeze.

The next group is considering whether silver ear studs will rust at the beach:

Student: [reading card] Silver ear studs during a beach holiday in Spain (Eldorado).

Student: Yeah.

Teacher: Silver ear studs.

Student: They don't exactly go rusty.

Student: No, they don't.

Student: Your ears go bad, but the earrings...

Student: It doesn't say whether they're sterling silver.

Student (Fiona): They don't go rusty at all.

Student: Miss, they can't go rusty because you'd get an ear infection.

Student: I don't think they will.

Student: They don't.

Teacher: Why do you say that?

Student: 'Cos your ear goes bad, but you can't imagine all the rust...

Teacher: I think what Fiona was saying was that some things don't go rusty, like some metals - like stainless steel.

Student: So it won't go rusty - no.

Student: No.

Teacher: If you have a silver ring it doesn't go rusty, even if...

Student: No, it just goes black.

Teacher: Yes.

Student: Mind you, it might be a form of rust.

Student: Yeah, I think it is...

Lynne allows the group to discuss their ideas about the silver ear studs and is thereby able to ascertain their present thinking on the problem. The students draw on experience and agree that the silver studs don't go rusty. Lynne encourages the girls to think about 'why' the studs do not rust. Fiona has already suggested that 'they don't go rusty at all' and Lynne 'retrospectively elicits' this idea and builds on it, introducing the idea that 'some things don't go rusty'. She exemplifies this idea by referring to 'stainless steel', a familiar metal which does not rust. In this way Lynne helps the students to recognise that silver is one of those substances, like stainless steel, which does not rust. The final student comment 'Mind you, it might be a form of rust' offers some indication that the group is following the line of argument offered by the teacher and, indeed, is prepared to take it further.

A final group is considering a lunar rocket module left on the surface of the Moon:

Student: [reading card] Part of a lunar rocket module left on the surface of the Moon.

Student: No, 'cos there's no gravity up there.

Student: And there's no air.

Student: No air up there.

Teacher: If there's no air it can't go rusty.

Student: Just write rocket.

Teacher: I don't suppose there's any rain there either, is there?

Student: No.

Student: No water.

The students recognise that there is no air on the Moon and Lynne applies the condition in a more formal statement, 'If there's no air it can't go rusty.' In a matter-of-fact way Lynne then offers, 'I don't suppose there's any rain there either, is there?' This is taken up by the students.

Each of these three examples (and there are many more) show Lynne supporting students in applying the criteria for rusting. In these instances the form of the discourse is very distinctive. Lynne allows each group to discuss their ideas and *responds* to what the students say; rather than take the initiative to introduce new ideas she tends to be *one step behind* the students, gently prodding and offering support as needed. Thus in the first example Lynne simply observes that the water is frozen in the deep freeze (and therefore rusting is not possible). With the silver ear studs Lynne encourages the students to think about why they don't rust and makes the link to materials such as stainless steel which don't rust at all. In the final example, Lynne makes a formal statement of what is being discussed in the group, 'If there's no air it can't go rusty....' and draws attention to the lack of water. In all of these examples the teacher's role is an understated one. As the students demonstrate that they are able to succeed with the task then Lynne allows them to take the initiative. In Bruner's terms she 'hands-over' control to the students.

So far in this section each of the characteristic features of scaffolding has been reviewed in the context of the case study data and attention has been drawn to the issues involved in applying the feature to the classroom context. Building on this

analysis two general forms of scaffolding, applicable to the classroom situation, are now introduced and discussed.

5.6.2 Pedagogical and instructional scaffolding

The examples of scaffolding outlined in the preceding sections involve interactions in which the teacher responds to students' existing thinking by offering some explanation or further information which links to each student's existing thinking and enables them to progress with their learning. There is a spontaneous quality to these pedagogical interventions as the teacher responds directly to what students are doing and saying. Such interventions are referred to here as *Pedagogical Scaffolding*. Pedagogical scaffolding is typically enacted through relatively brief exchanges between teacher and individual or teacher and small groups of students.

A second aspect of the teacher's practice which can *contribute* to scaffolding of learning involves the design of instructional sequences. The idea proposed here is that an instructional scheme can provide a framework for teaching which *enables* the teacher to scaffold learning over the course of a sequence of lessons. Such an approach to instructional design is referred to here as *Instructional Scaffolding*. The point must be emphasised at the outset that instructional scaffolding can *only* provide an enabling framework for the teacher interventions of pedagogical scaffolding. The situation can be summarised:

Scaffolding: is enacted through the interactions of
'pedagogical scaffolding'
Scaffolding: can be supported through instructional design or
'instructional scaffolding'.

Two parts of the instructional scheme used in the case study can be seen as providing instructional scaffolding. Firstly, the 'rusty nail' activity was designed to elicit all of the students' spontaneous ideas about rusting. Through this activity, the students' ideas were taken onto the 'talking agenda' for the lessons, and Lynne became aware of the initial thinking of the members of the class. This, to emphasise the point, was not achieved through the teacher interacting individually with all of the members of the class (as in the individual or small group tutoring approach of pedagogical scaffolding) but by planning and implementing a particular instructional approach which was used with the whole class. By this instructional means Lynne was able to *monitor* the present performance of the students *analyse* the nature of any differences between present performance and

that required by the target competence and then begin to *respond* to those differences. In other words the instructional design enabled Lynne to be responsive to student thinking at the start of the lesson sequence.

Towards the end of the lesson sequence (Episode 3.5) the students were involved in an activity to apply the conditions essential for rusting to various given situations whilst Lynne moved around the groups offering support. As argued in the previous section this activity provided the opportunity for Lynne to *handover* to the students the responsibility for applying the conditions. In some cases support was not removed entirely and Lynne offered 'light' pedagogical scaffolding through maintaining an understated role, keeping 'one step behind the students'. In other words, handover was addressed through a combination of instructional design and sensitive pedagogical scaffolding.

What is being suggested here is that in the context of classroom teaching scaffolding might be approached via two means, Pedagogical scaffolding and Instructional scaffolding:

Pedagogical scaffolding	Instructional scaffolding
• operates through teacher-student interactions	• is provided by the planned framework of an instructional sequence
• is directly responsive to what students do and say and thereby has a spontaneous quality	• is planned in advance of the teaching and thereby has a pre-planned quality

Fig. 5.1 Pedagogical and instructional scaffolding

In summary, an argument has been set out in this section that the characteristic features of scaffolding can be approached in the classroom through two possible means. The first has been termed 'pedagogical scaffolding' and involves the close interactions between teacher and students in which the teacher is able to respond directly to students' thinking. The second is referred to as 'instructional scaffolding' and involves designing instructional approaches which are planned ahead of teaching. Two examples of instructional scaffolding have been taken

from the case study; the first involved instructional scaffolding being used to enable monitoring of student thinking at the start of teaching and the second illustrated how instructional scaffolding was used to enable handover to students.

5.6.3 Scaffolding and non-scaffolding

At the beginning of this section attention was drawn to the way in which the concept of 'scaffolding' tends to be used in an indiscriminate manner; any form of assistance or help provided by the teacher is likely to be referred to as scaffolding. The foregoing analysis of scaffolding is based on four characteristic features which specify that scaffolding should: be directed towards a specific learning goal; be responsive to the learning of individual students; offer guidance through the learning event; involve handover of responsibility to the learner.

With regard to this particular case study it has been possible to identify teaching interventions at various points in the lesson sequence which demonstrate the responsiveness required of pedagogical scaffolding. Activities have also been identified which enable monitoring of student thinking and handover of responsibility, and which therefore constitute instructional scaffolding. Throughout the lessons there are instances of teacher providing guidance through the learning event by means of an ongoing commentary. These teaching interventions and planned activities observed in the case study all involve features of scaffolding. However, given the fact that scaffolding involves providing support for individual learning it is clear that in working with a group of 25 students, most of the whole class teaching will *not* exhibit the features of scaffolding.

In the rusting lessons there are a number of instances where Lynne actively *overlooks* a particular question or statement from an individual student; such actions were referred to in Section 5.4.1 as a form of pedagogical intervention to 'select ideas' in developing the conceptual line of the narrative. Thus in Episode 2.3, teacher and class are talking about designing an experiment to test whether 'dark' is essential for rusting:

> **Teacher:** Right - so let's come back to our experiment now - hang on - now Peter, have you got an idea then?
>
> **Peter:** Miss, I put mine in my pencil case and it went..
>
> **Teacher:** ..you did - yes - people have been trying lots of places. That's right. So - now then, how can we - sh, sh - I think you've stopped thinking, haven't you? Come on...Right, go on Cheryl - sh sh.

Lynne actively interrupts Peter as he begins to talk about his pencil case. There is clearly no sense of teacher being responsive to student thinking here; Lynne has judged that the conceptual line of the narrative will not be extended through Peter's ideas about his pencil case and so stops him. Time and support for development of individual thinking are withdrawn to enable progress of the conceptual line of the narrative on the social plane.

This brief exchange captures the tension which the classroom teacher always faces in striking a balance between being responsive to individual thinking and maintaining the progress of the narrative on the interpsychological plane; it is a tension which militates against the possibility of scaffolding during whole class teaching. At other times Lynne 'paraphrases student ideas' or 'selects a student response' in developing the conceptual line. Once again such interventions contribute to the development of the narrative on the social plane but offer nothing in terms of scaffolding individual learning.

5.7 Summary

In this rather detailed and lengthy chapter the four theoretical features (forms of pedagogical intervention, authoritative-dialogic nature, content, pedagogical interventions in terms of scaffolding) derived from Vygotskian theory have been applied to the task of analysing the teacher talk of the first case study.

The interventions which the teacher made throughout the lesson sequence have been described in terms of five forms or categories of pedagogical intervention: developing the conceptual line; developing the epistemological line; promoting shared meaning; checking student understanding; maintaining the narrative. Each of these categories has been exemplified through a range of teacher interventions. The pedagogical interventions taken together constitute the teaching narrative through which the science view is made available to students. That is, the teaching narrative is considered to have conceptual and epistemological lines and is presented in such a way that the teacher promotes shared meaning, checks developing student understanding and provides a commentary to maintain the narrative.

In addition to analysing the performance of the teaching narrative in terms of the forms of pedagogical intervention, attention has also focussed on the authoritative and dialogic nature of the discourse. This analysis relates to how the narrative is

enacted and the concept of the 'rhythm of the discourse' has been introduced to draw attention to the way in which the nature of the talk changes as the narrative proceeds.

Finally, the interventions of the teaching narrative have been examined in terms of the concept of scaffolding. The point has been made that there is overlap between the forms of pedagogical intervention identified as part of the teaching narrative and the teacher actions which constitute the key features of scaffolding. Thus, for example, the pedagogical interventions to 'maintain the narrative' overlap with the 'guidance' which is required in scaffolding. The key feature of scaffolding which sets it aside from the forms of intervention identified as being part of the teaching narrative is the 'responsiveness' to individual learning (involving the actions of monitoring, analysing, assisting). In all of the teaching interventions of the first case, only a small number of instances of such responsiveness were identified and all of these were in the context of the teacher working with small groups of students. Given the demands discussed earlier which are inherent in the context of one teacher working with many students, this is only to be expected. In whole class teaching situations the teaching interventions which can be described as 'scaffolding' are likely to form a small sub-set of all pedagogical interventions.

Chapter 6: Case Study 2: Teaching and learning about air pressure explanations for simple phenomena.

6.1 Introduction

In this Chapter the analytical/theoretical tools developed in the context of the first case study are used to analyse the teaching interventions of the second case which focusses on teaching and learning about air pressure explanations for simple phenomena. In the previous chapter four features of classroom discourse were developed and exemplified in characterising the teaching interventions of the first case; these features of discourse refer to:

1. The five *forms of pedagogical intervention* which appear through the teaching narrative (Section 5.4):
   - developing the conceptual line (shaping, selecting, emphasising ideas)
   - developing the epistemological line
   - promoting shared meaning
   - checking student understanding
   - maintaining the narrative

2. The *authoritative* and *dialogic* nature of the discourse on the interpsychological plane (Section 5.5)

3. The *content* of the discourse in terms of the representation of *spontaneous* and *scientific* reasoning (Section 5.2).

4. Pedagogical interventions in terms of *scaffolding* (Section 5.6)

These theoretical features are now to be used in analysing the teaching interventions of the second case. This approach, of 'putting the theoretical tools to work' in a new context is taken with specific aims in mind:

1. To draw on these theoretical tools to investigate how the teacher of the second case used and guided classroom talk to support students in developing an understanding of concepts relating to air pressure.

2. To consider how the theoretical tools might be further elaborated and exemplified through application to the second case.

In the following section the context and background details of the case are set out. In Section 6.2 some insights to students' spontaneous reasoning about air pressure phenomena prior to instruction are presented and discussed. The substantive content of the case study is presented in Sections 6.3, 6.4 and 6.5 which relate to the three lessons in the sequence. For each of these lessons the classroom discourse is analysed with reference to the four features set out above and in Section 6.6 the main findings and issues arising from the analysis are reviewed.

6.1.1 Background to the Case

The school

This case study took place in an 11-18, mixed comprehensive school in a semi-rural location in West Yorkshire. The school is well established in the local community having the support of a broad range of working and lower middle class households. The school is housed in a combination of old and new buildings which generally provide a pleasant working environment for both staff and students. A low turnover in members of staff and the fact that the school easily meets its admissions target each year provide some indication of the stability and popularity of the school.

The class

The class focussed on in the study was a mixed-ability Year 8 group in which there were 27 students (17 boys and 10 girls) whose ages fell in the 13-14 years age-range. The class had a generally poor reputation in the school in relation both to their behaviour and to their overall ability. Despite being nominally a mixed-ability group the attainment profile of this group of students, across all subjects, was skewed towards the lower end of the range for the school year group. As regards behaviour, the class had a reputation in the school for being lively and requiring firm control from the teacher. This was the kind of class where the teacher needed to work hard to gain full attention and where noise levels tended to rise during activities through chatter and various off-task diversions. Attendance levels tended to fluctuate, full attendance was not achieved in any of the lessons observed.

In this second case two students, Jamie and Matthew, were selected to follow through the lessons. These boys were recommended by the teacher as being 'bright, lively and talkative'. As in the first case study, data on these students is referred to only insofar as it is helpful in setting the context for interpreting and analysing the teaching interventions.

The teacher

The teacher of the case study lessons, Richard, was an established member of the school science department and during the time of the study was promoted to the post of Senior Teacher within the school as a whole. Richard had close to twenty years teaching experience and was regarded by his colleagues as being a very competent teacher who had excellent relationships with the students that he taught. In the class Richard had a very calm but firm manner. Richard had been involved in various research projects with the Children's Learning in Science Research Group and had very clear ideas about teaching and learning science. His interest in, and respect for, the thinking of his students was demonstrated by his thoughtful, probing style in class; Richard was keen to 'get behind' the ideas of his students, to challenge them and to get them thinking about science.

The three case study lessons were taught in a conventional, modern school laboratory. The teacher's bench and chalkboard were located at the front of the room and the students sat on stools behind wooden benches, all facing towards the front. One side of the laboratory looked out over the school playing fields which contributed to the general impression of this being a bright and pleasant room.

The instructional approach

The topic of 'air pressure' was chosen for the study for a number of reasons. Firstly it was part of the school's existing Year 8 science curriculum and Richard was aware that students found it a difficult topic and welcomed the opportunity to think about his teaching of it. In addition and importantly (as outlined in Section 4.3.1) it was considered that air pressure offered a different kind of 'learning demand' compared with the rusting topic. With rusting there was some overlap between everyday and scientific views; in the case of air pressure there is a major difference between everyday views (of, for example, sucking) and the corresponding scientific view (based on the action of the surrounding air).

Prior to the lessons, the researcher talked with Richard about the instructional approach to be taken. Richard recognised that the scientific explanation for phenomena such as drinking through a straw, based on differences in air pressure, is likely to be implausible for many students (the problem being one of coming to terms with the idea that the 'air around' is able to exert large forces in driving liquid up through the straw). In planning the instructional approach, Richard therefore decided to differentiate explicitly between 'common-sense' and

'scientific' explanations by referrring to them as the 'old way' and 'new way' of explaining.

He planned to introduce the scientific or 'new way' of explaining through a combination of teacher demonstrations (the 'Bottles' and 'Balloons' demonstrations) and student activity (the 'Rubber Sucker' activity). The scientific way of explaining would be based on the idea that adding air to a fixed space raises the pressure in that space, whilst removing air from a fixed space reduces the air pressure. The effect of adding or removing air can then be explained in terms of the change in air pressure in the space with respect to the surrounding air. For example, a thin walled plastic bottle will collapse if air is removed from it because the air pressure inside becomes less than that of the surrounding air.

After introducing the science way of explaining and practising it in these different contexts, the students were then to be given the opportunity to apply the air pressure explanation to a range of different phenomena in the 'Pressure Circus' activity. One of the phenomena in the Pressure Circus, for example, involved explaining in terms of differences in air pressure the action of a 'sink plunger' as it is stuck to a smooth flat surface.

In the lessons leading up to the case study the class had been introduced to the concept of 'solid pressure' as involving both the size of a force and the area over which the force acts. The class was familiar with talk about 'pressure acting over a surface' and had, for example, considered the relative pressures generated under shoes with different areas of sole.

All Year 8 classes in the school had two double lessons of science each week. Each double lesson lasted for 65 minutes: the first double lesson was timetabled for after lunch on Wednesday afternoon; the second for first lesson on Friday morning. The overall schedule of lessons and episodes referred to in the case is as follows:

Lesson 1: Friday (first period in the morning).
Episode 1: The 'Bottles' demonstration. (10 minutes)
Episode 2: The 'Bottles' diagram (20 minutes)
Episode 3: The 'Balloons' demonstration (10 minutes)
Episode 4: The 'Rubber Sucker' activity (25 minutes)

Lesson 2: Wednesday (first period in the afternoon).

Episode 1: 'Rubber Sucker' review (15 minutes)

Episode 2: The 'Pressure Circus' (50 minutes)

Lesson 3: Friday (first period in the morning)

Episode 1: 'Pressure Circus' review (30 minutes)

Only the first part of the final lesson was used in reviewing the activities of the Pressure Circus.

6.2 The students' spontaneous reasoning about air pressure phenomena

Three weeks prior to the start of the teaching on air pressure two questions 'Apple Juice Carton' and 'Springback' were administered to all of the students in the class. The students completed their written responses individually and handed them back to the teacher. The teacher told the students that they would be returning to a topic which involved questions such as these after the forthcoming half term holiday. Copies of the two questions can be found in Appendix 1.

'Apple Juice Carton' poses the question of why the sides of a drinks carton bend inwards when juice is drunk from it through a straw. In 'Springback' students are asked to explain why the plunger of an air-filled, sealed syringe springs back when pulled out and then released. One of the students, Jamie, wrote the following responses to each question:

> **Apple Juice Carton:** 'Because you are sucking all the air out and the inside of the carton is trying to get more air from its outside but it can't because of the sides of the carton. So instead of sucking air in it sucks the sides of the carton'.
> **Springback:** 'Because when you pull the plunger out there isn't enough air to fill that space that's been made by pulling the plunger out, So it trys to pull in more air but it can't so it pulls in the plunger'.

Jamie's responses are both based on the idea of the 'inside' of the container 'trying to get more air from its outside'. In the case of the carton this results in the sides being sucked in and with the syringe the plunger is pulled in.

Another student, Matthew, wrote down the following:

> **Apple Juice Carton:** 'The sides move in because as you suck the juice or air out, nothing can fill the space, This means the carton has to create less space by sucking in the sides'.
> **Springback:** 'As you pull the plunger out there is no air in the trunk. Because of this, when you get rid of the force pulling back, the syringe fills up the empty space with the plunger'.

In both cases Matthew focusses on the space inside the container. With Apple Juice Carton, he suggests that the carton sucks in the sides to fill the space left by

removal of juice and air. In Springback, the syringe fills up the empty space created in the trunk with the plunger.

Immediately prior to the first lesson, and three weeks after the questions had been set, the researcher talked informally with various students about the two questions. Jamie was asked why the sides of the carton bend inwards:

> **Jamie:** When you suck, when you've sucked all the juice out and start sucking the air out, so there's no air in. So it's trying to - what I thought - it's trying to get more air into fill that space, but it couldn't so it's sucking the sides in...

Jamie gave this explanation without having the opportunity to refer back to his original written response. There is close agreement between what he says here and what he had written three weeks earlier. Jamie goes on to explain that he had not thought about these things before:

> **Researcher:** Had you thought about that kind of thing before, or was it just when you're answering this question that you thought through that explanation?
>
> **Jamie:** No I never thought about it really properly. At home I just blow them up [*apple juice cartons*] and pop them.
>
> **Researcher:** Do you think your explanation's right?
>
> **Jamie:** Yeah I wouldn't have wrote it if I didn't.

Jamie's verbal response to 'Springback' was also virtually identical to what he had written earlier:

> **Jamie:** Well, it was like, er, same as the carton...You're making the space bigger and it's only got a small amount of air. So it's trying to get more air in and it can't cos that's there. So instead of bringing more air from there [*from outside the syringe*], it's bringing that [*the plunger*] in.

The written and spoken responses from nearly the whole class were based on ideas of 'sucking' or 'pulling' from the inside of the container. As would be expected there was no suggestion of the external action of air pressure in the students' explanations. A number of students, like Jamie, also stated that they had never consciously thought about how these things might be explained. These kinds of responses are similar to those encountered in the first case in the context of rusting and represent the students' spontaneous or everyday reasoning about the phenomena.

In the absence of any formal teaching about the scientific concept of air pressure, it is hardly surprising that the students drew upon everyday notions of 'pulling' and 'sucking'. These 'alternative conceptions' are not necessarily explanations and ideas which have been previously considered and rehearsed by the students but they reflect the intellectual resources or 'conceptual tools' (Vygotsky, 1978) which the students have available to them and are likely to draw upon in responding to such questions. Whether or not the students have thought about these kinds of things before is, in a sense, irrelevant to the kinds of response they are likely to give. Those responses are framed and constrained by familiar, everyday ways of talking and thinking about such phenomena which the students have been exposed to over the years; they are a product of each student's social and experiential biography. In this particular context of learning, the students' spontaneous ideas based on notions of 'pulling' and 'sucking' are also quite different from the scientific view which is expressed in terms of differences in air pressure.

6.3 Analysis of the teaching interventions of Lesson 1

In the next three sections an analysis of the teaching interventions in the second case is presented. Each lesson is divided into a number of episodes, as set out in Section 6.1.1, and an analytical commentary is presented for each of those episodes. As outlined earlier the analysis is based on the theoretical tools (based on the four features of discourse) which were developed and elaborated through the first case. These features of discourse are marked with *italics* in the commentary which accompanies each episode. The reader might find it useful to refer to the appropriate summaries of the theoretical tools in Chapter 5 whilst reading through the second case, particularly with regard to the various forms of pedagogical intervention which are summarised in Section 5.4.6, on pages 118 - 119.

6.3.1 The 'Bottles' demonstration (Episode 1.1)

The first lesson begins with the students sitting around the teacher's bench at the front of the room so that they can see and follow what the teacher is doing. Richard shows the class two bicycle pumps which can be used to pump air into a plastic bottle and to remove air from the bottle; throughout the lessons Richard refers to the two pumps as the 'air adder' and the 'air remover' respectively. He connects the air adder to the bottle, starts pumping and asks the class what they can see happening.

Adam replies:

Adam: There's all t'air goes into it and it's pushed the, erm, creases out.

Teacher: Let's just concentrate on what you can <u>see</u>. You can see that it's pushed the creases out can you?

Adam: Yeah.

Teacher: And some people who seem to be sitting on this side are saying that they can still see a <u>few</u> creases. But I think I agree, <u>most</u> of the creases have been pushed out.

Adding air to, and removing air from, the plastic bottle is the physical context in which the air pressure ideas are first introduced. Through this demonstration Richard presents the phenomenon to the students and establishes what happens to the bottle when air is pumped into it.

As outlined in Chapter 2, Section 2.2.2, it cannot be assumed that all of the students in the class will 'see' what happens to the bottle in the same way; they don't share the same 'situation definition' (Wertsch 1985, p.159). Richard therefore raises the issue in the discourse of the interpsychological plane by asking one student to describe what he can see and thereby makes a first move in developing the conceptual line of the narrative. Adam responds in a way which is acceptable to Richard who therefore *selects* the student response and *marks* its acceptability by initiating a confirmatory exchange, 'you can see that it's pushed the creases out can you?' Richard further *marks* the acceptability of Adam's description, by validating it himself, 'I think I agree', and *promotes shared meaning* by repeating it carefully to the whole class. Not only has Richard presented the phenomenon through the simple demonstration, he has also portrayed, through his exchange with Adam, how the phenomenon is to be talked about (how it is to be described) and made that way of describing available to all of the students.

Richard repeats the demonstration with the air remover and the sides of the plastic bottle very obviously move inwards:

> **Teacher:** The sides have gone in. So we've had the bottle where we've put the air adder on and the bottle's gone up, and when we had the air remover on, the bottle goes down, and what we're looking for is an explanation of why.

Richard's summarises the phenomenological starting point to the conceptual line of the narrative by drawing attention to what actually happens with the two pumps. He refers to the pumps as the 'air adder' and the 'air remover' thus signifying their function in the demonstrations. Richard then declares an aim for what is to come: 'what we're looking for is an explanation of why'. In making the summary and considering aims Richard is framing and *maintaining* the narrative. Richard is also making an implicit distinction between description and explanation; this is an epistemological distinction which students are often not aware of and find confusing. Richard is sensitive to this issue and thus addresses the point which relates to the *epistemological* line of the narrative.

Richard now repeats the demonstrations with the plastic bottle, this time using an electric air-pump. He first uses the electric pump as an air adder:

> **Teacher:** Let's see what happens - well - yeah, that got rid of the creases just like it did with the air adder - did it faster. This is the air remover connected [*the plastic bottle collapses in spectacular fashion and the pupils are buzzing*

with excitement] Look at that! Well! Alright, so what we've done with this electric one is to do what we can do with the mechanical one faster.

The hand-pumps and the electric pump have the same function (of adding and removing air) and Richard signals this by using the same terms ('creases', 'air adder', 'air remover') to describe the apparatus and what happens to the bottles. Richard thus *shapes* development of the conceptual line by maintaining consistency in the use of terms from one part of the demonstration to the next.

Richard's purpose in this initial episode is to establish with the students what happens to the bottle when air is added to it and taken from it and this is apparent from the nature of the discourse. After the initial exchange with Adam, Richard makes a series of statements about what happens with the various pumps; these statements are *authoritative* in nature, they serve the function of conveying meaning rather than exploring or generating new meanings.

6.3.2 Introducing the science view (Episode 1.2)

Richard now returns to the previously stated aim of finding an explanation for what has been seen:

Teacher: We need to find out why. We talked about this the other day, when people were saying 'Ah, hang on, it's when it collapses in like that it's because there's something on the inside pulling it'. We're going to call that the old way of looking at it because I want you to think about it in a new way. I want you to think about it by thinking about pressure. I want you to think about it in terms of air pressure. We're going to say that where there's more air there's more air pressure. Where there's less air, there's less air pressure. So the more air there is in a space, the more air pressure there is and the less air there is in a space, the less air pressure there is. Jamie? [*Jamie has his hand up to attract the teacher's attention*].

This is an important sequence in the development of the conceptual line as Richard introduces the new way of explaining. He *marks* the importance of the ideas presented here by very noticeably modulating his speech and speaking in a slow, clear and deliberate manner. Richard, in fact, represents two voices in what he says. He achieves this by using reported speech, 'the mechanism by which one voice reports the utterance of another' (Wertsch 1991, p.80). Thus he represents to the class the 'old way' of explaining: 'we talked about this the other day, when people were saying...when it collapses in like that it's because there's something on the inside pulling it'; and then talks through the 'new way' of explaining which

is based on the concept of air pressure. Richard thus selects for consideration two perspectives and *shapes* development of the conceptual line of the narrative by *differentiating* between the explanatory mechanisms of the students' spontaneous views (where something pulls from the inside) and the scientific view (where the concept of air pressure is used).

The very act of labelling the two forms 'old' and 'new' makes the *epistemological* point that two ways of knowing can be applied to the same phenomenon and therefore contributes to developing the epistemological line of the narrative. Richard expresses the new way of explaining in the form of a decontextualised 'rule of thumb' or 'catch-phrase' : 'Where there's more air, there's more air pressure. Where there's less air, there's less air pressure'.

Before Richard has the opportunity to demonstrate how the rule can be applied to the 'Bottles' context, Jamie attracts his attention and, unbidded, speaks out:

Jamie: Well, when all the air's been sucked out, it's er, there's nowt in there so you'll have - air pressure's pushing the side of the bottle in.

Teacher: Which air pressure Jamie?

Jamie: From the outside.

Teacher: Say that again so that people can hear.

Jamie focusses on the case of air removal and correctly states that 'air pressure's pushing the side of the bottle in'. This is precisely the form of scientific explanation which Richard wants to promote and he *selects* the idea by focussing attention on it. Central to the scientific perspective is the fact that air pressure provides a resultant force on the outside of the bottle pushing the walls in. Richard is aware of students' spontaneous reasoning in contexts such as these (reasoning based on the idea that the walls are sucked inwards) and *checks understanding* by asking Jamie for clarification: 'Which air pressure Jamie?' Jamie provides the correct response and Richard instructs him to repeat this 'so that people can hear'. Jamie is not the kind of boy who has problems in making himself heard in class. At most times the converse is true! However, through asking Jamie to repeat the idea Richard contrives to rehearse the 'new way of explaining' on the interpsychological plane and to thereby *promote shared meaning*. Asking Jamie to repeat what he said also serves to *mark* the importance of these ideas.

Jamie now starts to repeat his explanation:

Jamie: Well, when you suck all the air out - there's - isn't - it's really thin compared to the air outside, so it pushes it in.

Teacher: Right, so you're saying that when we suck the air out of the bottle, there's less air inside the bottle, so there's less pressure, less air pressure, and why did the sides push in? What did you say again?

Jamie: Cos there's more air pressure outside.

Teacher: Because there's more air pressure on the outside pushing it...

Jamie's explanation differs slightly from what he said initially and Richard responds by repeating and paraphrasing it, 'Right, so you're saying...'. In paraphrasing Jamie's reply, Richard *shapes* it in the form of the new way of explaining; Jamie's reference to 'thin air' is replaced by 'less air' which is then linked to 'less pressure'. Richard breaks off mid-way through and returns to Jamie with a further key question, '...and why did the sides push in?' Clearly, Richard remembers what Jamie said. The purpose of the question is to sub-divide presentation of the explanation into its key component parts: having considered the conditions inside the bottle Richard returns to Jamie to rehearse what happens on the outside. In this way the scientific explanation is *shaped* and jointly rehearsed with Jamie on the interpsychological plane of the classroom, thereby *promoting shared meaning.*

Finally, Richard assumes his slow and very deliberate 'presentational voice' in reviewing and summarising what has been said:

Teacher ...that's what we're going to call the new way of looking. The new explanation is that there's two lots of air involved here not one. There's one lot inside the bottle and there's one lot in this room immediately surrounding it. And if we take air out of the bottle, that means there's less air pressure inside the bottle than there was before...there's more pressure outside, then, and it pushes it in.

Richard thus repeats the 'new way of looking' once more to the whole class, thereby *marking* its importance and *promoting shared meaning.* In doing so Richard focusses on a key feature which distinguishes between spontaneous and scientific views ('there's two lots of air involved here not one') and thus makes a *shaping move* in differentiating between the mechanisms of the old and new ways of explaining. This is the fourth time that the new way of explaining has been repeated in about the same number of minutes; Richard *marks* the importance of key ideas and makes them available to the whole class by repeating them.

6.3.3 Review of teaching interventions in Episodes 1.1 and 1.2

The conceptual line

In the first two episodes significant steps were taken in developing the conceptual line of the narrative. Richard first talked through what happened to the bottle as air was added to it and taken from it and the scientific explanation for this phenomenon was then introduced. Richard presented the scientific explanation in the form of a general rule and differentiated between key features of old and new ways of knowing through use of reported speech. He then rehearsed how this rule applied to the 'Bottles' context through his exchanges with Jamie. In these exchanges, Richard: focussed attention on Jamie's response (Selecting ideas); paraphrased Jamie's response, posed key questions, differentiated old and new ways of explaining, sub-divided the scientific explanation into its key component parts (Shaping ideas); spoke in a carefully modulated voice, repeated the new way of explaining (Marking key ideas).

The epistemological line

Two points relating to the epistemological line of the narrative were represented in the talk of these episodes as Richard distinguished between 'description and explanation' and also between 'new and old ways of explaining'. Making the distinction between new and old ways of explaining enabled differentiation between the two forms of explanation and thus also contributed to development of the conceptual line.

Promoting shared meaning and checking student understanding

Richard made interventions to promote shared meaning through: making statements to the whole class; enacting his 'public exchanges' with Jamie; repeating explanations to the class. By these means Richard was able to make key ideas available to the whole class. There was one instance of Richard checking meaning with Jamie ('Which air pressure Jamie?') and no moves to check meaning with the other students in the class.

Maintaining the narrative

Richard took steps to maintain the narrative by summarising what happened with the bottles and setting out aims for the instructional sequence in terms of moving from describing to explaining phenomena.

Nature of the discourse

The discourse throughout the two episodes was centred upon Richard and apart from the brief exchanges with Adam and Jamie in which he selected responses and checked meaning with those individuals, was authoritative in nature. The purpose of the talk was to establish on the interpsychological plane firstly a description of what happened to the bottle and then the scientific explanation for what happened.

Scaffolding

Although Richard was sensitive to students' spontaneous reasoning and differentiated between spontaneous and scientific views, the pedagogical approach taken did not involve the 'responsiveness' required of scaffolding. Richard was presenting the scientific view, the discourse was authoritative in nature and there were no interventions to check meaning or to monitor learning of the students as new ideas were introduced. With these points in mind it is clear that Richard's approach to introducing the scientific view cannot be described as 'scaffolding'.

6.3.4 The 'Bottles' diagram (Episode 1.3)

In the first two episodes of the instructional sequence the scientific way of explaining was made available to students on the interpsychological plane of the classroom but of course this activity does not necessarily coincide with student learning. Vygotsky (1956, pp.179-180, in Wertsch, 1985, p.169) makes the same point when he argues that the appearance of new words marks the beginning rather than the end point in the development of concepts and one should avoid thinking that, 'a ready made concept is given from the very beginning and consequently that there is no room for development'. It might be anticipated that there is 'room for development' here as students come to understand the scientific rule relating to air pressure and how it can be applied to different phenomena.

After completing the 'Bottles' demonstration Richard starts to draw a diagram on the chalkboard which depicts three possible states for the plastic bottle: bottle plus air remover; bottle plus air adder; bottle alone. The *completed* diagram is shown in Figure 6.1:

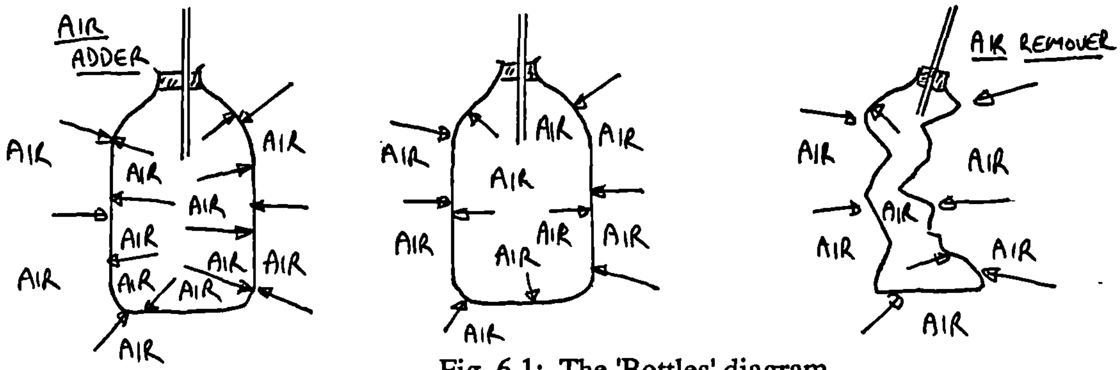


Fig. 6.1: The 'Bottles' diagram

When Richard has drawn just the outlines of the three bottles on the board he stops and calls for the attention of the whole class:

Teacher: Right, this is the important part. I think most people can remember what shape the bottles were, now we're trying to write down the explanation for why it does what it does. I've written down here the words 'air' to show where the air is and I'm trying to get it so there's approximately the same number of words 'air' on the inside as the outside [*referring to bottle alone*]. Now, when it comes to this one [*bottle plus air adder*], how will the labels change Adele?

The 'Bottles' diagram might serve a number of different functions and Richard draws attention to the purpose he has in mind, 'now we're trying to write down the explanation for why it does what it does'. Here the diagram provides the means for making a record of the scientific explanation and Richard makes this purpose clear, thereby acting to *maintain the narrative.* Lemke (1990, p.186) makes the point that, 'a word, or a diagram, or a gesture does not have meaning. A meaning has to be made for it...different people make different meanings for the same word, the same diagram, the same gesture' (see Section 2.2.2). Richard initiates the process of *promoting shared meaning* for this particular diagram by providing a spoken commentary as he adds the air labels, 'I'm trying to get it so that...' Richard then *checks* Adele's understanding about how the labels will change when air is added.

Adele responds to his question:

Adele: More on the outside.

Teacher: I'll have to put more here? [*on the outside*]

Adele: Yeah.

Teacher: Right why do you think that?

Adele: Because there's more air around, than what there is in the bottle, because it's just a little bit crumpled in.

Teacher: <u>This</u> one's not crumpled in!

Adele's reply is not what Richard expected, although taken at face value it makes perfect sense: there *is* more air surrounding the bottle than there is inside it. Perhaps the intended meaning of 'more air, more air pressure' is not shared by all students; there is certainly a discrepancy between the personal meaning constructed by Adele and the intended meaning of the scientific rule as presented on the interpsychological plane.

In scientific terms 'more air' as it is used by Richard means a greater *density* of air. The number of 'air labels' on the Bottles diagram represents the amount of air in a given space; thus if air is added to the bottle the density of the air in the bottle is increased and the number of 'air labels' is increased to show this. This point is implicit in what Richard says, 'I'm trying to get it so there's approximately the same number of words 'air' on the inside as the outside' but the point is not made explicit.

Richard *checks understanding* with Adele and asks her to explain her thinking. Richard does this in a very matter-of-fact kind of way; it is only when Adele refers to the bottle as being 'a little bit crumbled in' that the teacher responds strongly in declaring 'this one's not crumbled in!' By suggesting that the bottle is 'a little bit crumbled in' Adele has broken what Richard assumed was general agreement about the description of the phenomenon; she has challenged the 'phenomenological basis' of the conceptual line.

Debate breaks out across the room and Richard calls the class back to order:

Teacher: Well I think this is the bottle that's blown out, so the creases have gone out of this one, so shall I put more air inside or outside?
Students: Inside. [*voices calling out together*]
Teacher: Why do you think that? Let's try and see if everybody agrees. Does anybody agree that we should put more 'air' words on the outside?
Students: No, no, more on the inside. [*many students calling out*]
Teacher: More on the inside. Looks as though the insides have got it...

Richard re-asserts that this is 'the bottle that's blown out' and returns to the question of whether there is more air inside or outside. Students call out that there is more air on the inside and Richard *checks consensus* over this. There appears to be substantial agreement over the idea that there should be more air labels on the inside and Richard therefore *selects* this point of view, 'looks as though the insides have got it'. However, the issue raised initially by Adele about the meaning of 'more air' has not been directly addressed. The development of the

conceptual line of the narrative thus proceeds on the social or interpsychological plane, whilst there is evidence here that variations in understanding of individual students have not been pursued and resolved.

Now Jamie calls out that the air is the same on the inside and outside. Richard asks Jamie to clarify what he means and then Matthew joins in:

Teacher: Why should it be the same Jamie?

Jamie: Cos it's the same, air inside as it is on the out, the same..

Teacher: ..we're using the air adder remember, the pump..

Matthew: ..it's not the same air pressure though is it..

Jamie: ..it's a different air pressure but it's the same air..

Teacher: ..I don't think it is. I think we put air inside and we said that the more air there is in a place the more air pressure there is. The greater the air pressure.

Jamie: Yeah, but there's, there's all this space out here and there's only that small space in there.

This brief sequence is interesting for its *dialogic* form. There is genuine interanimation of voices as Richard firstly asks Jamie about his reasoning and then Matthew spontaneously joins in to make a point which Jamie reponds to. Jamie is struggling to make personal sense of the state of the air inside and outside the bottle; his final comment seems to echo what Adele said earlier.

Richard responds to Jamie's uncertainty by posing a series of instructional questions to*shape* the presentation of an explanation for what is meant by 'more air':

Teacher: Have we changed the amount of air on the outside of the bottle?

Students: No. [*many voices call out*]

Teacher: Have we changed the amount of air on the inside of the bottle?

Students: Yes. [*many voices call out*]

Teacher: What have we done to it?

Students: Added more in.

Teacher: Added more in. So we're going to put more words inside, to say 'air' inside, and leave the ones on the outside the same. Alright?

The contrast with the previous dialogic exchanges could hardly be sharper as Richard develops this *authoritative* sequence to present the notion that 'more air' is associated with a 'change in the amount of air', which involves 'adding more in', and that this is represented by more 'air words' on the diagram. In this way

Richard's intended meaning for 'more air' is rehearsed on the interpsychological plane.

Richard finally adds arrows to the diagram to represent the pressure acting on respective surfaces:

> **Teacher:** Just to make it absolutely clear what we're doing, I'm going to put some arrows on the diagram to show the air pressure... the bigger the arrow the bigger the air pressure. Somebody said in this one, where the bottle stays the same, there's the same amount of air inside and outside... the pressure's the same inside and outside... so we're going to put the same number of arrows inside and outside, and they're both working on the sides of the bottle... but because they're both the same it doesn't move in or out.

In introducing the arrow convention Richard uses the 'bottle alone' case as an exemplar and states that there is 'the same amount of air inside and outside'. This phrase is potentially misleading, as has already been seen with Adele and Jamie. In fact, it is very difficult to concisely express what Richard wants to say here without using the concept of density; the concept of density is not, however, drawn upon in presenting the scientific rule. Whilst drawing the arrows onto the diagram Richard once again provides a spoken commentary to share with the whole class what the arrows represent, thereby *promoting shared meaning.*

6.3.5 Review of teaching interventions in Episode 1.3

In this episode the Bottles diagram was introduced as a means of recording the scientific explanation and Richard provided a spoken commentary as he drew the diagram to promote shared understanding of its various features. However, when he questioned Adele in checking meaning it transpired that there was a mismatch between Adele's thinking and the intended meaning for 'more air'. There followed a dialogic exchange in which Jamie, Matthew and Richard briefly explored ideas. Richard cut this short and made an authoritative delivery, based on a series of instructional questions, to present what he meant by 'more air'.

At the start of the episode Richard drew attention to the function of the diagram as a means for recording the scientific explanation. The events which followed bring to light a further function of the diagram: that of acting as a focus for talk about the scientific rule. The activity of teacher and students 'talking around' the construction of the 'Bottles' diagram proved to be very productive in raising issues relating to the meaning of the scientific rule and in particular to the intended meaning of the term 'more air'. Roth (1995) draws attention to this function of

diagrams, as a focus for exploration of meaning, when he suggests that a diagram can act 'as a mediating device in the construction and negotiation of the meaning of scientific concepts'. Roth (1995, p.189) reports that, in the context of a particular classroom teaching sequence, 'diagrams became objects in our joint visual fields which we could jointly and individually point to, talk about or modify. The visual and thus palpable aspects of the diagrams then became opportunities to check whether we were in fact talking about the same things'.

In the context of this study the 'Bottles' diagram provided a concrete focus which enabled talk between teacher and students about aspects of the air pressure explanation. In this respect the diagram acted as a device for exploration of meanings between teacher and students on the interpsychological plane. There is a third function which the 'Bottles' diagram (with its symbolic labels and arrows) might serve and that is to provide students with the means for thinking about the phenomenon. In other words the diagram might be used by individuals as a psychological tool for thinking about the phenomenon on the intrapsychological plane.

6.3.6 The 'Balloons' demonstration (Episode 1.4)

Having introduced the 'new way' of knowing in relation to the 'Bottles' demonstration, Richard next turned to demonstrating how that rule can be applied to other contexts. When the students finished copying the 'Bottles' diagram into their books Richard called them back to the front of the room for a second demonstration. This demonstration focussed upon two partially inflated balloons positioned under a bell jar which was connected to a vacuum pump (Fig 6.2).

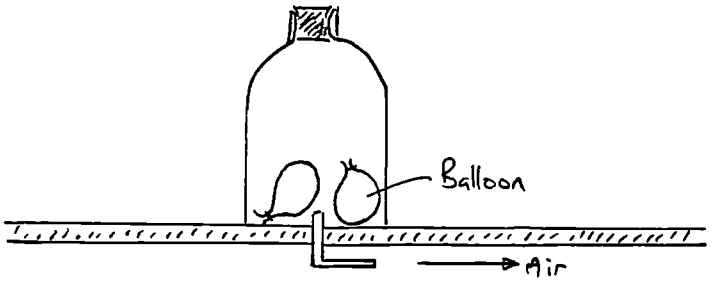


Fig 6.2: The 'Balloons' demonstration

Richard first describes the apparatus to the class:

Teacher: This big jar's got two bungs in. One of them's got a little valve in it so we can connect the pump to it...Inside it, it's just air - we hope - and the're two balloons which have got a tiny bit of air in. They're partly blown up but then there's been a knot tied in the neck of the balloon...and then put a bung in

the top [*of the jar*]...fits so it's quite tight and we're going to connect it to the air remover.

As Richard describes the apparatus he *shapes* presentation of the scientific explanation by drawing attention to various features of the set-up (inside the big jar, 'it's just air'; the two balloons 'have got a tiny bit of air in'); these practical features relate directly to key aspects of the pressure difference explanation which is to be presented. Richard switches on the pump and the balloons begin to slowly inflate, much to the amusement of the class:

Students: They're going up. Yeh, Yeh they are! They're floating...[*much laughter*] ...They're going to pop! I hope they do!

Richard now draws attention to something which Matthew has been muttering to him during the demonstration:

Teacher: Hang on, hang on. Just you hang on a minute Matthew. Alright I'm going to have to stop this now.

Students: Look, look ...[*laughter*].

Teacher: [*teacher switches off the pump*] Matthew's just told me that if we suck all the air out of this jar, the pressure in the jar is less. There's low pressure 'cos there's less air in the jar. Now what's the next bit Matthew? Why should that make the balloons go up?

Matthew: Cos the balloons, erm, have got the same air pressure as outside still, so that when there's less air pressure in the jar there's more air pressure in the balloons and, cos the pressure is more, it, inflates.

The form of this exchange is familiar. Richard *retrospectively selects* Matthew's ideas which are consistent with the scientific explanation. Richard starts to repeat the ideas *promoting shared meaning* with the whole class and then pauses asking Matthew to continue. In this way Richard *shapes* presentation of the explanation breaking it down into its key component parts and jointly rehearses the explanation with Matthew. The exchange is very similar to that between Richard and Jamie in Episode 1.2; it involves the teacher taking an idea suggested by an individual student and rehearsing it on the interpsychological plane of the classroom so that it is made available to all, thereby *promoting shared meaning.*

Richard continues:

Teacher: Good lad! We haven't affected the air in the balloon because the air in the balloon is fixed, it's been sealed in when somebody tied a knot in the balloon, so we're only taking air away from inside the jar. We're not taking air

> out of the balloons. The air in the balloons stays the same, that's the same air pressure as they are right now before we started connecting the pump. So if we make less air in the jar, there's less air pressure in the jar, the pressure in the balloons is still the same as it was before and so the balloons inflate.

Richard responds positively to Matthew's explanation *marking* the importance of these ideas to the rest of the class. He then *promotes shared meaning* by repeating the scientific explanation drawing particular attention to the fact that the air inside the balloons has *not* been disturbed so that as air is removed from the 'jar' the pressure inside the balloons becomes greater than in the jar and the balloons inflate. This is a key feature in differentiating between the 'Bottles' and 'Balloons' cases; in 'Bottles' air is removed from, and added to, the 'focus' object (the plastic bottle) whereas here air is removed from the space around the balloons (which are the focus objects). Richard thus *shapes ideas* on the conceptual line by *differentiating* between the two cases.

Richard finally repeats the full explanation once more, speaking slowly and deliberately in his now familiar presentational voice *marking* the importance of the ideas and *promoting shared meaning* by making them available to the whole class.

6.3.7 Review of teaching interventions in Episode 1.4

The conceptual line

The events of this episode contributed to a significant development in the conceptual line of the narrative as the differential air pressure explanation was first applied to a new context. Richard introduced the scientific explanation for the 'Balloons' case by retrospectively referring to comments made by Matthew and then rehearsed those ideas with Matthew in front of the rest of the class.

A striking feature of the discourse of this episode is the fact that only two voices were heard throughout. The exchange between Richard and Matthew enabled Richard to shape presentation of the scientific view: emphasising different parts of the explanation by alternating speaking roles with Matthew and marking key ideas by repeating what Matthew said.

The epistemological line

The purpose of the 'balloons demonstration' was to demonstrate how the scientific air pressure explanation could be applied to a new context. Implicit in this move from applying the scientific rule in one context to applying it in another is the

epistemological principle of the *generalisability* of scientific explanations. The rationale underlying the selection and sequencing of activities in this part of the teaching narrative thus rested on a fundamental characteristic of scientific knowledge (generalisability) but this point was left implicit as the demonstration was performed. In fact no reference at all was made to the purpose of the balloons demonstration and it can be argued that this omission constituted a 'gap' in the teaching narrative in relation both to the 'Epistemological line' (the issue of generalisability not being addressed) and to 'Maintaining the narrative' (the aims of the demonstration not being stated).

Scaffolding

In talking around the demonstration Richard displayed sensitivity in introducing the scientific explanation through: drawing attention to significant features of the apparatus; distinguishing between the practical set up in this and in the previous demonstration; in separating out the component parts of the scientific explanation. At the same time there was little or no opportunity for students to talk through the scientific explanation for themselves and no attempt by Richard to monitor the developing understandings of the students. In fact throughout the episode there were no instances of dialogic discourse and no instances of Richard checking meaning with the class. The teaching approach in this episode did not include the 'responsiveness' which is a key feature of scaffolding.

6.3.8 The 'Rubber Sucker' activity (Episode 1.5)

In this final activity of the first lesson the students were given the opportunity to think through how the scientific rule could be applied to a further new context. The students worked in pairs and were given two different rubber suckers, a smooth base board and access to a range of forcemeters. The practical task was to measure the force needed to remove each of the suckers from the board and to explain how the suckers stuck to the board. It was Richard's intention that the act of making measurements should help focus students' attention on the phenomenon and particularly on the large forces holding the suckers in place; however, the main aim of the activity was for the students to apply the scientific explanation to this new situation.

Prior to the students starting the practical activity Richard sets the scene and outlines the explanation:

> **Teacher:** I want you to understand how these things work using that new idea we've got about air pressure. Inside here the cup is curved and if I put it against the flat surface the air inside the curved bit, inside the cup, is trapped.

> Now if I push on the middle of the sucker, it squashes that trapped air out so there's now less air in the cup. If I let it go again there's no way the air can get back in, because it forms a seal with the surface. So that means we've got less air inside than we have in the room, there's less air inside, that means less pressure, that means there's greater pressure on the outside pushing the cup, the sucker against the surface.

Richard states the aim of the activity thus contributing to *maintaining* the narrative and then presents the scientific view, step by step, *shaping* the presentation of the explanation. In presenting the scientific explanation Richard repeats the kind of phrasing which earlier created problems for Adele and Jamie: 'that means we've got less air inside than we have in the room'. The students start work on the activity which creates much interest; they are genuinely surprised by the magnitude of the forces needed to remove the suckers.

As the students worked at the activity, the *researcher* talked informally with various pairs of students, first of all visiting the group in which Matthew was working:

> **Researcher:** Has anybody got any idea what this has to do with what Mr N. was doing before - where he was taking the air out of the bottle?
> **Matthew:** Well, erm, it's got air actually in the sucker at the back..
> **Researcher:** ..let's start there then. Put it on there [*the base board*] and air's underneath it.
> **Student:** Yeah, and then you push it down..
> **Matthew:** ..getting all the air out.
> **Researcher:** So when you press down, it pushes the air out? There's no air under there. Go on.
> **Matthew:** There's a seal round, so no air can get in. There's hardly any air in there, the air pressure is really, really small..
> **Researcher:** ..where?
> **Matthew:** Inside - and the air pressure out here is a lot higher, so, because this one's higher it's pushing down on there *[indicating, with his fingers, a force pushing down on the outside of the sucker]*.

Matthew is thus able to provide an explanation for the action of the rubber sucker based on difference in air pressure. The researcher now turns to Nick and Jamie who are working together:

> **Reseacher:** Do you understand what this's got to do with what Mr N. was saying before [*about the plastic bottles*].

Student: Yeah basically.
Researcher: Let's go through it. You start off and you put that [*the rubber sucker*] on there [*the base board*]..
Student: ..yeah and there's air trapped inside and it's the same pressure as the air outside.
Researcher: Right, so if you don't do anything, if you don't actually push it down, it just slips off..
Student: ..and when you push that like that, it's the same area, except the air's been pushed out the sides..
Student: ..there's low air pressure.
Researcher: So there's lower air pressure under the sucker..
Student: ..and higher on the outside.
Researcher: You haven't changed the pressure on the outside..
Student: ..no, it's keeping it down on t'low pressure..
Student: ..yeah, and there's high pressure outside.

Nick and Jamie are also able to talk through an explanation in terms of air pressure; it is clear from the transcript that all of the key ideas in the explanation are introduced by the students themselves.

6.3.9 Review of teaching interventions in Episode 1.5

In this final episode of the first lesson, Richard first introduced the practical activity and presented the scientific explanation for the working of the rubber suckers. This was an *authoritative* presentation with no moves to check understanding or to involve the students in any way. In a sense Richard was 'modelling' the presentation of the explanation for the students; later they would be asked to reconstruct the scientific way of explaining for themselves.

One point to be made here concerns the form and substance of the scientific explanation which Richard presented to the students. Just as the teacher can choose to use certain forms of pedagogical intervention in developing the teaching narrative, then there are also choices available in deciding on how the scientific content of the narrative is to be presented. The teacher can select from a range of 'conceptual tools' (Vygotsky 1978, p.52) in representing and presenting the scientific view. These conceptual tools have both social and psychological functions as they firstly enable communication between teacher and students and then provide the means for individual student thinking. This point about the dual function of psychological tools is made by Vygotsky (Vygotsky, 1981, p.157, in Wertsch 1985, p.81): 'a psychological tool (or sign) is always originally a means

used for social purposes, a means of influencing others, and only later becomes a means of influencing oneself'.

In the context of teaching about air pressure there are a number of different approaches to presenting the scientific view which can be taken, each involving the use of different conceptual tools. Richard might, for example, have decided to refer to the concept of 'density' or drawn on the 'gas laws' or the 'kinetic theory of gases'; these are all conceptual tools which are relevant to this problem area. There has been some evidence from the first lesson to suggest that the 'scientific rule' (more air, more air pressure; less air, less air pressure) introduced by Richard led to confusion over the intended meaning of 'more air.' This confusion might have been reduced if, for example, the concept of density was used in presenting the science view.

6.4 Analysis of the teaching interventions of Lesson 2

The second lesson gets under way with the students sitting in their normal places and Richard begins by reviewing what had happened in the 'Rubber Sucker' activity in the previous lesson.

6.4.1 'Rubber Sucker' review (Episode 2.1)

Richard first of all refers to the large forces needed to pull the rubber suckers from the boards:

Teacher: Some people had to tug really quite hard before it [*the rubber sucker*] started to come off and when it came off, it came with quite a bang! Some people didn't quite fly across the room but they went reeling backwards. That was a tremendously big force. Why does it take so much force as all that? Adam.

Adam: Right, the clear one [*referring to one of the rubber suckers*] when you push it down more air can get out than the white one and so more had to - get out - or..

Teacher: ..so what exactly was sticking it on the board Adam?

Adam: Air pressure and..

Teacher: ..air pressure, where was this air pressure that was sticking the sucker on the board?

Adam: Well air were inside the sucker and then it came out - and so it could let air pressure off - it let air get back inside it to pull it off.

Teacher: Where was the air pressure highest then, inside or outside the sucker?

Adam: Er, in.

Teacher: Inside. You went 'er' then as if you weren't too sure and that's not quite what I explained to you before.

At the start of the lesson Richard takes steps to *maintain* the narrative by reviewing what happened with the rubber suckers and then *checks understanding* by investigating whether the students can explain the effect. As Adam starts his explanation a now-familiar pattern of discourse appears to be unfolding in which the teacher elicits a student explanation and then jointly rehearses it with the student on the interpsychological plane. This time, however, Adam is unsure. Richard uses a series of instructional questions ('what exactly was sticking it on the board?'; 'where was this air pressure?'; 'where was the air pressure highest?') in attempting to *shape* Adam's response to the pattern of the scientific view but

Adam offers an explanation which refers only to the air pressure under the sucker. In this respect Adam's response is more akin to *spontaneous* than scientific reasoning. Richard now asks where the air pressure is highest, inside or outside the sucker; he attempts to *shape* development of the argument by offering a direct choice between two ideas.

A mismatch in perspectives is being played out in this exchange. Adam is basically drawing on *spontaneous* views to explain the sucker effect (referring only to the air under the sucker) whilst Richard is questioning him in terms which make reference to the *scientific* view. Adam and Richard are thinking and talking in different (spontaneous and scientific) domains of knowing. Given this situation, it almost doesn't make sense to ask Adam where the air pressure is highest; it comes as no suprise when Adam suggests that the air pressure is highest *inside* the sucker.

Richard signals that this is not the required answer and turns to Jamie:

Teacher: Jamie, you have a try.

Jamie: Y' know when you push it down? It forces the air out of the sides. It's the same area inside the sucker, it's the same area, it's just been pushed down and all the air's been pushed out. So it's a smaller amount of air in the same area.

Teacher: So where would you say the air pressure was the highest? Inside or outside the sucker?

Jamie: Inside.

Jamie, like Adam, draws on *spontaneous* reasoning in referring only to what happens under the sucker. Richard *checks understanding*with Jamie by posing the key question which *differentiates* between scientific and spontaneous views ('where would you say the air pressure was highest? Inside or outside the sucker?'). Jamie replies 'inside'.

At this point Damian indicates that he has an answer:

Teacher: Damian, what would you say?

Damian: I'd say it's more pressure on t'outside cos there's more pressure from the room pushing down on the sucker.

Teacher: I don't think you've all got it yet.

Although Damian provides the required response, Richard decides to *overlook* it and acknowledges that there may still be problems for the class as a whole. This

is a critical point in the development of the conceptual line of the narrative. Richard has started the lesson with a routine review to rehearse the scientific pattern of explanation for the rubber sucker on the interpsychological plane. Both Adam and Jamie offer explanations which draw on spontaneous views and when pressed by Richard state that the pressure is greater under the sucker. In the face of these responses, Richard makes the decision to return to the start of the conceptual line and to review the scientific explanation as it was first presented in the context of the 'Bottles' demonstration. This action constitutes the kind of 'recursive loop' referred to by Tharp and Gallimore (1988) in setting out their four stages of the ZPD (see Section 2.4.1). Richard is returning to a point in the narrative where he judges that 'shared understanding' can be re-established:

> **Teacher:** I want you to think back to what we did at the beginning of the lesson last time - put your hand down. We had a bottle, we connected it to an air remover and we pumped the air remover until the air was taken out the bottle, and the sides of the bottle did something. What did they do Steven?
> **Steven:** Went in
> **Teacher:** Right they crushed in.

Richard takes the students back to the beginning of the previous lesson by describing the apparatus used in the demonstration. It is quite clear that this is a *univocal* statement, contributions from the class are not encouraged: 'put your hand down'. Richard then *checks understanding* about what happened to the sides of the bottle. Steven offers the correct answer, which Richard validates and repeats to the whole class, *promoting shared meaning*.

Richard then returns to the scientific explanation in terms of air pressure:

> **Teacher:** And we said that, that we'd got this bottle and we'd taken some air out - what happens to the air pressure when you've taken some of the air <u>out</u> of a space?
> **Clare:** Took it out of t'bottle and all sides come in.
> **Teacher:** You're not telling me what's happening to the pressure though Clare. You wrote this down in your books. If you remember we said, the less air in a space, something happens to the pressure. Natalie?

Richard uses the *collective we* expression as if referring to some previously shared agreement, 'we said that...', and then attempts to *shape* development of the scientific explanation by posing a question in terms of air pressure: 'what happens to the air pressure when you've taken some of the air <u>out</u> of a space?' Clare

responds by describing the phenomenon. Richard *differentiates* between Clare's description and an explanation in terms of air pressure,'you're not telling me what's happening to the pressure...'. Richard then appeals to the authority of what was recorded in the students' exercise books and rephrases his question to fit the format of the scientific rule, 'the less air in a space....something happens...to the pressure'. At this point all that Richard is asking for is a single word, the students are not being asked to provide a detailed explanation.

Natalie now takes over:

Natalie: The air's been taken out.

Teacher: So what happened to the pressure?

Natalie: [*no answer: general noise*]

Teacher: If you take the air out so there's less air in a space, what happens to the pressure, Natalie?

Natalie: Well - it tries to get back in, don't it?

Teacher: Is the air pressure the same, or is it less, or is it more?

Natalie: More.

In each of these exchanges with Natalie, Clare, Jamie and Adam there is a strong sense of teacher and students 'sliding passed' each other in the discourse as Richard poses questions in terms of the *scientific* view and the students respond by drawing upon *spontaneous* ideas. Furthermore, Richard does not react to this mismatch in views; he continues to pose questions about air pressure as he receives answers about 'what happens'. Teacher and students are 'worlds of knowing apart' (Solomon, 1983) and Natalie ends up stating that removing air results in 'more' pressure.

Richard continues:

Teacher: We're struggling here. Right, all pay attention. I'm going to ask you all to put your hands up in a minute. You wrote a sentence in your book underneath a diagram of three plastic bottles. One plastic bottle had air added, one plastic bottle had air removed, and the other plastic bottle was just as it came. And you wrote underneath that less air in a space equals, something pressure. Did you write in your book, less air in a space equals smaller pressure? less air in a space equals bigger pressure? [several voices call out 'yes' in the background] or did you write down less air in a space equals the same pressure?

An impasse has been reached and Richard attempts to resolve it by drawing on the authority of what the students have recorded in their books (although the books are not available to the students at this point). The students duly vote on the three options: two indicate that less air gives a smaller pressure; one that less air gives the same pressure; fifteen that less air gives a greater pressure. The others aren't sure. Richard responds to this outcome:

> **Teacher:** Well I'm afraid 15 people are wrong. If you take air out of an object so that there's less air inside the space it means the pressure is less.

He then restates the pressure difference explanation:

> **Teacher:** The explanation that I suggested last week was that when you take the air out there's less air left inside the bottle and when there's less air there's less pressure inside the bottle. So the pressure on the outside is more than the pressure inside and the greater pressure on the outside squeezes the sides in. That's what we said and that's what we wrote in your books.

6.4.2 Review of teaching interventions in Episode 2.1

Given the proficiency with which Matthew, Nick and Jamie had been able to talk through the air pressure explanation for 'Rubber Sucker' at the end of the first lesson, then the students' responses in this review were possibly surprising. Richard responded to their ideas by: asking questions in terms of air pressure; reviewing the 'Bottles' demonstration from the first lesson; referring the students to the record in their notebooks; staging a vote on one aspect of the air pressure explanation.

Each of these interventions was strongly *authoritative-univocal* in nature as Richard focussed on the scientific view, not attempting to probe the understandings which lay behind what the students were saying. The univocal nature of Richard's approach became even more apparent as he turned to the notebook record of the scientific view. The notebook inscription was not referred to here as a possible 'thinking device' or 'generator of meaning', it was offered as an authoritative record to be consulted. The strategy of asking pupils to vote was directed simply at trying to ascertain what the students had written down in their books. Richard's final words ('that's what we said and that's what we wrote in your books') were presented and phrased almost as though he was referring to a broken agreement. Indeed there had been a break-down in shared understanding between teacher and students relating to the conceptual line of the narrative.

Throughout the exchanges of this episode, Richard focussed on the scientific view and as a result overlooked the students' thinking. There were no dialogic sequences where Richard might pause to probe what the students were saying. Richard judged each of the students' contributions in terms of the scientific view and quickly passed on from one student to the next as each failed to provide that view. There was certainly no evidence of the *responsiveness* to students' thinking which has been posited as a key feature of scaffolding.

6.4.3 Student reasoning after Episode 2.1

During the remainder of Lesson 2 (and after 'Rubber Sucker' review), the researcher took the opportunity to talk informally with various students, to probe their thinking about 'Rubber Sucker', to try to find out why there should have been this apparent shift in understanding between the end of one lesson and the start of the next. First is Jamie:

Researcher: You said you thought it would be a bigger pressure under the sucker, what did you mean when you said bigger pressure?

Jamie: I thought it'd be more pressure, cos it's - Cos it was harder to pull up, there'd be bigger pressure under there. Y' see if it were low pressure it'd be easier to pull up.

Researcher: The question is where is the bigger pressure?

Jamie: Inside the sucker.

The reasoning underlying Jamie's earlier response in class (bigger pressure under the sucker) becomes apparent as he argues that a big pressure is needed to hold the sucker in place. Jamie makes no reference to the action of the surrounding air; he is drawing on *spontaneous* ideas for which the centre of action lies under the sucker.

Researcher: So what do you think is the explanation now, from what Mr N. was saying. Did you follow it?

Jamie: Yeah. That - it isn't a bigger pressure it's a smaller pressure.

Researcher: Right, so what's actually holding the rubber sucker onto the table as far as you're concerned?

Jamie: The pressure underneath the sucker.

Researcher: Mmm, it's just that you were saying at the end of the previous lesson, it's not just thinking about the air under the sucker, but y' also have to think about the air on the outside.

Jamie: Yeah, cos there's air pressure pushing down on the sucker.

The researcher reminds Jamie of Mr N's explanation but Jamie still maintains that it is the pressure underneath the sucker which holds the sucker to the table. The researcher then reminds Jamie of what he was saying at the end of the previous lesson and Jamie, in a matter-of-fact kind of way, slips back into talking about external air pressure. There is a 'fluidity' of performance here as Jamie now relates the big force needed to remove a sucker to a big pressure under the sucker (*spontaneous* view); then, when the pressure difference argument (*scientific* view) is suggested, he takes that up without any apparent problem. A little later Jamie confirms that the pressure difference explanation makes sense to him, relating it to an earlier idea of his: 'Yeah, that's right cos if you went up in outer space where there's no air pressure, it'd [*the rubber sucker*] pop up'.

The researcher talks to two other students Tarben and Adam who, with support, are able to present a good pressure difference explanation for the rubber sucker. The researcher then asks:

Researcher: Right, well why did you say it was high pressure in the lesson?
Tarben: I forgot, I just put me hand up..
Adam: ..I forgot all about it.

Tarben and Adam's comment bears the hallmark of the real world of schools; they have been introduced, in an earlier lesson, to a novel way of talking about a familiar phenomenon (why the sucker sticks) and have simply forgotten the 'workings of the new explanation'. As a result they drift back to their *spontaneous* way of thinking about the phenomenon, where the point of action is located under the rubber sucker and the external air pressure has no part to play.

All three boys are at a point in their learning where they still require assistance from some other person if they are to correctly apply the science view. All three boys are operating at a stage within their Zone of Proximal Development where they still require assistance if they are to achieve the learning goal. According to Tharpe and Gallimore (1988) they are operating in the *first* stage of the ZPD 'where performance is assisted by more capable others' (see Section 2.4.1). The events of this episode demonstrate that learning in the ZPD has an associated time line and that it cannot be assumed that one demonstration of competence by the learner equates with fully developed understanding and a mature state of learning.

6.4.4 The 'Pressure Circus' (Episode 2.2)

In the remainder of the second lesson the students worked in pairs on the 7 activities of the Pressure Circus (see Appendix 2 for details of the activities). The Pressure Circus was the culminating activity of the teaching sequence in that it allowed the students the opportunity to apply the air pressure difference rule to a range of different phenomena.

Richard first briefs the students about the circus:

> **Teacher:** You're going to have seven activities to do where it's going to ask you to do something and then write down what you think is the explanation for it, and we want you to use those new ideas. Those ideas about more air in a space means more pressure. So dotted around the room...[*Richard continues with detailed and lengthy procedural instructions for working on the circus of activities*].

In each of the activities of the first lesson Richard took the lead in presenting the scientific explanation. Here the situation is different in that the students, working in pairs, are handed the initiative for talking and thinking through an explanation for each of the phenomena. In Bruner's (1983) terms the circus format enabled 'handover' of responsibility for applying the scientific rule to the students. It also allowed Richard to interact with small groups of students and to provide whatever assistance might be needed in applying the scientific rule; in other words it provided the opportunity for Richard to *scaffold* the performance of the students in applying the scientific rule.

In the following paragraphs three interventions, which were made by Richard in working with pairs of students during the circus, are analysed with reference to the four characteristic features of scaffolding developed earlier (see Section 5.6.1). In the first intervention Richard is talking to Natalie and Clare about 'Plunger':

> **Teacher:** So when you press it down?
> **Student:** You can feel the air, the air round.. [*the air squeezed from under the plunger*]
> **Teacher:** ..the air pushes out..
> **Students:** ..yeah and it's out - that's why it stays on the table.
> **Teacher:** Now, it says 'explain in terms of air pressure'. So where does the air pressure come into it?

Student: The pressure's holding it down. It's like on here [*pointing to the outside surface of the plunger*] and it pushes it down.
Teacher: What was it that you had before about, 'less air in a space - small air pressure?' So in this case where would the small pressure be and where would be the big pressure?
Student: Small pressure's inside and the big pressure's outside.
Teacher: So you press down - get rid of the air - that makes the pressure underneath smaller?
Student: Yeah.
Teacher: You've still got all of the air on the outside, which makes the pressure - and it's just holding it there.
Students: Yeah.

Richard poses a series of key questions to lead the discourse, step by step, from phenomenon ('so when you press it down?'), to air pressure ideas ('so where does the air pressure come into it?'), to differences in air pressure ('so in this case where would the small pressure be and where would be the big pressure?'). In this way Richard *shapes* Natalie and Clare's responses to the 'pattern' of the scientific explanation as he uses questions to lead the girls from one idea to the next.

The pattern of discourse for each step in the explanation is distinctive. For example in the first step:

Teacher: So when you press it down?
Student: You can feel the air, the air round..
Teacher: ..the air pushes out.
Students: ..yeah and it's out - that's why it stays on the table.

Richard poses an instructional question, the student responds, Richard 'talks back' the student response and the students continue. The utterances from teacher and students read like a continuous text as Richard provides just enough prompting and assistance to allow Natalie and Clare to talk through the explanation. Crucially Richard allows Natalie and Clare the opportunity to introduce each of the key points ('you can feel the air, the air round'; 'the pressure's holding it down'; 'small pressure's inside and the big pressure's outside') and is therefore able to both *check* their understanding and 'handover' responsibility for presenting the explanation. Richard concludes the intervention by summarising the whole explanation: 'So you press down - get rid of the air - that makes the pressure underneath smaller?...You've still got all of the air on the outside, which makes

the pressure - and it's just holding it there'. This is 'pedagogical scaffolding' in action.

In the second intervention, Ian and Monica are working with a U-tube water manometer with one side connected to the gas supply ('Gas Tube'). Ian has already turned on the supply and Richard asks him what happened:

Ian: The water goes up and stays there.

Teacher: Did it keep going out the end of the tube?

Monica: No, it went to a certain point.

Teacher: Why not? - you kept the gas on and it stopped? So how do you explain that?

Monica: I dunno.

Ian: I get it! [*excitedly!*] - the gas gets stuck sir!

Teacher: Right, the gas is stuck in the tube.

Ian: Yeah!

Teacher: So why doesn't it come out of the other side?

Richard focusses the talk on the question of why the water in the tube *stops* going up when the gas is kept on. This is a key question which anticipates the students' likely thinking: that the gas pressure acts on the water to push it round the tube and no account is taken of the air pressure acting down on the water in the second limb of the U-tube. For many students this demonstration therefore constitutes a discrepant event, they expect the water to be ejected from the tube when the gas supply is turned on.

Monica responds:

Monica: I dunno [ ] Is it because the gas is coming out of the other end [*of the U-tube*] and not staying pushing there?

Teacher: Do you mean the gas is going <u>through</u> the water somehow?

Monica: Yeah!

Teacher: Couldn't see any bubbles going..

Monica: ..Mmmm.

In this brief dialogic exchange Monica is happy to try out ideas and Richard responds in a supportive way in helping her to evaluate those ideas.

Richard continues:

Teacher: What about air pressure? Now would that have anything to do with it?

Monica: The air pressure's going through that [*the open end of the U-tube*] and it pushes down on t'water.
Teacher: Right, the air pressure's going in the other end and pushing down. Right..
Monica: ..and that one's trying to push up so they stay the same.
Teacher: So they balance out. Good. You've got it!

As Monica comes to a halt with her talk and thinking Richard introduces the notion of 'air pressure'. He offers the idea tentatively 'would that have anything to do with it?' In this way Richard assists Monica in applying the concept of air pressure to this particular problem; furthermore he has provided just the level of support which enables Monica to demonstrate that she can apply the concept, by herself, to this situation. Richard 'hands-over' the conceptual tool to Monica and she is able to take and use it.

An interesting point in this exchange is the way in which, after Richard poses the key question, Ian makes his light-hearted remark and then fades out of the discourse. It is clear from Monica's responses that she has become fully involved in this scaffolding event. Ian is not involved and in fact drifts away from this area of the laboratory as Richard and Monica talk. This difference in response highlights the problem of scaffolding the learning of more than one person at a time, even when it is just one other who is involved.

It is also noticeable that in the intervention Richard focusses upon the action of 'air pressure' on the water in the second limb of the tube and does not draw attention to the fact that the gas pressure provided by the supply is balanced by a combination of external air pressure and the weight of the column of water in the second limb. In this way Richard 'simplifies' the scientific explanation, possibly so that the part played by air pressure is given full prominence.

The analyses of both of these interventions demonstrate how Richard was able to use a combination of 'instructional' (through the planning of the circus and the selection of individual phenomena) and 'pedagogical' scaffolding to assist the performance of students. In both cases Richard was sensitive to the learners' current levels of performance and was able to provide just the right amount of support to enable them to progress with their ideas and to ultimately apply the scientific view.

In the third intervention John is working on 'Plunger' when Richard appears:

John: Sir I don't understand it.

Teacher: What's making that plunger stick to the tile?

John: Air pressure..

Teacher: ..where's the air pressure that makes it happen?

John: Is it inside this here? And it's sucking the plunger down so that it sticks?

Teacher: Watch what happens. There's air in here, alright? There's still air in there and it's not sticking. Now when you push it down that's pushing the air out and when you let go, the air's been pushed out, there's less air inside, there's less pressure inside, there's more pressure on the outside, so it sticks it to it. Now, let's have a margin and a title.

This exchange contrasts markedly with the previous two. John starts by declaring that he does not understand; he talks about air pressure but is clearly thinking in *spontaneous* terms (focussing on what happens under the sucker). Richard does not respond to John's present thinking but instead talks through the scientific explanation. For whatever reason, Richard is *not* responsive to the learner's starting point and is therefore not acting to scaffold learning. This third intervention actually occured towards the end of the circus activity. It could be that Richard simply didn't have the time (or the energy?) to go back to the basic ideas of air pressure with John.

6.4.5 Student reasoning during Episode 2.2

As the class worked at the circus activities the researcher talked briefly with Nick and Jamie who were working together and Matthew who was working with Paul.

Nick and Jamie are explaining how, when the teat is squeezed and released, water comes up into a pipette ('Dropper'):

Nick: I think it's when you're doing that - put it under [*the water*], you push in, it squashes all the compressed air, so all the air's compressed into there [*the barrel of the pipette*] - so then it's under water, so when you let go - the air stretches back up - and pulls all the water back up as well.

Researcher: Right, the only thing we haven't mentioned is air pressure, cos it says..

Jamie: ..that <u>is</u> the air pressure, the pressure of the air pushing down on the water.

Nick explains that the air inside the dropper becoming compressed and then 'pulls all the water back up'; he is drawing upon spontaneous ideas in framing the explanation. Jamie then refers to the action of air pressure as the teat is squeezed to *empty* the water from the dropper.

Discussion turns to what happens when the teat is released:

Jamie: All t'air comes out - some more water comes in.

Nick: And then it thinks it's going to get air back in, can't get the air back in that it needed, so you get water back in..

Jamie: ..instead.

Once again Jamie and Nick make no reference to the action of external air pressure in their explanation. A little later Nick and Jamie are considering what happens inside the tube when water is removed from the top of it ('Tube'):

Researcher: Well go on, go through it. You've got your air remover.

Student: Yeah - and then the air - as the air comes out - well, there's more room for the water to go in..

Student: ..cos you're sucking all the air with this [*the pump*] - its nothing left to pull out, so it's pulled water up.

As with 'Dropper', Nick and Jamie draw on *spontaneous* ideas of pulling water up to explain why the water rises up the tube when air is removed. They make no reference to the concept of air pressure.

Matthew and Paul are working on 'Tube'.

Researcher: You took the air remover and took the air out of there..

Students: ..yeah..

Researcher: ..and what happened?

Matthew: Replaced by water..

Researcher: ..and why does the water go up the tube?

Matthew: Because the air pressure inside the tube pressing onto the water is a lot less than the air pressure outside, so the water is forced up in the tube.

Matthew correctly uses pressure difference ideas to explain why the water rises up the tube. Matthew and Paul next consider 'Plunger':

Researcher: So what happens when the plunger's pressed down onto the table?

Matthew: Sticks to the table.

Researcher: Right, and explain in terms of air pressure.

Matthew: Well, it's when you push all the air out of there [*from under the plunger*], the air pressure is less in there, so the air pressure here [*outside the plunger*] cos it's more than that, presses that down, so it doesn't come off again.

Once again Matthew is able to construct an explanation in terms of differences in air pressure.

6.4.6 Review of teaching interventions in Episode 2.2

Nick and Jamie's responses to 'Dropper' and 'Tube' demonstrate the problems involved for learners in applying a scientific explanation which has been introduced in one context to other different contexts. In both 'Dropper' and 'Tube' the scientific explanation involves considering the air pressure difference across the water present in each system. Whilst Matthew was able to do this, Nick and Jamie drew on spontaneous ideas of 'pulling up water' to explain what happens. Vygotsky has made the point that everyday or spontaneous concepts stand, 'between the conceptual system and the world of objects' (Vygotsky 1987, p.180). For Nick and Jamie it appears that (at this point in their learning and in these contexts) the immediacy and common-sense qualities of everyday notions were sufficiently compelling to short-circuit attempts to construct an explanation based on pressure difference ideas.

A related point arises here which concerns the students' perceptions of the *purpose* of the Pressure Circus. From the teacher's point of view the circus involved applying the pressure difference explanation to a range of phenomena; implicit in the activity is the epistemological principle that the scientific explanation is generalisable across contexts. However, given the way in which students such as Nick and Jamie readily used non-scientific ideas to frame explanations, a question arises as to whether the students shared the same understanding as their teacher of the purpose of the circus.

This is precisely the point that was raised and discussed in the context of the 'Balloons' activity in the first lesson. In presenting this part of the instructional sequence Richard did not refer to the key organising feature, which is the epistemological one of the 'generalisability' of scientific explanations. There is the same 'gap', in the epistemological line of the narrative as that referred to in the context of 'Balloons' and there is some evidence here to suggest that this omission may have had an effect on how students viewed the purpose of the 'Pressure Circus' and subsequently approached the various activities involved in it (being

prepared to develop an explanation for each phenomenon and apparently not recognising the key requirement that the explanation should be based on the new way of explaining).

6.5 Analysis of the teaching interventions of Lesson 3

The final episode of the teaching sequence extended for approximately the first 30 minutes of the third lesson. The students are sitting in their normal places and Richard starts the lesson by reviewing some of the activities from the Pressure Circus.

6.5.1 'Pressure Circus' review (Episode 3.1)

Richard firstly asks the class about 'Springback':

Teacher: This was called 'Springback' on the card I think. If you pull the plunger out and let go, what happens Ian?

Ian: Just, erm, - goes in - back.

Teacher: It goes back in. Right. Has that got anything to do with air pressure?

Students: Yeah...

Teacher: Can you say what Ian?

Ian: Cos, it's erm - the air pressure is pushing it, pushing, erm - the syringe.

Teacher: Where's it pushing it? Where's this air pressure pushing the syringe?

Ian: Erm, it's - it goes back right slow because the air pressure is pushing it [ ].

Teacher: Is it, everywhere - or is it on here, or is it inside? Where's the air pressure? There's some air pressure inside?

Ian: Yes.

Teacher: Is there any pressure outside?

Ian: Yes.

Teacher: What does the air pressure do? Which air pressure's making it go back in?

Ian: The outside air

Teacher: The outside air pressure. I think we're getting somewhere!

In this opening sequence Richard takes steps to *maintain* the narrative by reviewing one of the Pressure Circus activities and *checks* understanding of the scientific explanation by asking one of the students to explain how air pressure makes the plunger go back in.

The form of this interaction with Ian is similar to that observed in Episode 2.2 where Richard was talking to Natalie and Clare during the Pressure Circus.

Richard starts by asking Ian to describe what happened when the plunger was released then poses a series of key questions to lead the discourse, step by step, from phenomenon ('if you pull the plunger out and let go, what happens?'), to air pressure ideas ('has that got anything to do with air pressure?'), to differences in air pressure ('which air pressure's making it go back in?'). In this way Richard *shapes* Ian's responses to the 'pattern' of the scientific view. An important purpose of the exchange is not only to check understanding but also to rehearse the scientific explanation on the interpsychological plane *promoting shared meaning* .

Richard briefly refers to two other activities from the circus and then makes a statement about the general form of the scientific way of explaining:

> **Teacher:** What I'm trying to get you to think about is that they all work because there are <u>two</u> lots of pressure working. There's always <u>two</u> lots. Can anybody think of any exceptions, where there was really only <u>one</u> lot of air pressure that made it work?
> **Student:** Don't understand what you mean sir.
> **Teacher:** Don't you? Well good lad for saying, let me just try and show you. Ian was saying that this [*the 'Springback' syringe*] has just got two lots of air pressure. He was saying there's some <u>inside</u> and there's some on the <u>outside</u>. And its not just something on the <u>inside</u> that's making it work, but there's something on the <u>outside</u> as well which is pushing - it's the air on the outside pushing to where the pressure's less [*at this point there is absolute silence in the class*]. Alright, is there anybody who's not quite clear why there's two lots of pressure on this one? OK, so if that's an example, can you think of any of the others where there's <u>not</u> two lots of pressure?

Richard differentiates between explanations based on one and two lots of air pressure and in doing so further *shapes* the form of the scientific explanation. He also *marks* the importance of these ideas by talking in a very clear and deliberate manner. Richard uses the syringe example to illustrate what he means and there is silence in the room as the students listen, at this point Richard has the full attention of the class. When he has finished Richard looks to *check* student understanding by asking for any questions.

There is some discussion then Richard acts to *maintain* the narrative by making a summary statement:

> **Teacher:** What I'd like you to try and think is that when things happen due to air pressure - its when you change the air pressure in <u>one</u> place so that its

different to the air pressure in a different place. And its the difference between them that makes things happen.

There is a sense in which the narrative has now come full circle. Richard started the lessons by introducing the scientific explanation as a decontextualised rule (more air, more air pressure; less air, less air pressure). He then demonstrated how that rule could be applied to a range of phenomena and allowed the students the opportunity to practice applying it for themselves. Finally the scientific explanation is reviewed and summarised here in a decontextualised form.

Richard now moves on to consider 'Tube' and asks what happens when more air is pumped into the top of the tube. Jamie responds:

Jamie: It [*the water inside the tube*] goes down.
Teacher: Why's that?
Jamie: Putting more, er, pressure into it, pushing the air, creating pressure and so it's pushing water down.
Teacher: Right, when you make the pressure inside higher, it pushes the water down.
Jamie: And when you make it less..
Teacher: ..and when you make it less than what's around the outside, the water goes up. So why does the water go up?
Jamie: Cos there's less air - plus the water - I mean, air taker's taken all the air out..
Teacher: ..yeah..
Jamie: ..and it hasn't got a lot of stuff left to take out - so its got to try and get what's nearest - and that's the water.
Teacher: The air taker, takes the water out?
Jamie: Yeah.
Teacher: It's the air taker, when you do that, that's drawing the water up? [ ] No!
Jamie: Sir?

Jamie and Richard talk through the case of 'adding air'; Richard paraphrases Jamie's response to *shape* presentation of the scientific view: 'when you make the pressure inside higher - it pushes the water down'. Jamie then takes the initiative in turning attention to to the situation where the air pressure is made less. Richard intervenes to further *shape* presentation of the scientific view asking 'why does the water go up?' Jamie responds by drawing on *spontaneous* ideas of the air taker pulling the water out; this is same the kind of explanation as that proposed

by Jamie and Nick during the Pressure Circus activities in the previous lesson. Richard repeats Jamie's reply, *checking* that this is what Jamie means and then responds with an abrupt, 'No!'. This is quite a dramatic intervention by Richard; even Jamie appears to be taken aback! Furthermore, Jamie appears to be genuinely surprised that his answer, which again is based on *spontaneous* ideas of pulling the water up, is not accepted as being correct.

Richard turns to Matthew who has his hand up:

Matthew: Cos the air pressure inside the tube is less than the air pressure outside. The air pressure outside pushes the water in then it goes up in the weakest - amount of air pressure is - it goes up into the tube.

Teacher: The air pressure on the inside is less. The air pressure on the outside in the room is therefore greater. Then you said, the air on the outside then pushes the water down which is in the the basin and it goes up inside the tube. Yeah. That's right.

Matthew's explanation contains all of the key scientific points; Richard repeats Matthew's points about the air pressure inside and outside the tube to the whole class, *promoting shared meaning*, and then *shapes* the second part of the explanation by paraphrasing and reporting what Matthew said, 'then you said, the air on the outside...'. Once again Richard *marks* the importance of this explanation by talking in a slow and very deliberate way.

Richard now continues:

Teacher: What I'd like you to write in your books in a moment. I'd like you to describe what happened - in other words what you saw for each of the three [*'Plunger', 'Springback', 'Dropper'*]. Then I'd like you to write your explanation for why - using the new way. I'm going to go through it now...

Richard starts by reviewing 'Plunger':

Teacher: Let's start with the plunger. This is to describe what happens. When you put the plunger on top of the flat surface nothing happens. But when you push it down it then sticks to the surface. Alright? That's a description of what happens. What's the explanation - using the new way of explaining how air pressure works? What's the explanation Adam?

Adam: The air comes out from underneath the sides, like the sucker - and then the..

Teacher: ..right. We've got two lots of air pressure, one inside the the cup of the sucker and one on the outside. When you push it down, you're squashing

the air out of the cup. There's less air inside, that means there's less pressure inside so the greater air pressure in the room pushes it down, holds it down. Is there anybody who couldn't write that down in their books? Brilliant!

Richard starts by making the *epistemological* distinction between describing and explaining and asks Adam for an explanation in terms of air pressure. Adam begins tentatively and Richard takes over to *present* the scientific explanation in an *authoritative* way. The time for discussion and exploration of meaning has passed and this is clear from the *univocal* nature of Richard's delivery. Here he is simply registering the scientific explanation, for a final time, on the interpsychological plane.

Richard next turns to 'Syringe':

Teacher: This is the second one. This is the syringe. If you pull the plunger out what happens to it Clare if I let go?

Clare: It goes back in.

Teacher: It goes back in. That's a description of what happens. When you pull the plunger out and let go, it goes back in. What's the explanation using this new way of describing it Glenn?

Glenn: Are you like stretching the air pressure..

Teacher: ..right - there's only a little bit of air inside, but when you do that [*pull the plunger out*], it's got a much bigger space to fill in. In other words the air's more spread out, so there's less air pressure, so there's less pressure inside than there is outside. The pressure on the outside pushes it [*the plunger*] back in.

Richard once again starts with a description of the working of the syringe and *checks understanding* of what happens with Clare. He then turns to Glenn for an explanation of why this happens. Glenn makes a tentative suggestion, 'are you like stretching the air pressure?' Richard *overlooks* Glenn's suggestion and *presents* the air pressure explanation in an *authoritative* manner.

The final example which Richard refers to is 'Dropper':

Teacher: Last one. This is the hard one. This dropper is dead easy to describe what happens. Anybody like to have a go at describing what happens? Yes Nick.

Nick: Get the water in here and then it pulls the water up and then you squeeze it again and it lets all the water run back out.

Teacher: Good lad - description of what happens - when you squeeze it, bubbles come out. That's if the bottom's under water. When you let go, water goes up inside. If you squeeze it again, water comes back out. That's a description of what happens. Sharon?
Sharon: The air pressure outside is pushing the water inside because it's trying to get into the tube..
Teacher: ..right - so it's nearly the same as this thing [*referring to the 'Tube' apparatus*]. If you do that [*squeezing the teat*] you're squeezing the air out. So now there's less air inside than there was before. When you let it go, the bulb springs open again, then we've got less air inside than there was before. There's air pressure on the outside, but the air can't get in because the water's in the way, so the air on the outside pushes the water up instead.

Nick describes what happens and Richard *selects* certain parts of what he says 'squeeze it again, water comes back', whilst *overlooking* other parts, 'then it pulls the water up'. Richard thus shapes presentation of the scientific explanation by *paraphrasing* what Nick has said; he then repeats it to the whole class with a view to *promoting shared meaning*. Sharon then offers an explanation which is consistent with the scientific view; Richard acknowledges this, makes a link to the 'Tube' example and then *presents* the explanation step by step.

The final words of the three lessons belong to Richard:

Teacher: I reckon that everybody's going to get all this right. It's almost a waste of time you doing it I was thinking - but let's just see! What you need to do in your exercise book...

6.5.2 Review of teaching interventions in Episode 3.1

This final episode of the teaching sequence started with Richard reviewing some of the activities from the Pressure Circus. Through the exchange with Ian, Richard was able to rehearse the scientific explanation for 'Springback' in front of the whole class. As outlined earlier Richard achieved this through guiding the exchanges with Ian by means of a series of key questions moving from phenomenon to air pressure ideas to differences in air pressure. Richard then made his statement of the generalised way for thinking about air pressure situations: 'when things happen due to air pressure - its when you change the air pressure in one place so its different to to the air pressure in a different place...its the difference between them that makes things happen'.

The subsequent exchange between Jamie and Richard, about 'Tube', clearly indicated that Jamie at least was still drawing on spontaneous ways of explaining. Through his sharp response to Jamie, Richard demonstrated that he was not about to talk through and discuss the scientific explanation for this particular context a further time. Instead he was able to present the scientific view by means of an exchange with Matthew. In the subsequent exchanges with Adam, Clare and Nick it is just as clear that Richard's intention was to rehearse the scientific explanations for 'Plunger', 'Syringe' and 'Dropper' for a *final* time on the interpsychological plane, making those explanations available to all of the members of the class. Although Richard involved students in rehearsing parts of the explanations it is clear that these were authoritative statements delivered in a univocal manner. The time for dialogue and negotiation of meaning had passed as the teaching narrative was brought to a close.

6.6 Post script: student reasoning two weeks after the lessons

Two weeks after completion of the final lesson all of the students in the class were set a standard school science test which included three questions, 'Plunger', 'Strawball' and 'Springback' from the work on air pressure. The questions are set out in Appendix 3. The following are the written responses from Jamie and Matthew to the questions.

Jamie

Plunger: When the plunger is pressed down the air in its rubber dome is been forced out so the air pressure decreases so the pressure is greater on the outside of the rubber dome so the pressure is pinning the plunger down.
Strawball: When you suck the air out of the straw you are making the air pressure decrease so the pressure outside of the straw is greater so the air pressure which is around us pins the ball to the end of the straw.
Springback: The plunger goes back in because when you pull it out your making the air pressure decrease so the air pressure all around us pushes the plunger back in.

For each of the three questions Jamie draws on pressure difference ideas to provide a full scientific explanation.

Matthew

Plunger: When the plunger is pressed onto the table air is pushed out of the bell. This means that there is less air pressure in the bell than outside, since there is less air. The air pressure pushing down on the outside of the plunger is therefore greater than the air pressure pushing up inside the plunger. This keeps the plunger on the table.
Strawball: When you suck through the straw air is taken out. The air pressure in the straw is now less than the air pressure outside. The air pressure on the outside pushes the ball onto the straw and there isn't enough air pressure on the inside of the straw to push it off.
Springback: When you pull the plunger back the air is spread over a bigger area. Therefore there is less air pressure. The greater air pressure on the outside pushes the plunger back in.

Matthew draws on pressure difference ideas to explain all three cases.
Both sets of responses provide evidence of the boys being able to remember and to apply the scientific explanation.

6.7 Review of the theoretical tools after analysis of Case Study 2

In the previous sections of this chapter an analysis of the teaching interventions of the second case has been carried out using the theoretical tools developed in the first case and relating to:

1. The forms of pedagogical intervention
2. The authoritative and dialogic nature of the discourse
3. The content of the discourse
4. The pedagogical interventions in terms of scaffolding.

In this section these theoretical tools are now reviewed and re-evaluated in light of their application to the teaching interventions of the air pressure lessons.

6.7.1 The forms of pedagogical intervention

The preceding analyses have shown that each of the five forms of pedagogical intervention developed in the first case (developing the conceptual line; developing the epistemological line; promoting shared meaning; checking student understanding; maintaining the narrative) was represented in the teaching interventions of the second case. There were also instances where Richard employed new sub-categories of intervention relating to the five forms. In the following paragraphs each of the five forms is reviewed in turn:

1. Developing the conceptual line

i. Shaping ideas

In the analysis of the first case the following categories of teacher intervention to shape ideas were identified:

a. Teacher introduces a new term or idea (using devices such as: anecdotes; making links to physical evidence; making links to common experience)
b. Teacher guides students through the steps of an argument or explanation by means of a series of key questions.
c. Teacher paraphrases student ideas
d. Teacher differentiates between ideas
e. Teacher offers a direct choice between ideas.

In the second case, the overall instructional approach taken by Richard involved his taking the lead in *presenting* the scientific view at the start of the first lesson in the context of 'Bottles' and then demonstrating how that explanation might be

applied to other systems ('Balloons' and 'Rubber Suckers'). The introduction of the scientific explanation was therefore linked to particular systems and shaping moves were prominent in the pedagogical interventions used by Richard as he talked through the air pressure explanation for each of those systems. Furthermore as it became apparent that students were having problems with understanding and applying the new ideas, Richard intervened to review and to re-explain those ideas. Over the full lesson sequence interventions to shape development of the conceptual line were therefore common.

A specific shaping intervention used by Richard on a number of occasions involved him in guiding students through the steps of the scientific explanation by means of a series of key questions (listed 'b' above). Examples of this approach were enacted in Episode 1.3 where Richard explained the intended meaning of 'more air' and in Episode 2.1 where Richard used a series of questions in attempting to shape presentation of the explanation for 'Rubber Suckers'.

The use of such interventions by Richard to 'shape presentation' of the scientific explanation illuminates a clear point of difference between the first and second case studies. This difference turns on the fact that the 'air pressure' explanation involves a number of linked steps (...remove air...pressure reduced...pressure greater in this place than that...therefore this happens) whilst the 'rusting' explanation simply involves identifying whether or not certain conditions exist in particular locations. Given this difference in the nature of the scientific explanations then it follows that there should be *more* teacher interventions to shape explanations in the second case and particularly interventions (such as the use of key instructional questions) aimed at linking the various parts of the explanation together.

Related to the same point of working with multi-step explanations, is the way in which Richard made interventions to sub-divide the presentation of an explanation into its key component parts. Richard employed this form of shaping intervention when he talked through the scientific explanation for 'Bottles' with Jamie in Episode 1.2 and also when he rehearsed the explanation for 'Balloons' with Matthew in Episode 1.4.

New sub-categories of interventions, identified in Case Study 2, and which involved shaping ideas on the conceptual line of the narrative include:

- Teacher sub-divides presentation of an explanation into its component parts.

- Teacher maintains continuity and consistency in use of terms .
  This was identified in the first lesson where Richard used terms such as 'air adder' and 'air remover' (and even specific words such as 'creases' in describing what happened to the plastic bottle) consistently across different contexts.
- Teacher makes links between different contexts and ideas
  One example of this occured in Episode 3.1 where Richard made a link between 'Dropper' and 'Tube' in reviewing the scientific explanations for both.

ii. Selecting ideas

In the analysis of the first case the following examples of teacher interventions to select ideas were identified:

a. Teacher selects a student response, or focusses on part of a student response
b. Teacher implicitly accepts a student idea
c. Teacher retrospectively elicits a student response
d. Teacher overlooks a student response

If interventions to *shape* ideas were prominent in the second case, then the reverse is true for interventions to *select* ideas. Given that Richard introduced the air pressure concept as the 'new way' of explaining at the beginning of the first lesson, then there were relatively few instances where Richard selected from students' ideas in developing and applying the scientific view. This contrasts with the first case where the 'Nails Activity' allowed all of the students to represent their views and Lynne then deployed various interventions to select from those views. In other words the difference in use of interventions to select ideas by respective teachers reflects the difference in the overall instructional approach taken. In the first case instruction started with students' ideas and Lynne 'worked' on these with various selection interventions; in the second case instruction started with presentation of the scientific view so students' ideas were not represented in the initial discourse and fewer situations arose for Richard to select from student ideas.

Despite the fact that there were fewer interventions to select ideas in the second case, there were certainly instances where Richard selected a specific student idea to help in shaping the development of the scientific view. One example of this occured in Episode 1.4 (see Section 6.3.6) when Richard retrospectively elicited

Matthew's explanation for the 'Balloons' demonstration. In fact each of the sub-categories of intervention listed above (a-d) were identified in Richard's teaching.

iii. Marking key ideas

In the analysis of the first case the following examples of teacher interventions to mark key ideas were identified:

a. Teacher repeats an idea
b. Teacher asks a student to repeat an idea
c. Teacher enacts a confirmatory exchange with a student
d. Teacher poses a rhetorical question
e. Teacher uses a particular intonation of the voice

Each of these examples of teacher interventions identified in the first case was represented in Richard's teaching of the air pressure lessons. Particularly prominent in Richard's overall teaching approach was his use of repetition in signalling the importance of new ideas. For example, in introducing the 'scientific way of explaining' in Episode 1.2, Richard contrived for that explanation to be repeated by himself and students four times over in about as many minutes. Richard also modulated his voice to mark important sections of discourse, particularly in summarising key ideas. Richard proved to be a master of the 'con gravitas' presentational style.

On a number of occasions Richard marked the importance of ideas suggested by students simply by reacting positively to them and thereby validating them. Thus in Episode 1.1 Adam described what happened to the plastic bottle and Richard responded: 'I think I agree ... most of the creases have been pushed out'. In Episode 1.4 Richard responded to Matthew's explanation for 'Balloons' with: 'Good lad! We haven't affected...'.
Thus:

- Teacher validates a student idea.

At other points in the lesson sequence Richard explicitly stated that important ideas were being considered. For example in Episode 1.3, Richard was introducing the features of the 'Bottles Diagram' and stated: 'Right, this is the important part. I think most people can remember what shape the bottles were...'. In this way Richard explicitly marked the importance of what was to follow.
Thus:

- Teacher makes explicit statement about the importance of certain ideas

2. *Developing the epistemological line*

In the analysis of the first case the following examples of teacher interventions to develop the epistemological line of the narrative were identified:

a. Teacher refers to a specific epistemological feature
b. Teacher refers to the validation of scientific knowledge
c. Teacher makes a distinction between different kinds of knowledge

In the air pressure case, Richard used the third form of intervention (c) to explicitly draw attention to the difference between 'old' and 'new' ways of explaining. In Episode 1.2, he made use of this distinction in highlighting the features of the scientific way of explaining 'the new explanation is that there's two lots of air involved here not one'.

A new form of intervention used by Richard and related to the Epistemological Line of the narrative involved distinguishing between 'describing' and 'explaining' phenomena. As outlined earlier this is an epistemological distinction which often creates problem for students. Throughout the case Richard took great care in explicating whether the focus of attention was on describing or explaining. In Episode 3.1, for example, Richard reviewed what happened with 'Plunger' in the pressure Circus and states, 'That's a description of what happens. What's the explanation?'

Thus:

- teacher distinguishes between describing and explaining

The overall instructional approach taken by Richard involved introducing the scientific way of explaining in one context, demonstrating how it could be applied to other contexts and then providing opportunities for students to apply that view to further different situations. The basic 'theme' underlying the structuring of the instructional framework was therefore the 'generalisability' of scientific explanations. This is an epistemological issue and attention has already been drawn to the fact that the concept of generalisability was *not* referred to explicitly during the teaching. In this respect it has been argued that there were 'gaps' in the Epistemological Line of the narrative. In the analyses of the lessons such gaps were identified in relation to the 'Balloons demonstration' and to the 'Pressure Circus'. In both cases the *purpose* of the activity was never made explicit by Richard; the purpose was to make use of the generalisability of the air pressure explanation in applying it to different phenomena.

This notion of a 'gap' in the Epistemological Line raises a fundamental point about what is involved in learning science. In relation to the air pressure case, it can be claimed that learning the scientific view involves: coming to understand the new conceptual tools introduced by the teacher; developing the ability to apply them in a range of situations; *and* recognising that the power of these new tools follows from the fact that they *can* be applied to a range of situations. In other words, learning science involves both conceptual and epistemological goals. Just as Richard distinguished between the *conceptual* bases of the 'old' and 'new' ways of explaining, then there is an important *epistemological* distinction to be made between spontaneous knowledge (where generalisability is not a key feature of explanations) and scientific knowledge (where generalisability *is* a key feature).

The point being made here is not some peripheral aspect of what the teaching of the case study was about. Indeed there is some evidence from the analysis of the case that the failiure to make explicit the epistemological underpinnings of the teaching activities might have led to confusions about the purpose of those activities (in the cases of 'Balloons' and 'Pressure Circus') and might thereby have had a negative influence on students' progress towards achieving the intended learning goals.

3. Promoting shared meaning

In the analysis of the first case the following examples of teacher interventions to promote shared meaning were identified:

a. Teacher presents ideas to the whole class
b. Teacher shares the experiences of individual students with the whole class
c. Teacher shares group findings with the whole class
d. Teacher repeats a student idea/response to the whole class
e. Teacher jointly rehearses an idea with a student in front of the whole class
f. Teacher uses the 'collective we' form in making a statement to the class

All of these interventions to promote shared meaning were represented in Richard's teaching. Particulary prominent were the interventions to jointly rehearse an idea with a student in front of the class. One example of this was enacted in Episode 1.2 when Richard drew on Jamie in rehearsing the scientific view for the first time. On another occasion in Episode 1.4 , Richard retrospectively elicited Matthew's explanation for the 'Balloons' demonstration, repeated it to the whole class and then proceeded to jointly rehearse it with Matthew in front of the class. In addition Richard frequently used the technique

of repeating student ideas making them available to the whole class (as well as marking their importance).

In Episode 1.3 Richard was involved in drawing the 'Bottles diagram' on the chalk board and as he did so he made a spoken commentary relating to the key features of the diagram. In this way he was able to share with the whole class the thinking behind the diagram.
Thus:

- teacher provides a spoken commentary to make explicit the thinking behind a specific activity.

4. Checking student understanding

In the analysis of the first case the following examples of teacher interventions to check student understanding were identified:

a. Teacher asks for clarification of student ideas
b. Teacher checks student understanding of particular ideas
c. Teacher checks consensus in the class about certain ideas.

One feature of the air pressure lessons which became apparent through the analysis concerns the limited extent to which Richard checked students' developing understandings. In a number of episodes full attention was given to shaping presentation of the scientific view and there were few, if any, interventions to check the meanings made. On those occasions where student difficulties did come to light, such as with Adele's understanding of 'more air' in Episode 1.3, Richard did not take steps to *probe* what lay behind that difficulty. In Episode 2.1 Richard checked consensus of the class over the working of the 'Rubber Sucker' by calling upon the students to 'vote' for their idea. Although 15 students indicated the wrong idea, Richard once again did not probe why they should think this way but simply re-asserted the scientific view.

5. Maintaining the narrative

In the analysis of the first case the following examples of teacher interventions to maintain the narrative were identified:

a. Teacher declares intentions/ states aims
b. Teacher refocusses discussion/ maintains focus
c. Teacher rehearses/anticipates possible outcomes
d. Teacher reviews the progress of the narrative

Richard used all of these interventions in framing and maintaining the progress of the narrative.

6.7.2 The authoritative and dialogic nature of the discourse

The characterisation of authoritative and dialogic discourse developed in the context of the first case study (see Section 5.5.2) proved to be useful in analysing the data of the second case.

This analysis indicates quite clearly that authoritative discourse predominated during the three lessons with only short and isolated sequences of dialogic discourse. The analysis demonstrates how Richard used authoritative discourse to: develop and 'perform' explanations (either alone or jointly with a student); to select and represent different voices; to review and summarise different parts of the narrative. This focus on authoritative 'delivery' was accompanied by few instances of dialogic exchange. There were few instances where teacher and students engaged in talk to explore meanings thereby allowing those not directly involved to listen to, and to reflect on, the questions and issues raised.

This focus on authoritative discourse is consistent with the point made earlier that Richard made relatively few interventions to check and probe students' developing understandings. When Richard did gain feedback on any difficulties the students had in applying the scientific rule, he tended not to explore those difficulties but responded by repeating the scientific view. This approach was most apparent at the start of the second lesson in 'Rubber Sucker review'. In contrast to the first case, there was not the mix of authoritative and dialogic forms of discourse. Sequences in which new ideas were introduced were not followed up with opportunities for students to talk about, and to explore, those ideas. There was not the same 'rhythm' to the discourse in the teaching of the air pressure lessons as there was in the rusting lessons.

6.7.3 The content of the discourse

In planning (see Section 4.3.1) the second case it was anticipated that the scientific context of air pressure would entail significant 'learning demands' for students due to the nature of the air pressure explanation and the difference between the scientific explanation and 'everyday views'. In the event this turned out to be the case.

The students in Richard's class completed two diagnostic questions ('Apple Juice Carton' and 'Springback') prior to instruction and their responses, not surprisingly,

drew on everyday notions of 'pulling' and 'sucking' (see Section 6.2). These kinds of responses are referred to as the students' spontaneous reasoning about the phenomena. During the lessons Richard introduced the scientific perspective through a series of demonstrations and student activities. The analysis of the *content* of the discourse set out in the previous sections has shown quite clearly that the students experienced difficulties in coming to understand and to be able to apply the scientific view and that at different times in the lesson sequence students drew upon both spontaneous and scientific concepts. At the end of the first lesson, for example, Jamie was able to talk through an explanation for 'Rubber Sucker' which was consistent with the scientific view; at the start of the second lesson he had reverted to using spontaneous reasoning.

In summary, the Vygotskian distinction between 'spontaneous' and 'scientific' concepts provided an effective basis for monitoring developments in both the content of the classroom discourse and the understandings of individual students. The point was made in Chapter 4 (Section 4.5.2) that in analysing the teaching interventions in the two cases, reference would be made to developing student understandings. This approach has been effectively operationalised through the 'spontaneous' and 'scientific' categorisation of concepts .

6.7.4 Pedagogical interventions in terms of scaffolding

The preceding analysis of Richard's teaching in relation to forms of pedagogical intervention demonstrates the ways in which he assisted students in developing an understanding of the air pressure explanation for a range of phenomena. Bearing in mind the way in which 'scaffolding' was defined in earlier chapters, it is clear that most of these interventions to provide assistance do *not* constitute scaffolding.

In Section 5.6, four characteristic features of scaffolding were discussed and developed in the context of the first case. According to that analysis scaffolding involves:

1. The learner developing some specific competence
2. The teacher being responsive to the thinking of the learner
3. The teacher offering guidance through the learning event
4. The teacher handing over responsibility to the learner

In the teaching of the second case there is evidence of Richard focussing on specific learning goals. Throughout the lessons Richard offered 'guidance' through the learning event in the form of stating aims, reviewing progress,

providing summaries. As outlined in Section 5.6.1 there is overlap here with the pedagogical interventions to maintain the teaching narrative. Richard also set up an instructional framework to enable 'handover' of responsibility for applying the science view, by means of the Pressure Circus. If these aspects of scaffolding were present in the teaching of the second case, it is just as clear that the *responsiveness* to student thinking which is a crucial part of scaffolding was mostly *not* in evidence.

In Section 5.6.1 the responsiveness to student thinking required in scaffolding was broken down into three parts:

i. monitoring present performance of the learner (*monitoring*).
ii. analysing nature of any differences between present performance and performance required by target competence (*analysing*).
iii. responding with an appropriate intervention to address differences in performance (*assisting*).

The point has already been made in the previous section that in Richard's predominantly authoritative instructional approach he made relatively few interventions to check or monitor student understanding. Furthermore Richard tended not to respond by providing assistance based on any differences between the students' present level of performance and the scientific view. For example in reviewing the explanation for 'Rubber Sucker' at the start of lesson 2, Richard responded to students' spontaneous views by repeating ideas and questions relating to the scientific view. In this respect there were few instances where Richard could be said to be scaffolding learning.

Those situations in which Richard did demonstrate the responsiveness to student thinking required in scaffolding occured in interactions with pairs of students during the Pressure Circus. For example in Episode 2.2, during the Pressure Circus, Richard scaffolded Natalie and Clare in applying the air pressure explanation to 'Plunger'. In this intervention Richard was able to provide just enough support to guide the girls through the various steps of the explanation whilst at the same time allowing them sufficient space to introduce each of the new ideas to the argument. In this way Richard was able to both monitor the girls' understandings and handover some responsibility for developing the explanation.

6.8 Summary

In this chapter the theoretical tools developed in the context of the first case study have been applied to analysing the teaching interventions of the second case. In carrying out this analysis, both of the aims set out at the start of the chapter in Section 6.1 have been addressed. That is, the theoretical tools proved to be applicable to the teaching interventions of the second case and enabled analysis (in terms of the forms of intervention, the nature and content of the discourse and the pedagogical interventions as scaffolding) of the ways in which the teacher supported students in developing an understanding of concepts relating to air pressure. In addition, the process of applying the tools to this second case has allowed for further elaboration and exemplification of those tools.

Chapter 7: Summary and Review of Findings

In Chapter 4 three aims were outlined for this thesis. The first of those aims involves explicating, from a perspective informed by Vygotskian socio-cultural theory and framed in terms of the concept of the teaching narrative, how the teachers in the two case studies used and guided classroom talk, over an extended period of time, to support students in developing an understanding of specific scientific concepts. The second aim involves developing and elaborating the theoretical tools used in analysing that talk. The final aim is to consider what general statements can be made about teaching and learning scientific conceptual knowledge from a Vygotskian perspective. In this final chapter these aims are revisited as the findings from the study are reviewed.

7.1 Vygotskian foundations

The theoretical perspective underlying this study follows from Vygotsky's 'General genetic law of cultural development'. This law offers an account of learning higher mental functions, such as scientific concepts, which maintains that those functions appear first as an interpsychological category between people, represented largely through language, and then as part of an individual's intrapsychological functioning. Through the process of internalisation there is transferral of concepts from social to personal planes, a process which does not involve direct copying of social processes but is consequent upon restructuring by the individual.

According to this theoretical perspective a key aspect of understanding mental functioning in the individual is to analyse the nature of the formative social processes enacted on the interpsychological plane. Wertsch (1991, p.47) describes how towards the end of his life Vygotsky, 'became interested in how the forms of speaking encountered in the social institution of formal schooling provide the framework within which concept development occurs'. Unfortunately this line of work was cut short by Vygotsky's death and his analyses of interpsychological functioning lack detailed explication. The present study is directed towards this area of investigation and involves developing theoretical tools for analysing the interactions of the interpsychological plane of the classroom, focussing on teaching and learning scientific conceptual knowledge

7.2 Interactions of the interpsychological plane: the teaching narrative

According to the Vygotskian perspective on learning and development the teacher has a key role to play (see Section 2.4) in introducing students to the language and modes of reasoning of a new way of knowing such as that offered by science. The teacher addresses this task principally through talk and in this study the performance of teacher talk throughout a sequence of lessons has been conceptualised as constituting a 'Teaching Narrative'.

The concept of the teaching narrative is intended to provide an overarching theoretical structure which supports recognition of the fact that teaching and learning in the classroom (certainly of the kind observed in the two case studies) has an extended timeline with beginning and end points, and which involves the teacher in laying a 'language trail' from students' cognitive starting points towards the intended learning goal of the scientific view. This involves a performance on the interpsychological plane of the classroom in which the teacher makes different kinds of interventions to direct and sustain presentation of the scientific view.

As outlined in Chapter 5 (Section 5.3) the study of narrative discourse has received a great deal of attention (see, for example, Bruner, 1990) and it might be argued that appropriating the term 'narrative' to this context of teaching scientific knowledge in the classroom overly strains the generally accepted meaning of the term. It is certainly true that the concept of the teaching narrative extends beyond the original meaning of 'narrative'; the teaching narrative does not include fictional characters or actors involved in the enactment of a story based on some specific plot. The teaching narrative *does*, however, involve the development and presentation of a particular 'story' (a particular way of talking and thinking) about natural phenomena. This scientific story is developed through the conceptual line of the teaching narrative. Using the terms introduced by Ogborn et al (1996) the scientific story involves 'a cast of protagonists' (see Section 3.3.1) each of which has its own capabilities which are what makes it what it is. The protagonists might include entities such as those encountered in the two case studies (air pressure differences and oxide layers); scientific explanations rely on the existence of the 'worlds of protagonists' whose possible behaviours make up the scientific story.

In the science teaching observed in this study each teacher orchestrated presentation of the 'science story', drawing on various conceptual tools (or protagonists), developing particular themes, offering previews and summaries and involving the audience (the students) in the telling, all with a view to making the scientific story available and accessible to students. As outlined in Chapter 3, this perspective on learning science as coming to accept (and to be able to 'tell') a particular 'story' about the behaviour of aspects of the natural world is one which is currently gaining some support (Arnold and Millar 1996; Sutton 1996) in science education circles.

Support has also been given to interpreting more broadly what is meant by narrative discourse. Deborah Hicks (1995), in a major review article on discourse, learning and teaching argues that: 'narrative can be explored as a family of discourse genres in which children and teachers construct extended oral or written texts that order, describe, explain or emplot events both real and fictional'. Following Hicks' assertion, it can be argued that in this thesis the concept of the teaching narrative has been introduced to capture the ways in which the teacher, working with students, constructs an extended oral text to order, describe and explain physical phenomena from a scientific perspective. The teacher talk of the interpsychological plane of the classroom has therefore been conceptualised in terms of a developing and multi-faceted teaching narrative.

What are the key features of the teaching narrative? Reference to Vygotskian theory and the analyses of the two case studies presented in earlier chapters have led to characterising the narrative in terms of four inter-related aspects:

- the forms of pedagogical intervention
- the authoritative and dialogic nature of the discourse
- the content of the discourse
- the pedagogical interventions as scaffolding

In the following sections each of these aspects are reviewed and the relationships between all four are considered.

7.3 The teaching narrative: the forms of pedagogical intervention

The teaching narrative consists of different forms of pedagogical intervention each directed towards achieving a specific purpose. Five categories of intervention have been identified through the analysis of the case study data in

Chapters 5 and 6; these five categories can be grouped into three main strands according to their different purposes as shown in Figure 7.1:

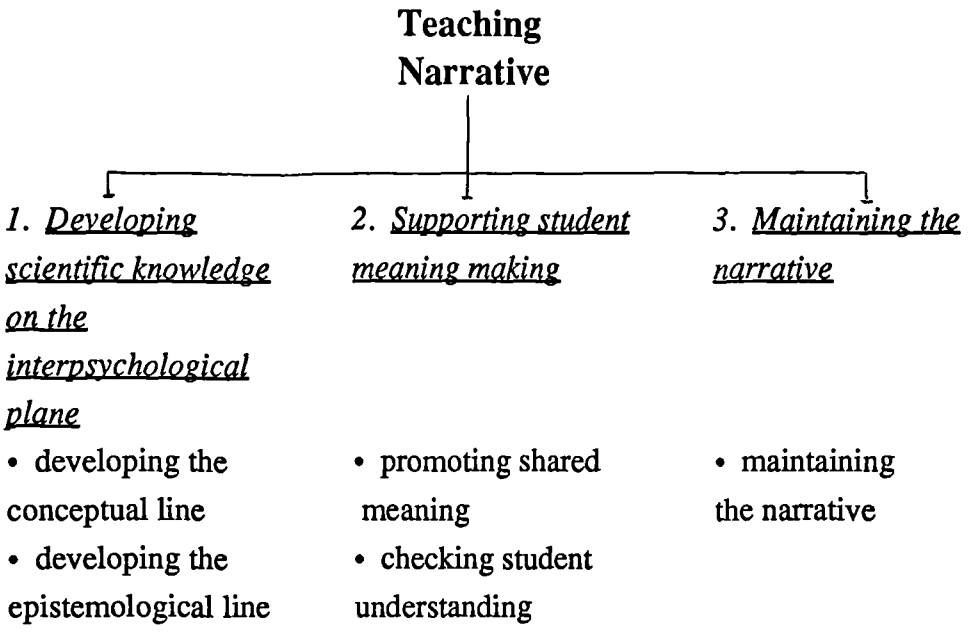


Fig. 7.1 Three main strands of the Teaching Narrative

The first strand of the teaching narrative is concerned with developing the 'science story' on the interpsychological plane of the classroom; the second strand focusses on making the science story available to all of the students in the class and checking the meanings and understandings that they subsequently develop; the third strand consists of interventions which the teacher makes to direct and sustain the narrative, this is talk *about* the narrative rather than 'talking the narrative'. Each of these three major strands of the teaching narrative is enacted through particular forms of pedagogical intervention which are reviewed and summarised in the following sections.

7.3.1 Developing scientific knowledge on the interpsychological plane

Two categories of pedagogical intervention have been identified as contributing to this strand of the narrative:

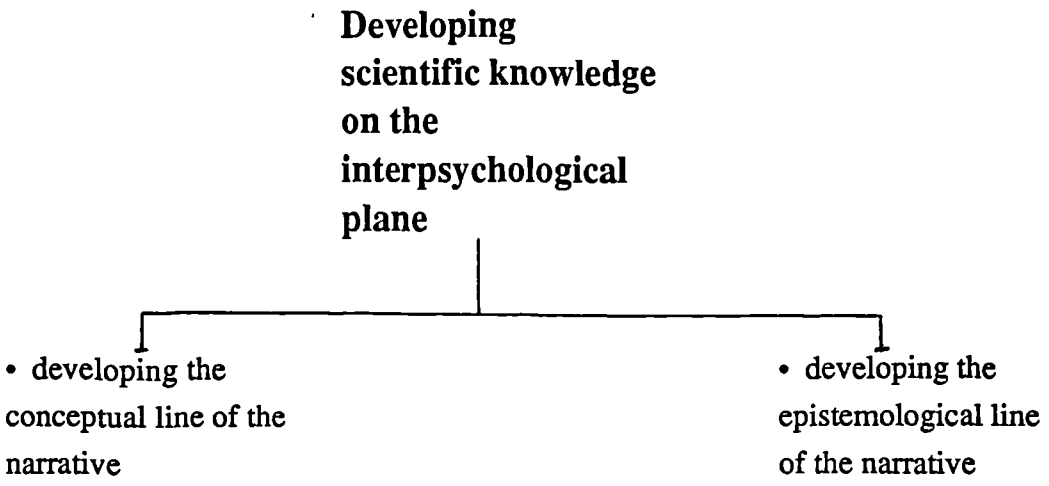


Fig. 7.2 The pedagogical interventions contributing to developing scientific knowledge on the interpsychological plane.

Developing the conceptual line of the narrative

This part of the narrative consists of those teacher interventions which contribute to development of the conceptual line on the interpsychological plane of the classroom. Through analysis of the case studies three forms of intervention for developing the conceptual line have been identified. These are:

- Shaping ideas
- Selecting ideas
- Marking key ideas

Shaping ideas

These are the interventions made by the teacher to shape presentation of the scientific view. In making interventions to shape ideas the teacher might introduce new terms or ideas through a variety of means: by recounting illustrative anecdotes; by relating the new ideas to particular phenomena (phenomena which might be devised and demonstrated in the laboratory or simply be part of common experience). The teacher might guide students through the steps of an argument or explanation by means of a series of key questions and also sub-divide the presentation of a particular explanation in order to highlight its component parts. The teacher might paraphrase student ideas, differentiate between ideas or offer a direct choice between ideas. The teacher might maintain continuity and consistency in use of terms throughout a sequence of lessons and makes links between different contexts and ideas. One form of shaping intervention which was *not* represented in the teaching of either case was the use of analogy or metaphor.

Selecting ideas

These are the interventions made by the teacher in selecting those ideas which contribute to the development of the scientific view on the interpsychological plane. In selecting ideas the teacher might: select a student idea or part of a student idea; implicitly select a student idea; retrospectively elicit a student idea; overlook a student idea.

These interventions involve the teacher in drawing upon *student* ideas and using them to develop the scientific perspective on the interpsychological plane. Such interventions were common in the first case study where the teaching approach involved eliciting students' spontaneous ideas about rusting and subsequent 'selection' from those ideas; they were less common in the second case where the teaching started with a presentation of the scientific view.

Marking key ideas

These are the interventions made by the teacher to mark and emphasise the importance of those concepts and ideas which are critical for the development of the scientific view. The performance of the teaching narrative involves a great deal of talk by both teacher and students and these interventions allow the teacher to signal, and to emphasise the importance of, key ideas. In marking key ideas the teacher might: repeat an idea; ask a student to repeat an idea; enact a confirmatory exchange with a student; validate a student idea; pose a rhetorical question; use a particular intonation of voice; explicitly draw attention to the importance of certain ideas.

In both case studies Lynne and Richard made frequent and striking interventions to mark key ideas. At different times both teachers were able to gain and hold the full attention of their classes simply through stressing the importance of the ideas which were being talked about and presenting those ideas in a very careful and deliberate way. Non-verbal signals at these points in the lessons were particularly prominent with the teacher maybe raising a hand, shaking their head, walking slowly across the front of the room, in whatever way signalling that matters of import were being talked about at that moment in time.

Developing the epistemological line of the narrative

The point has been argued earlier, drawing on the data from both case studies, that learning science involves not only learning how to use scientific conceptual tools but also coming to appreciate and understand the related epistemological characteristics of scientific knowledge. In the first case study it became apparent

that an appreciation of the concept of 'essential conditions' was a fundamental part of developing an understanding of the scientific perspective on rusting. In the second case the whole instructional approach centred on developing a scientific explanation in one context and then demonstrating how it might be generalised and applied to other contexts.

In both lesson sequences, however, points relating to the epistemological line of the narrative tended to be addressed implicitly or neglected altogether by the teacher. Thus in the rusting lessons, the issue of what is meant by 'essential conditions' was not focussed upon specifically in the teaching and this gave rise to some mixed understandings by the students. In the second case the 'generalisability' of scientific explanations was never directly referred to. It has been argued in Section 6.4.6 that this neglect of the epistemological underpinnings of the teaching on air pressure constituted a 'gap' in the epistemological line of the narrative which might have affected the way in which students viewed the purpose of the 'Pressure Circus' activity. Indeed a striking feature of the way in which students did respond to the pressure circus lay in their readiness to use *spontaneous* or non-scientific ideas.

The general point being made here is that learning to talk and think science involves not only learning how to use the conceptual tools of science but also coming to appreciate the epistemological framing of those tools. The evidence from the case studies suggests, however, that even though epistemological features might implicitly underpin specific instructional approaches the epistemological line of the narrative is an aspect of science instruction which tends to be neglected. Furthermore a case has been made to suggest that giving increased prominence to the epistemological line might help students in coming to understand and make sense of new scientific conceptual knowledge.

Addressing ontological issues

In the previous two sections the strand of the teaching narrative which concerns 'developing scientific knowledge' has been reviewed in relation to pedagogical interventions to develop the conceptual and epistemological lines. A further fundamental issue relating to this strand of the narrative concerns the *ontological* status of the scientific concepts which are the subject of instruction.

The differential air pressure explanation introduced in Case Study 2 is based on the idea that air exerts a force on any surface it is in contact with; this is a relatively large force (on a human scale) as was illustrated through the 'Rubber

Sucker' activity. Viewed from the student's everyday commonsense perspective the differential air pressure explanation is quite likely to lack plausibility. Indeed for some students the concept of air as being 'substantial' (rather than 'nothing') might well be problematic; that air is also able to exert large forces constitutes a further challenge to basic assumptions about the nature of air. This is a challenge to basic personal ideas about how the world is, a challenge to fundamental ontological commitments (see Chi et al, 1994).

Put simply, coming to understand the differential air pressure explanation is likely to involve some shift in perspective for the learner on what air *is* and what air *can do*. Ogborn et al (1996, p.14) refer to the need to 'talk into existence' the entities from which explanations are constructed. In the context considered here there is the need for the teacher (and students) to talk into existence the notion of air as a substantial medium which creates considerable pressures and, importantly, to acknowledge that this way of thinking may appear somewhat implausible for students on first meeting. The case study data show that there were no teacher interventions to address this aspect of learning about air pressure explanations. From the outset the scientific explanation was presented as though it was generally accepted by the students that air can behave in this way.

This notion of there being 'ontological shifts' attached to learning is also relevant to the analysis of the rusting case; there is a 'protagonist' (Ogborn et al, 1996) which is common to the scientific explanations developed in both lesson sequences and that, of course, is the air. In the second case the 'capability' of the air to exert pressures is central to the scientific explanation and, as argued above, coming to terms with this idea might involve a shift in basic assumptions about the properties of air. In a similar way the 'capability' of air (along with water and iron) to form rust is central to the scientific view and coming to accept this view might entail a further (and different) ontological shift. To be specific: if air is nothing or lacks substance how can it contribute to the formation of rust? Once again, and now in this different context of rusting, the scientific explanation demands a re-appraisal by the learner of basic ideas about what air is and what it can do.

The general point which is introduced here serves to extend the perspective on teaching interventions used to 'develop scientific knowledge on the interpsychological plane'. The analyses of the two case studies have demonstrated how teachers might address conceptual and epistemological issues in talking through and making scientific knowledge available to students. What was

missing from the talk of the teachers in both cases is any reference to the ontological shifts which may be part of learning in specific scientific contexts (the nature of the ontological shift will obviously be different for different scientific contexts).

'Talking into existence' scientific knowledge on the interpsychological plane involves the teacher in making interventions to address conceptual, epistemological and ontological issues. Thus the strand 'Developing scientific knowledge on the interpsychological plane' might be re-represented as follows:

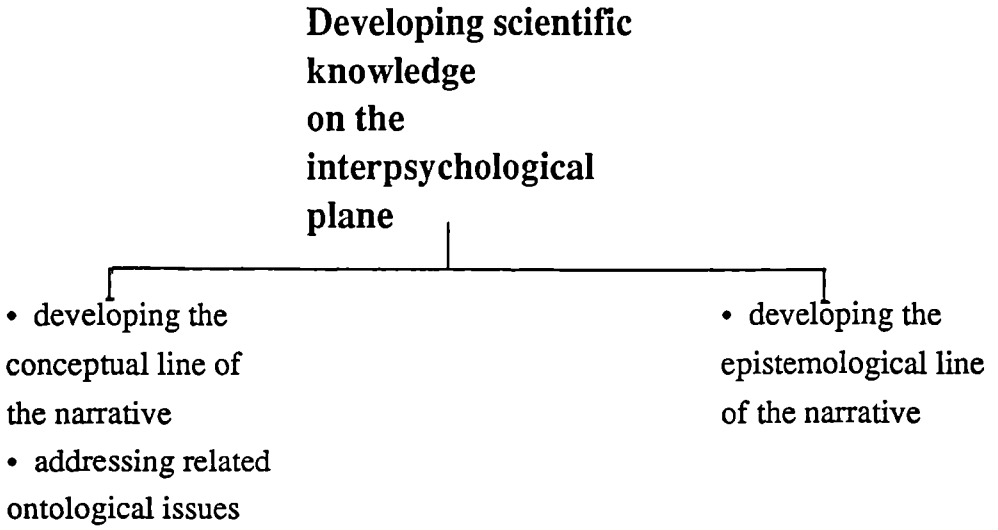


Fig. 7.3 The revised pedagogical interventions (including addressing ontological issues) contributing to developing scientific knowledge on the interpsychological plane.

7.3.2 Supporting student meaning making

Two forms of pedagogical intervention have been identified in the case study data for this second strand of the narrative:

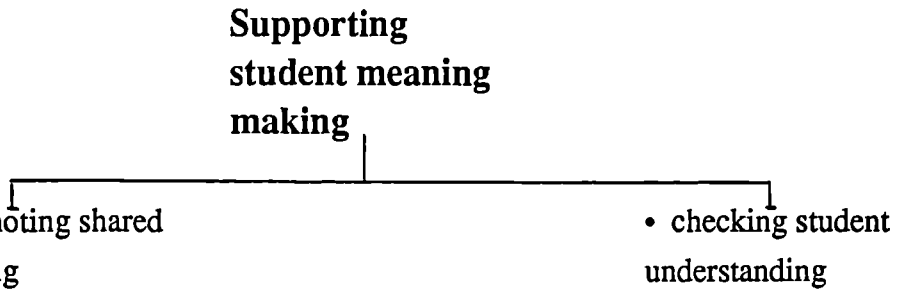


Fig. 7.4 The pedagogical interventions contributing to supporting student meaning making.

Promoting shared meaning

These are the interventions made by the teacher to make the 'science story' available to all of the students in a class. The need for interventions to promote shared meaning follows from the practical logistics of one teacher working with over twenty students; the teacher needs to guide presentation of the science story in ways which make it available to all students.

In promoting shared meaning the teacher might: present ideas to the whole class; share individual student ideas with the whole class; share group findings with the whole class; jointly rehearse an idea with a student in front of the whole class; provide a spoken commentary to make explicit the thinking behind a specific activity that they are engaged in; use the 'collective we' expression.

Both Lynne and Richard used a range of interventions to promote shared meaning. Particularly striking were the routines of teacher and student jointly rehearsing an explanation in front of the class: the teacher initiating an explanation and then asking the student to continue; the student responding and the teacher asking them to repeat what they have just said; the teacher continuing a little further, and so on. It is difficult to think of other situations where discourse is enacted in such a way, apart from scenes in the theatre where some point in the plot is being explicitly talked through by two characters for the benefit of the whole audience. It is certainly the case that the interventions to promote shared meaning are a central part of the 'performance' aspect of the teaching narrative.

Checking student understanding

These are the interventions made by the teacher to check and to clarify students' developing understandings. In 'checking understanding' the teacher might: ask for clarification of student ideas; check individual student understanding of particular ideas; check consensus in the class about certain ideas (possibly through voting).

7.3.3 Maintaining the narrative

The third and final strand of the narrative consists of those interventions through which the teacher provides a commentary on the unfolding science story with a view to helping students follow the development of particular lines of argument and explanation.

In maintaining the narrative the teacher might: state aims/purposes for the next part of the narrative; look ahead to anticipate possible outcomes; review progress of the narrative; refocus discussion. These various interventions to maintain the narrative contribute to the teacher establishing lines of *continuity* (Mercer 1995) in the discourse from one part of the narrative to another. In the first case, for example, Lynne made regular interventions in which she reviewed the progress made along the conceptual line thereby keeping certain issues prominent within the classroom discourse.

7.3.4 Discussion: the forms of pedagogical intervention

In the preceding sections the Teaching Narrative has been reviewed in terms of three major strands which reflect the different purposes of the narrative and the five categories of pedagogical intervention which address those purposes. This scheme is presented in Figure 7.5:

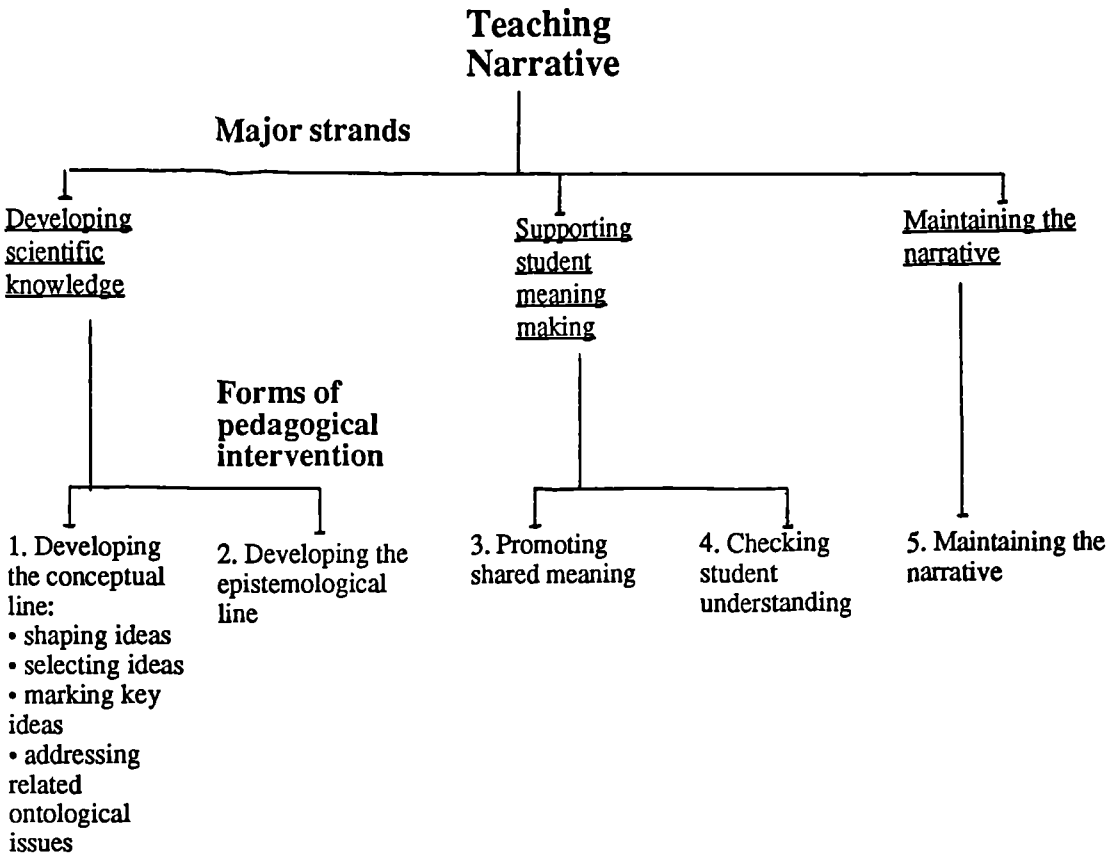


Fig. 7.5 The teaching narrative, major strands and forms of pedagogical intervention.

The concept of the teaching narrative with its five categories of intervention has been developed from Vygotskian theory and analysis of the two case studies as a way of describing and analysing the teacher talk of the interpsychological plane which supports students in learning science concepts. The value of this theoretical structure might be judged from both theoretical and practical perspectives.

In theoretical terms it can be argued that the three major strands of the teaching narrative (developing scientific knowledge; supporting student meaning making; maintaining the narrative) together constitute an appropriate and viable scheme for analysing how a teacher can present a 'science story' in a classroom teaching situation and make it available to all students. The three strands reflect the basic elements of Vygotskian Theory in representing purposes which focus on: making scientific knowledge available on the interpsychological plane (developing scientific knowledge); supporting internalisation of that knowledge to the intrapsychological plane (supporting student meaning making); providing guidance through the learning event (maintaining the narrative).

The five categories of pedagogical intervention reflect the ways in which each of these strands can be operationalised: paying attention to conceptual, ontological and epistemological issues (developing scientific knowledge); performing the science story so that it is made available to all students and checking student understanding (supporting student meaning making); maintaining the narrative so that students are able to follow the various lines of argument.

From a practical perspective, the analyses of the two case studies suggest that the five categories provide a comprehensive scheme for analysing and interpreting the teacher talk aimed at supporting conceptual learning. The forms of intervention which were developed initially in the context of the first case proved to be adequate in analysing the data of the second case with new examples of each form of intervention being identified.

An important point to bear in mind here is that the teaching narrative and the categories of pedagogical intervention offer a means for analysing, for talking and thinking about how *meanings* are developed in the classroom; they provide a scheme or set of theoretical tools to help in interpreting how the talk of the classroom can give rise to individual student understanding. As such it is to be expected that analyses of different sequences of teaching will generate new examples of how specific forms of intervention can be operationalised. It is the outline theoretical scheme (Fig. 7.5) which is offered as an important product of this thesis; the intention is not to produce a comprehensive schedule of the ways in which the various interventions identified in that scheme can be operationalised.

One final point concerning the scheme of pedagogical interventions presented here is that through the analyses of both cases it has become apparent that particular teaching interventions can serve more than one purpose. One example of this 'multi-purpose' quality of teaching interventions can be seen in those interventions where *repetition* of utterances by the teacher might serve both to 'emphasise a key idea' and to 'promote shared meaning'. In other words the different purposes identified for the forms of intervention are not necessarily to be considered and applied exclusively of one another. This point does not signal a weakness in the analytical structure but reflects the complexity of classroom discourse where single utterances can fulfil a number of different functions.

7.4 The teaching narrative: the authoritative-dialogic nature of the discourse

In the preceding sections three principle strands of the teaching narrative have been identified and the various pedagogical interventions by which the teacher puts these into action have been reviewed. This section focusses on *how* those interventions are enacted, drawing on the distinction between authoritative discourse (whose principle purpose is to convey meaning) and dialogic discourse (which centres on exploring meaning or generating new meanings).

Through the analysis of the data of the first case study a characterisation of authoritative and dialogic discourse was developed and this was used in analysing the discourse of the second case. The characterisation refers to three aspects of the discourse: general features of discourse; the nature of teacher utterances; the nature of student utterances.

General features of discourse

Authoritative discourse	Dialogic discourse
• focussed principally on the 'information transmitting' voice	• involving several voices
• low internal heterogeneity: interanimation of voices limited	• high internal heterogeneity: rich in interanimation of voices
• closed: new voices not acknowledged, unless supporting message to be transmitted	• open: new voices contribute to the act of developing meaning
• fixed intent: outcome controlled	• generative: outcome may not be anticipated.

In dialogic discourse several voices are represented and the interaction between voices leads to an outcome which may not be anticipated. In authoritative discourse the outcome is fixed in advance by the information transmitting voice and there is little interaction between voices.

Nature of teacher utterances

Authoritative discourse	Dialogic discourse
• 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'
• often based on instructional questions (where the teacher already has the answer).	• often based on open or genuine questions where the answer is not obvious
• often involving formal review or factual statements which offer few 'invitations' to dialogue	• directed towards sustaining dialogue
• selectively drawing on other voices	• representing other voices

In dialogic discourse the teacher's contributions encourage thought and debate and often involve genuine questions, possibly relating to matters of personal opinion. In authoritative discourse, the teacher's contributions are intended to convey information, offer few invitations to genuine dialogue and often involve instructional questions to guide students through a particular argument or explanation.

Nature of student utterances

Authoritative discourse	Dialogic discourse
• often in response to teacher questions	• often spontaneously offered (not elicited by teacher) and triggered by comments from other students.
• 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
• often direct assertions	• often tentative suggestions open to interpretation and development by others

In dialogic discourse the students offer ideas spontaneously, quite often in whole phrases and sentences and in a tentative manner which invites comment from others. In authoritative discourse the students contributions are usually in

response to the teacher's instructional questions and are short, often single word answers.

As stated earlier it should be borne in mind that the positions outlined in these two columns represent forms of discourse which lie at the extreme ends of a continuous dimension and real discourse will contain elements of both. The analyses of the two case studies indicate that there was greater variation, along the authoritative-dialogic dimension, in the nature of the discourse in Case Study 1 than in Case Study 2. The notion of the 'rhythm of the discourse' was introduced as a means of identifying and talking about such variations in the nature of the discourse over the extended time-line of the teaching narrative.

Given the Vygotskian perspective that the process of learning higher mental functions originates on the interpsychological plane, then it seems reasonable to suggest that learning in the classroom is likely to be enhanced through achieving some kind of 'balance' between presenting information and allowing opportunities for exploration of ideas. Just as the teacher is responsible for introducing new scientific ideas, then so too must the teacher plan to develop situations where student thinking is challenged and new ideas are explored in relation to existing patterns of reasoning. Such situations need to be explicitly created on the social plane if meaningful personal learning is to follow. In other words, within any teaching sequence there needs to be a balance between authoritative and dialogic discourse; there needs to be a 'rhythm' to the discourse.

The analysis of Case Study 2 provides some support for this point of view. Here Richard tended to concentrate on presenting the scientific view and allowed few opportunities for dialogic exploration of those ideas. The outcome to this was the breakdown in shared understanding between teacher and students which took place at the beginning of the second lesson during the review of the 'Rubber Sucker' activity.

7.5 The Teaching Narrative: the content of the discourse

In both case studies, the content of the discourse on the interpsychological plane has been analysed in terms of the Vygotskian distinction between spontaneous and scientific concepts.

In the first case the analysis of the content of the discourse was framed in terms of the progressive decontextualisation of mediational means. Prior to instruction the

students drew upon spontaneous ideas about rusting (as was revealed by the 'Iron Nail' activity) and these ideas tended to be linked to specific instances of rusting. Through the instructional approach taken teacher and students worked on these ideas to move towards an identification of the conditions essential for rusting to occur. These conditions (the presence of air, water, iron) are not limited to any particular context but can be generally applied, and it is in this sense that the instructional approach can be said to involve a progressive decontextualisation of mediational means (moving from spontaneous knowledge linked to particular situations to generally applicable scientific conditions).

In the second case a different instructional approach was taken with the scientific view, based on differences in air pressure, being introduced at the start of the teaching through a series of demonstrations and practical activities. The spontaneous forms of reasoning about the various phenomena were acknowledged in the teaching (through the 'old way'-'new way' distinction) and throughout the lesson sequence a mix of spontaneous and scientific views was represented in the classroom discourse. In this particular scientific context there is a significant difference in the nature of the spontaneous (based on notions of 'pulling' and 'sucking') and scientific views (based on differential air pressure explanations). This difference between the two views enabled the content of the classroom discourse and of student understandings to be effectively monitored in terms of the spontaneous and scientific views represented.

7.6 The teaching narrative: a theoretical framework

In the preceding sections the concept of the 'teaching narrative' has been addressed in relation to the forms of pedagogical intervention, the authoritative-dialogic nature of the discourse and the content of the discourse. These three theoretical perspectives or tools, taken together, offer a theoretical *framework* for analysing the ways in which the teacher guides the discourse of the interpsychological plane to support student meaning making.

Whilst the 'forms of pedagogical intervention' can be used to describe the moves made by the teacher to support development of the various aspects of the narrative, the 'nature of the discourse' offers the means to describe *how* those interventions are carried out in relation to the authoritative-dialogic dimension and the 'content of the discourse' provides the means for analysing the discourse in terms of the spontaneous and scientific ideas represented. This notion of an analytical framework is represented in Fig. 7.6:

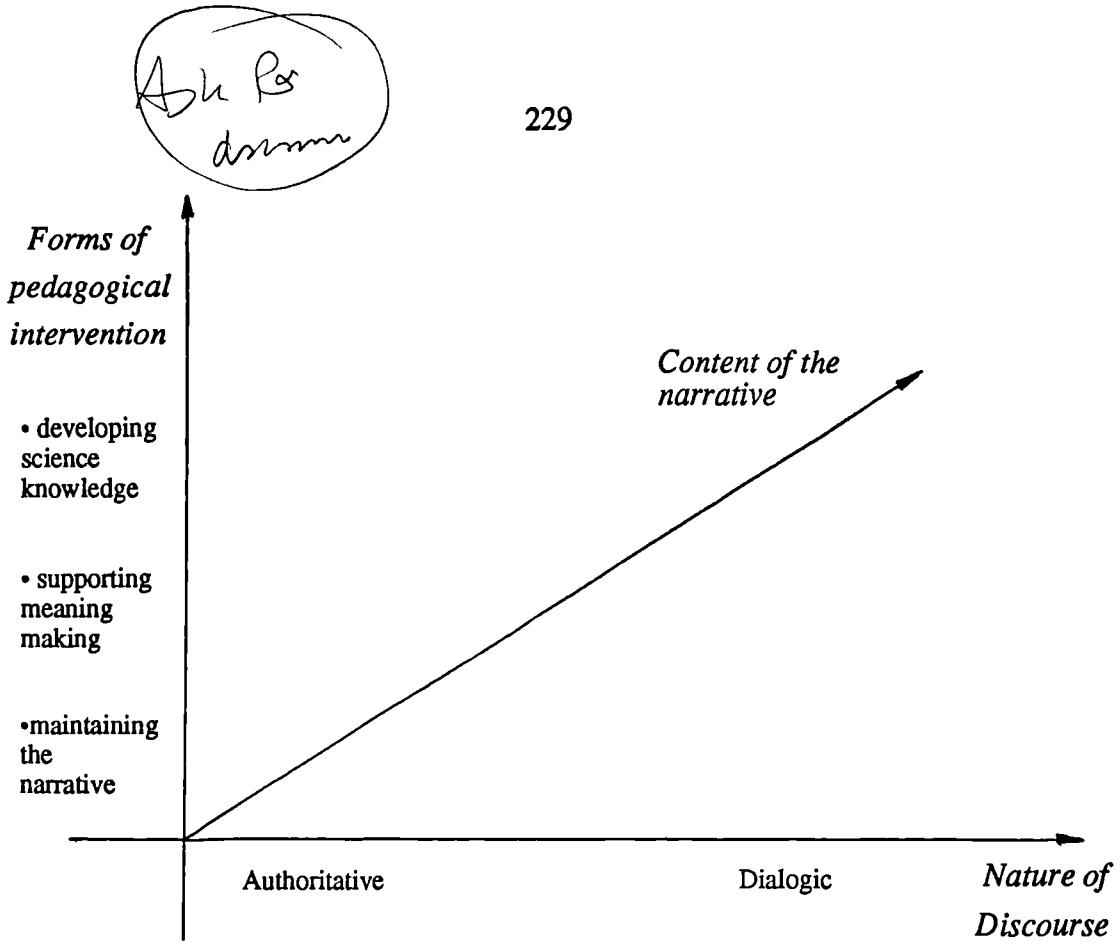


Fig. 7.6 Theoretical framework for analysing the discourse of the teaching narrative

The theoretical framework presented here is based on Vygotskian theory and developed and exemplified with particular reference to data collected from the two case studies. Nevertheless it is anticipated that, given the broad theoretical grounding of this framework, it could be applied more widely to other instructional sequences in science and would be useful in analysing key features of the teaching. Furthermore this framework would provide a useful reference point in *planning* teaching; that is the framework could be used in a *prescriptive* as well as in an analytical mode. As such this theoretical framework, based on the theoretical tools developed in the context of the two case studies, is presented as a further important product from this study.

7.7 Pedagogical interventions in terms of Scaffolding

In the preceding section a theoretical framework for analysing and characterising science instruction has been presented; the framework is based on three theoretical dimensions which relate to the *forms* of teacher intervention, the

nature of the discourse through which those interventions are enacted and the *content* of the discourse.

The fourth and final element of theory (or theoretical tool) which has been addressed in this thesis concerns the concept of 'scaffolding'. The theoretical origins of scaffolding have been traced back through the work of Wood and Bruner to Vygotsky's concept of the Zone of Proximal Development and from this analysis four characteristic features of scaffolding have been identified (see Section 2.6.2). These four features focus on teacher assistance which: is aimed at specfic learning goals; is responsive to student progress; offers explicit guidance through the learning event; enables gradual handover of responsibility to the learner. Examination of the case study data has led to the suggestion that scaffolding can be achieved through a combination of pedagogical (spontaneous interactions) and instructional (pre-planning) means.

7.7.1 Teacher responsiveness in scaffolding

From a theoretical point of view it can be argued that it is teacher responsiveness to student learning which lies right at the heart of scaffolding; this is teacher assistance (as envisaged by Vygotsky) during teaching and learning in the ZPD which is responsive to *differences* between the present level of student performance and the level of performance specified by the learning goal. This teacher responsiveness is such that as learning proceeds and progress is made towards the learning goal (changing the current level of performance) then the nature of the teacher assistance is modified appropriately.

In Chapter 2 (Section 2.6.2) the notion of 'responsiveness' was broken down into three elements: monitoring, analysing and assisting. These elements can be represented in terms of an action cycle or loop as shown in Fig. 7.7:

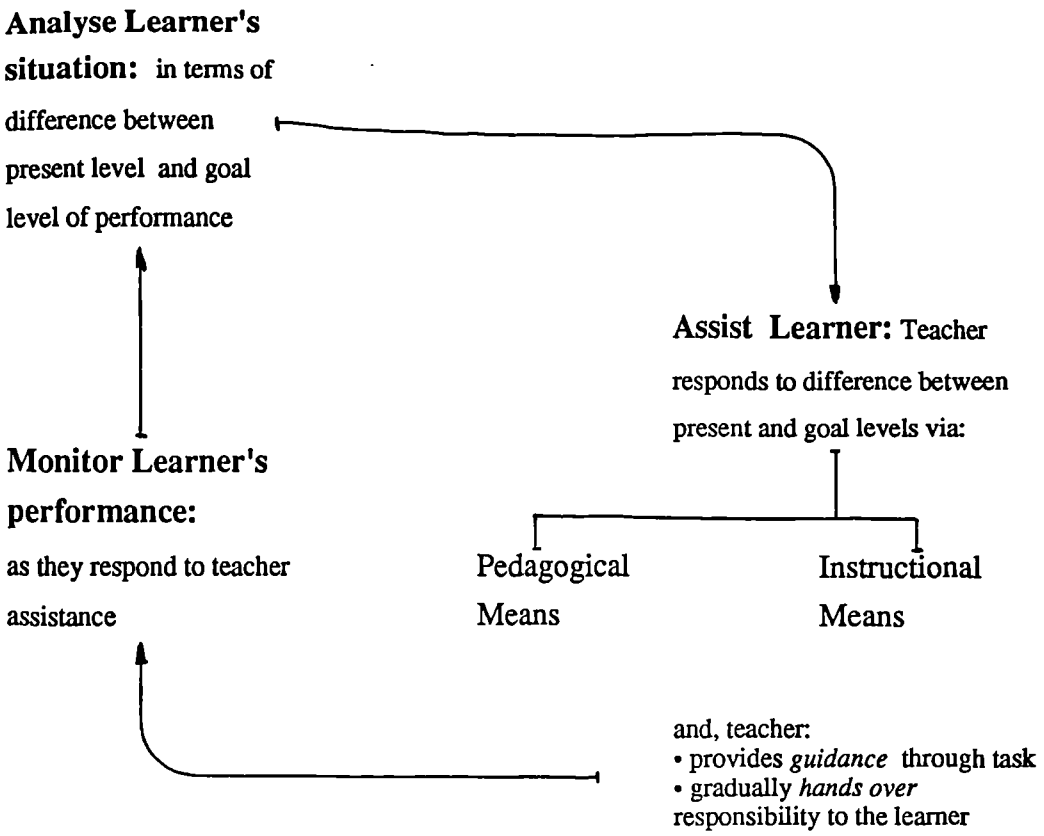


Fig. 7.7 Cycle of responsiveness in scaffolding.

In an extended intervention to scaffold learning the teacher moves around the elements of the cycle: monitoring the child's performance, analysing how that level of performance relates to the goal level, taking action to help the child towards the goal, monitoring the child's new performance...and so on. As the child progresses in capability towards the learning goal then the level of assistance is reduced; if the child indicates through its performance that more help is needed then the teacher responds accordingly to provide greater assistance. Scaffolding consists of continuous cycling around the three elements with the teacher varying the type and amount of assistance according to the learner's needs.

Tharp and Gallimore (1988) refer to scaffolding as a 'metaphor to describe the *ideal role* of the teacher' (my emphasis). In the context of a teacher tutoring an individual child it seems reasonable to suggest that the kind of 'responsiveness' represented here would, indeed, constitute an 'ideal approach' to supporting learning. The question which remains to be answered concerns the extent to which the concept of scaffolding, as defined here, is meaningful for a classroom teaching and learning context.

7.7.2 Scaffolding in a classroom context

The problem of numbers

The single biggest problem for the classroom teacher who wishes to scaffold learning is the number of students involved. Put simply it is impossible for the teacher to be responsive to each individual student's learning if there are as many as 25-30 children who require attention. However in both case studies there are examples of teacher working with pairs of students to scaffold their learning, particularly in the context of providing support whilst applying new ideas.

Not scaffolding, but doing something else

The analyses of both case studies demonstrate that in whole class teaching situations neither Lynne nor Richard developed interventions which could be classed as scaffolding. A fundamental point to be made here, and one that might easily be overlooked, is that Lynne and Richard were not scaffolding learning in these situations, simply because they were doing something else; they were making interventions to enable development of the teaching narrative. Such interventions might involve 'overlooking' a student response, paraphrasing a student idea, presenting new ideas and not pausing to check student understanding. All of these interventions are directed towards making the scientific story available on the social or interpsychological plane, they are not concerned with supporting individual meaning making on the personal or intrapsychological plane.

The point was made in Chapter 5 (Section 5.6.3) that in classroom teaching there exists a *tension* for the teacher in attempting to support activity on both interpsychological and intrapsychological planes. This tension is exemplified by an incident in the second case (Episode 1.3) when it became clear that Adele had problems with the meaning of 'more air'. Richard responded to this by checking the level of consensus over this issue and it appeared that the class generally did not agree with Adele. Adele's problem was therefore left to one side and Richard proceeded with the narrative; a problem of individual understanding was overlooked so that the social enactment of the narrative might continue.

The point which is being made here is that in whole class teaching situations scaffolding very often does *not* constitute an appropriate pedagogical approach; the focus is upon the broader social plane of the whole class rather than upon the personal understandings of individual students. The issue of whether it is even

possible to scaffold learning in whole class situations is a further question to be addressed.

Scaffolding and whole class teaching

The basic problem here is that scaffolding is defined in terms of supporting individual learning and classrooms operate not with individuals but with large groups of students. The question is therefore one of whether the concept of scaffolding can be applied in any meaningful way to large groups of students.

At first sight the answer to this question would appear to be 'no'. The concept of scaffolding is based on providing assistance which enables the learner to progress in their Zone of Proximal Development from the present level of performance towards the goal level. If there are 25 students in a class, each with their own unique ZPD for the task in hand, then it seems that the teacher is unlikely to be able to be responsive to all students in scaffolding learning.

There is an alternative perspective, however, which can be brought to bear on the situation. This perspective acknowledges the fact that there are 25 students in the class but draws attention to the level of *commonality* in the thinking of the students; although there are 25 students it is not the case that there are 25 completely different sets of ideas on whatever is being taught. In both case studies, moves to probe students' reasoning prior to instruction revealed substantial commonality in the spontaneous ideas drawn upon by the students. Furthermore, all of the research into children's alternative conceptions has shown that in any area of science learning there tends to be a limited range of alternative conceptions which children might develop during and after instruction. The degree of heterogeneity in the ZPD's which are represented in a class of students is therefore unlikely to be as great as might at first be imagined. From a Vygotskian developmental view, this is not surprising; people's present thinking reflects their own social histories and if those histories are similar then so too will be their thinking.

Following on from these ideas it might be argued that it is possible to imagine a ZPD which represents the thinking of the whole class of students. In other words the ZPD is conceptualised not as belonging to individuals but as being socially distributed in representing the thinking of a group. The extent to which this notion of a 'socially distributed ZPD' is viable depends, of course, on the degree of homogeneity of thinking of the group involved. If the level of homogeneity is high then it becomes possible to imagine how a teacher might in effect scaffold

the learning of a whole class through the cycle of monitoring, analysing, assisting. If the level of homogeneity is low then the student thinking represented in the classroom becomes too fragmented and diverse to allow the teacher to scaffold learning.

The concept of a 'socially distributed ZPD' which has been suggested here offers one way forward in thinking about how the concept of scaffolding can be applied as the move is made along the path from individual tutoring to whole class teaching situations.

7.8 Evaluation of the instructional approaches and pedagogical interventions of the two case studies

In the previous sections a review of the theoretical tools which have been developed in this thesis has been presented. This development of tools is now taken full circle as they are 'turned back on the data' and used to *evaluate* aspects of both the instructional approaches and pedagogical interventions drawn upon in teaching each case.

7.8.1 The instructional approaches taken

There is an obvious contrast between the instructional approaches taken in each of the two case studies. In the first case the teaching started with the students' spontaneous ideas about rusting and the teacher worked from those ideas towards the scientific view. In the second case the teaching started with the presentation of the scientific perspective based on differences in air pressure and this scientific view was then applied to various other phenomena. The contrast in approaches is between starting instruction 'where the students are at' and starting with the scientific view.

What, in retrospect, can be said about each of these instructional approaches from the theoretical perspective developed in this thesis? An important point to return to in responding to this question is that the Vygotskian theory which underpins this study is based on a particular view of *learning* and *development* and does not directly offer a theory or model for *teaching*. Nevertheless, the concept of the Zone of Proximal Development and the view of teaching as 'assisting performance' do offer some indication of what might constitute effective teaching. Following ideas previously discussed in relation to the ZPD, effective teaching requires the teacher to be aware of and responsive to students' existing and developing ways of thinking as the scientific perspective is introduced. Effective

teaching is based on *dialogues* between teacher and learners in which each understands what the other is talking about.

Viewing effective teaching in this way largely pre-empts questions about whether it is preferable to use instructional approaches which start either with the students' ideas or with the scientific view. The obvious point is that either approach might be successful depending on the extent to which the teacher is able to support and develop effective teaching and learning dialogues. In the first case study, the strategy of eliciting students' spontaneous ideas about rusting was effective in getting those student ideas onto the 'talking agenda' and indeed they formed a prominent part of the discourse in subsequent lessons. In the second case Richard explicitly referred to 'old ways of knowing' in introducing the scientific view but tended not to acknowledge and talk around those spontaneous ideas as they re-emerged after introduction of the scientific view. This was not, however, necessarily attributable to the overall instructional approach taken.

In general terms perhaps one piece of guidance which *can* be offered in respect of selecting instructional approaches is to start by considering the nature of the differences (conceptual, ontological and epistemological) between students' spontaneous ideas and the scientific perspective. If there are obvious areas of commonality then it might be effective to start instruction with the students' views; if there is little overlap between the two sets of ideas it might be better to present the scientific view and to later relate that view to spontaneous ideas. Such a perspective on planning instruction is based on the ways in which the scientific view articulates with the students' existing spontaneous views.

7.8.2 The pedagogical interventions used

In this section various issues relating to the teaching interventions carried out in the two cases are reviewed.

Developing the conceptual line: selecting conceptual tools

One problematic issue relating to developing the conceptual line of the narrative arose in the air pressure case and concerned the selection of conceptual tools to represent the scientific point of view.

The process of selecting conceptual tools is part of planning any instructional approach; it pre-figures the classroom interventions through which the tools selected are made available to students on the interpsychological plane. In the air pressure case the scientific viewpoint was introduced by means of the rule: 'more

air, more air pressure; less air less air pressure'. The form of this rule led to some confusion for students particularly in those situations where Richard argued, for example, that there was 'more air' inside the bottle than there was outside it. The point was made earlier that the differential air pressure explanation might have been more clearly represented for the students by drawing on the concept of density.

The general point here is that presentation of the conceptual line of the teaching narrative involves *selection* of conceptual tools through which the scientific view is represented. It is not just a case of presenting *the* science view; there are always likely to be choices available with regard to representing the scientific conceptual content of the narrative. The tools are represented in the narrative as the teacher shapes development of the conceptual line (paying attention to ontological and epistemological issues) and any lack of clarity or coherence in the conceptual tools selected can lead to problems in meaning making for students.

Developing the conceptual line: addressing ontological issues

The point was made earlier that neither teacher in the two case studies developed the talk of the interpsychological plane to address issues relating to the *ontological* status of the scientific concepts being taught. This finding raises the question of *how* teachers might make interventions to address such ontological issues.

In the context of teaching about air pressure, one possibility would be for the teacher to be explicit in acknowledging to the students that they are being asked to think about air in a new and different kind of way. Thus: 'you may think it odd that air, this stuff all around us, can create such large forces on the sucker. If you do think it's odd you'd be right. It is odd. In fact if you *don't* reckon that this is a strange idea on first meeting then you can't be thinking too hard about it! But look at it this way...'. In such a way the teacher might introduce and prompt further talk about the ontological status of the scientific concepts; such interventions might help in rendering the scientific concepts and explanations more plausible for learners.

At the end of the first lesson in the rusting case the researcher asked two students, Ajay and Matthew, about the part played by air in the rusting process. Ajay suggested that, 'there might be different chemicals in the air and they could help rust' whilst Matthew maintained that, 'air dries the water, so it makes it damp, then damp gets in and rusts'. Both of these responses present air as something

which might *influence* the rusting process; neither refers to air as being a substance which contributes to the actual formation of rust. It seems that there is a learning issue here of reconceptualising air as a substance which can contribute to the formation of a new solid substance such as rust (rather than viewing it as a medium which lacks substance). Developing the scientific perspective on rusting involves extending the learner's perspective on what air is and what it can do; it involves an ontological shift which needs to be addressed through the talk of the interpsychological plane.

All too often in learning the physical sciences the student is faced with ideas and explanations which simply do not appear to make sense. In many of these situations (as exemplified by the rusting and air pressure cases) this lack of plausibility can be linked to the need to assign the entities from which the explanations are constructed to new ontological categories (see Chi et al, 1994). In such situations it is not helpful for the science teacher to talk about these ideas and explanations as if they are quite 'commonplace' and 'obvious'. They are not, they are the products of the scientific community and as such are not part of day-to-day talk and thought. The teacher must help students in 'talking into existence' scientific concepts bearing in mind, and explicitly addressing, any ontological shifts entailed in developing this new scientific perspective.

Developing the epistemological line

One point which has become apparent through the analyses of the teacher interventions in both case studies is that few explicit references were made to key epistemological issues. In the first case this resulted in some confusion for students with regard to the meaning of 'essential conditions'. In the second case the overall instructional approach was structured around the 'generalisability' of the scientific explanation but this point was never made explicit to the students. It was argued earlier that this might have had an effect on the ways in which students perceived the purpose of tasks such as the 'Pressure Circus'.

Taking the 'Pressure Circus' as a specific example, an alternative approach to framing that activity would have been for the teacher to draw attention to the issue of generalisability: to state quite clearly that the whole purpose of the circus is for the students to try to apply the new scientific way of explaining to the full range of phenomena; to emphasise that this is a powerful and exciting feature of scientific explanations, that they can be used to explain apparently disparate phenomena; to warn that certain examples might prove to be difficult; to suggest that if students are drawn towards 'old way ideas' such as pulling and sucking then

they should ask for help from the teacher. The purpose of the activity, 'Is for you to talk around and figure out how the new way of explaining can be used for each item or activity in the circus'. Such an approach would contribute to strengthening the presentation of the epistemological line of the narrative; it would help students to understand more clearly the purpose of the activity and might possibly lead to a better understanding of the scientific explanation and how to apply it.

7.8.3 Instructional approaches and pedagogical interventions: final comments

The points made in the preceding paragraphs have focussed on various perceived shortcomings in the teaching approaches represented in the two case studies. What were the positive features of either case?

Firstly, the 'Nails Activity' proved to be very successful in motivating students, in 'drawing them into' the problem area and allowing the teacher access to the students' spontaneous ideas. In addition the instructional approaches in both cases allowed students the opportunity to take the new scientific ideas and to apply them, for themselves, to new situations, through the 'will rust/will not rust' and 'pressure circus' activities respectively. These activities allowed 'handover' of responsibility from teacher to students in applying ideas; they enabled the teacher to engage in dialogic discourse with small groups of students as they worked on the activities and thereby offered opportunities for scaffolding learning.

Both teachers skillfully drew upon a range of forms of pedagogical intervention. In developing the conceptual line they were able to effectively shape, select and mark key ideas. In shaping ideas both teachers made moves to differentiate between spontaneous and scientific perspectives: in the first case this was achieved through actually starting with students' spontaneous ideas and moving towards the scientific view; in the second case the two sets of ideas were clearly labelled 'old way' and 'new way' of explaining.

Perhaps the most impressive feature of the teaching was the way in which both Lynne and Richard were able to maintain the ongoing flow of the narrative through stating aims, re-focussing discussion, reviewing progress, offering summaries. In such ways they were able to sustain the talk on the interpsychological plane over a total period of approximately 3 hours. This is quite an achievement given the abilities of the children in either class and current pre-occupations with the fleeting one-lesson-units of modularised courses .

7.9 Teaching and Learning Science: the perspective from this thesis

In this thesis a particular perspective on teaching and learning science has been developed. This perspective focusses on the talk which constitutes teaching and provides the means for learning. It is a perspective which is rather different from contemporary approaches to science teaching and learning which have tended to focus on specific instructional activities based on providing pieces of 'critical evidence' to promote conceptual change (see Scott, Asoko, Driver, 1991). In these approaches the key planning questions for the teacher are: 'What can I show them? What can they do?... so that they get the idea.' The teaching and learning described in the two case studies presented here *does* involve reference to empirical evidence; however the analysis of those cases suggests that the way in which the teacher 'talks around the evidence' is at least as important as the evidence itself.

Clive Sutton (1996) refers to science learning as 'learning to talk in new ways' and sees science lessons as offering 'access to new conversation'. He also suggests that part of the job of the science teacher is 'to persuade pupils of the value and reasonableness of those new ways'. This notion of *persuading* pupils resonates with what has been observed in these science lessons where the teachers introduce arguments, establish lines of continuity in the way that they talk about phenomena, develop points through anecdotes, review and summarise ideas and repeat important ideas time and time again. In the terms developed in this thesis, the teacher enacts a 'teaching narrative' to support students in developing an understanding of the scientific perspective.

This is not to suggest that children should be taught science by process of brow-beating or indoctrination and indeed in both case studies it can be claimed that rational arguments were developed by the teachers to support learning. Sutton's perspective helps draw attention to a view of learning science which involves taking on new ways of talking and thinking about the world, a view which is supported in this thesis. Here the teacher has a key role to play in acting as the 'vicar of their culture' (Bruner, 1985, p.32) and presenting the scientific view through extended and elaborate talk in the classroom. At times the teacher may well feel that she or he *is* persuading students to try this new way of talking about the world and indeed if there are major differences between everyday and

spontaneous views in a particular concept area, then this is precisely what the teacher will need to do.

Joan Solomon (1994) offers a metaphor for learning which has a great deal in common with the ideas being developed here. In it Solomon imagines a child sitting outside the family circle: listening to the words and phrases used; building up ideas; trying out the sense of those ideas with elders; receiving new and helpful explanations; gradually having ideas accepted by others; being encouraged to use those ideas in new ways. This is a picture of learning which brings to the fore the importance of talk in exploring new ideas and learning how to use them in appropriate contexts and in appropriate ways.

I would suggest that the theoretical ideas developed in this thesis offer a starting point for thinking and talking about classroom science teaching and learning in ways which are consistent with the ideas sketched out by Sutton and Solomon. A fresh perspective is offered in which the focus is no longer upon isolated instructional activities to promote conceptual change but is shifted towards viewing such activities in the critically influential context of an ongoing flow of discourse between teacher and learners. The importance of various 'key activities' in supporting learning is not being denied here; what is being argued is that the effects on learning might be better understood if such activities are considered in the context of the talk which surrounds them.

In this thesis, this flow of discourse has been characterised in terms of: a teaching narrative played out over an extended period of time and involving different forms of pedagogical intervention directed towards making the scientific view available and accessible to students; the authoritative-dialogic nature of the discourse; the content of the discourse in terms of the spontaneous and scientific concepts represented; the concept of scaffolding. These theoretical tools offer a framework for teachers to draw upon in reflecting upon and evaluating their own practice; they provide a means for thinking and talking about teaching. Some work has already been carried out which demonstrates that these theoretical tools can be usefully drawn upon in this analytic mode (see Scott, 1996; Scott, 1997).

There is also the potential for using the tools in planning and implementing science instruction and once again some work has already been carried out in this area (see Scott, 1993; Scott, Asoko, Driver and Emberton, 1994). Here the theoretical framework provides the means for thinking through how teaching (in both instructional and pedagogical terms) might appear in the classroom, which

features need to be attended to during planning. There is potential for using the framework in this way not only with experienced teachers but also with student teachers during initial teacher training.

The shift in perspective on science teaching and learning which has been outlined above follows from Vygotskian theory. I would argue that Vygotsky's ideas, based on the Genetic Law of Cultural Development, offer a theoretical means for unifying various disparate strands within contemporary science education research on teaching and learning. At a fundamental level Vygotskian Theory draws attention to the twin features of the social origins of learning (on the interpsychological plane) and the reconstructive step involved in personal sense making (on the intrapsychological plane); it provides a theoretical structure in which social and personal perspectives are inextricably linked through the process of internalisation. The Vygotskian perspective demands that attention be paid to both social and personal aspects of learning (Driver, Asoko, Leach, Mortimer and Scott, 1994; Driver and Scott, 1995).

Vygotskian theory also acknowledges the central position of the teacher in leading and supporting science learning. Through characterising teaching in terms of theoretical structures such as the 'teaching narrative' and 'scaffolding' then we are offering fresh means by which teachers might think and talk about their craft. We are offering conceptual tools for talking and thinking about teaching; an appropriate outcome for a Vygotsky-inspired thesis.

Bibliography

AAAS (1989) *Science for all Americans: Project 2061.* American Association for the Advancement of Science: Report of goals in science, mathematics and technology. Washington DC.

Amigues, R. (1996) Students' computer-based problem solving in electricity: strategies and collaborative talk. In: *Research in Science Education in Europe.* G. Welford, J. Osborne, P. Scott (Eds.). Falmer Press.

Andersson, B. and Bach, F. (1996) Developing new teaching sequences in science: the example of 'gases and their properties'. In: *Research in Science Education in Europe.* G. Welford, J. Osborne, P. Scott (Eds.). Falmer Press.

Arnold, M. and Millar, R. (1996) Learning the scientific 'story': A case study in the teaching and learning of elementary thermodynamics. *Science Education*, 80(3), pp. 249-281.

Askew, M., Bliss, J. and Macrae, S. (1995) Scaffolding in mathematics, science and technology. In: P. Murphy, M. Selinger, J. Bourne, M. Briggs (Eds.) *Subject learning in the primary curriculum: Issues in English, Science and Mathematics*, (pp. 209-218). Routledge, London.

Bakhtin, M.M. (1981) *The dialogic imagination: four essays by M.M. Bakhtin*, Ed. Michael Holquist, trans. Caryl Emerson and Michael Holquist. Austin: University of Texas Press.

Bakhtin, M.M. (1986) *Speech genres and other late essays.* Ed. C. Emerson and M. Holquist, trans. V.W. McGee. Austin: University of Texas Press.

Barnes, D. (1976) *From Communication to Curriculum.* Harmondsworth: Penguin.

Barnes, D. and Todd, F. (1977) *Communication and learning in small groups.* London: Routledge and Kegan Paul.

Barnes, D. and Todd, F. (1995) *Communication and learning revisited: Making meaning through talk.* Boynton/Cook, Portsmouth.

Bhaskar, R. (1978) *A realist theory of science.* London: Harvester Wheatsheaf.

Boulter, C. and Gilbert, J. (1996) Texts and contexts: Framing modelling in the primary science classroom. In: *Research in Science Education in Europe.* G. Welford, J. Osborne, P. Scott (Eds.), Falmer Press.

Brown, J.S., Collins, A. and Duguid, P. (1989) Situated cognition and the culture of learning. *Educational Researcher*, 21(5), 31-35.

Bruner, J. (1983) *Child's talk: Learning to use language.* New York: Norton

Bruner, J. (1985) Vygotsky: A historical and conceptual perspective. In: J. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian Perspectives* . (pp. 21-34) Cambridge University Press, England.

Bruner, J. (1990) *Acts of meaning*. Harvard University Press, Cambridge, Mass.

Camp, C.W. and Clement, J.J. (1994) *Preconceptions in mechanics: Lessons dealing with students' conceptual difficulties*. Kendal Hunt, Iowa.

Chalmers, A.F. (1982) *What is this thing called science?* 2nd edition. Milton Keynes: Open University Press.

Chi, M.T.H., Slotta, J.D. and de Leeuw, N. (1994) From things to processes: A theory for conceptual change for learning science concepts. *Learning and Instruction*, 4, pp. 27-43.

Cobb, P., Wood,T. and Yackel, E. (1991) Analogies from the philosophy and sociology of science for understanding classroom life. *Science Education* (75), 23-44.

Denzin, N. (1970) *The research act in sociology*. London, Butterworth

Driver, R., Asoko, H., Leach, J., Mortimer, E. and Scott, P. (1994) Constructing scientific knowledge in the classroom. *Educational Researcher*

Driver R. and Scott P. (1995) Mind in communication: A response to Erick Smith. *Educational Researcher*, Volume 24, (7), pp 27-28, AERA.

Edwards, D. and Mercer, N.M. (1987) *Common Knowledge: The development of understanding in the classroom*. Methuen, London.

Edwards, A. and Westgate, D. (1987) *Investigating Classroom Talk*. London: Falmer Press.

Eggleston, J., Galton, M. and Jones, M. (1976) *Processes and products of science teaching*. London, Macmillan.

Eichinger, D.C., Anderson, C.W., Palincsar, A.S. and David, Y.M. (1991) *An illustration of the roles of content knowledge, scientific argument, and social norms in collaborative problem solving*. Paper presented at the annual meeting of AERA, Chicago.

Fischer, K.W. and Bullock, D. (1984) Cognitive development in school-aged children: Conclusions and new directions. In: W.A. Collins (Ed.) *Development during middle childhood: The years from six to twelve* (pp 70-146). Washington DC: National Academy Press.

Gee, J.P. (1996) Vygotsky and current debates in education. In: D.Hicks (Ed.), *Discourse, learning and schooling*. Cambridge University Press.

Griffin, P. and Cole, M. (1984) Current activity for the future: The Zo-ped. In: B. Rogoff & J.V. Wertsch (Eds.), *Children's learning in the zone of proximal development (New directions for child development, No. 23)* pp.45-64. San Francisco: Jossey-Bass.

Halliday, M.A.K. and Martin, J.R. (1993) *Writing Science*. London: Falmer Press.

Harre, R. (1985) *Varieties of realism*. Oxford: Blackwell.

Hicks, D. (1995) Discourse, learning and teaching. In: M.W. Apple (Ed.) *Review of Research in Education (No. 21).* AERA.

Holquist, M. and Emerson,C. (1981) Glossary for *The dialogic imagination: Four essays by M.M. Bakhtin.* Ed. M. Holquist. Trans. M. Holquist and Caryl Emerson. Austin: University of Texas Press.

Johnston, K. and Scott, P. (1991) Diagnostic teaching in the Science Classroom: Teaching and learning strategies to promote development in understanding about conservation of mass on dissolving. *Research in Science and Technological Education*, Vol. 9, No.2, pp. 193-213.

Kelly, G. and Crawford, T. (1996) Students' interactions with computer representations: analysis of discourse in laboratory groups. *Journal of Research in Science Teaching*, Vol. 33(7).

Lampert, M. (1990) When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal*, 27, pp. 29-64.

Lave, J. and Wenger, E. (1991) *Situated learning: legitimate peripheral participation.* New York, Cambridge University Press.

Leach, J., and Scott, P. (1995) The demands of learning science concepts: Issues of theory and practice. *School Science Review*, 76 (277), pp. 47-51, Association for Science Education, Hatfield.

Lemke, J.L. (1990) *Talking Science: Language, learning and values.* Ablex Publishing Corporation, Norwood, New Jersey.

Leontiev, A.N. (1981) The problem of activity in psychology. In: J.V. Wertsch (Ed.) *The concept of activity in Soviet Psychology.* Armonk, N.Y., Sharpe.

Lotman, Yu.M. (1988) Text within a text. *Soviet Psychology*, 26(3): 32-51.

Luria, A.R. (1981) *Language and cognition* (J.V. Wertsch, Ed.). New York: Wiley Intersciences.

Maybin, J., Mercer, N. and Stierer, B. (1992) Scaffolding learning in the classroom. In: K. Norman (Ed.), *Thinking voices: The work of the National Oracy Project.* pp. 186-195. Hodder and Stoughton, London.

Mercer, N. (1995) *The guided construction of knowledge.* Multilingual Matters, Clevedon, UK.

Moje, E.B. (1995) Talking about science: an interpretation of the effects of teacher talk in a high school classroom. *Journal of Research in Science Teaching*, Vol. 32(4).

Moll, L.C. (Ed.) (1990) *Vygotsky and Education: Instructional implications and applications of sociohystorical psychology.* Cambridge University Press.

Mortimer, E.F. (1995) *Addressing obstacles in the classroom: An example from the theory of matter.* Paper presented at the European Conference on Research in Science Education, Leeds, 7-11 April.

National Research Council (1996) *National science education standards.* Washington DC: National Academy Press.

Newman, D., Griffin, P. and Cole, M. (1989) *The construction zone: Working for cognitive change in school.* Cambridge University Press.

Ogborn, J., Kress, G., Martins, I. and McGillicuddy, K. (1996) *Explaining science in the classroom.* Open University Press, Buckingham.

Patton, M.Q. (1990) Qualitative evaluation and research methods. Newbury Park, CA: SAGE Publications, Inc.

Pfundt, H. and Duit, R. (1985) *Bibliography: students' alternative frameworks and science education.* Kiel, IPN.

Piaget, J. (1962) *Judgement and Reasoning in the Child.* London: Routledge and Kegan Paul.

Posner, G.J., Strike, K.A., Hewson, P.W. and Gerzog, W.A. (1982) Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education,* 66(2), 211-227.

Richmond, G. and Striley, J. (1996) Making meaning in classrooms: social processes in small-group discourse and scientific knowledge building. *Journal of Research in Science Teaching*, Vol.33(8).

Rogoff, B. (1990) *Apprenticeship in thinking: Cognitive development in social context.*
Oxford, England: Oxford University Press.

Rogoff, B. and Gardner, W. (1984) Adult guidance of cognitive development. In: B. Rogoff and J. Lave (Eds.), *Everyday Cognition.* Cambridge, MA: Harvard University Press, pp. 95-117.

Roth, W.-M. (1995) *Authentic school science. Knowing and learning in open-inquiry science laboratories.* Netherlands: Kluwer Academic Publishers.

Roth, W.-M. (1996) Teacher questioning in an open-inquiry learning environment: interactions of context, content and student responses. *Journal of Research in Science Teaching*, Vol. 33 (7).

Roth, W.-M. and Roychoudhury, A. (1992) The social construction of scientific concepts or the concept map as a conscription device and tool for social thinking in high school science. *Science Education*, Vol. 76(5).

Roychoudhury, A. and Roth, W.-M. (1996) Interactions in an open-inquiry physics laboratory. *International Journal of Science Education*, 18, No. 4, pp.423-445.

Saussure, Ferdinand de (1959) *Course in general linguistics.* New York: Philosophical Library.

Scott, P., Asoko, H., Driver, R. (1991) Teaching for conceptual change: A review of strategies. In: *Research in Physics Learning: Theoretical issues and empirical studies.* R. Duit, F. Goldberg, H. Niedderer (Eds.), Kiel, Germany.

Scott P (1993) Overtures and obstacles: Teaching and learning about air pressure in a high school classroom. In Novak J (Ed.) *Proceedings of the Third International Seminar: Misconceptions and Educational Strategies in Science and Mathematics.* Cornell University, Ithaca, USA.

Scott P, Asoko H, Driver R, Emberton J (1994) Working from children's ideas: An analysis of constructivist teaching in the context of a chemistry topic. In: *The content of science: A constructivist approach to its teaching and learning.* Fensham PJ, Gunstone R, White R (eds), Falmer Press.

Scott, P. (1996) Social interactions and personal meaning making in secondary science classrooms. In: *Research in Science Education in Europe.* G. Welford, J. Osborne, P. Scott (eds), Falmer Press.

Scott, P. (1997) *Teaching and learning science concepts in the classroom: talking a path from spontaneous to scientific knowledge.* Paper presented at an international seminar held at Universidade Federal de Minas Gerais, Belo Horizonte, Brazil. March 1997.

Scott, P. and Driver, R. (in press) Learning about science teaching: perspectives from an action research project. In: *The international handbook of science education.* B.J. Fraser, K. Tobin (eds), Kluwer Academic Press.

Shepardson, D.P. (1996) Social interactions and the mediation of science learning in two small groups of first graders. *Journal of Research in Science Teaching*, Vol. 33(2).

Sinclair, J. McH., and Coulthard, R.M. (1975) *Towards an analysis of discourse: The English used by teachers and pupils.* London: Oxford University Press.

Silverman, D. (1993) *Interpreting qualitative data: methods for analysing talk, text and interaction.* London, Sage.

Solomon, J. (1983) Learning about energy: How pupils think in two domains. *European Journal of Science Education,* 5(1), 49-59.

Solomon, J. (1994) The Rise and Fall of Constructivism. *Studies in Science Education*, 23, pp. 1-19.

Stinner, A. (1995) Contextual settings, science stories and large context problems: toward a more humanistic science education. *Science Education,* 79(5).

Stubbs, M. (1984) Applied discourse analysis and educational linguistics. In: Trudgill, P. (Ed.): *Applied Sociolinguistics*, London, Academic Press.

Sutton, C. (1992) *Words, science and learning.* Buckingham: Open University Press

Sutton, C. (1996) The scientific model as a form of speech. In: *Research in Science Education in Europe.* G. Welford, J. Osborne, P. Scott (Eds.). Falmer Press.

Tharp, R.G. and Gallimore, R. (1988) *Rousing minds to life. Teaching, learning, and schooling in social context.* Cambridge University Press.

Tulviste, P. (1991) *The cultural-historical development of verbal thinking.* Commack, NY: Nova Science Publishers.

Voloshinov, V.N. (1973) *Marxism and the philosophy of language.* Trans. L. Matejka and I.R.Titunik. New York: Seminar Press. Originally published in 1929.

Vygotsky, L.S. (1934) *Thinking and speech: psychological investigations.* Moscow and Leningrad: Gosudarstvennoe Sotsial'no - Ekonomicheskoe Izdatel'stvo.

Vygotsky, L.S. (1956) *Selected psychological research.* Moscow: Izdatel'stvo Akademii Pedagogicheskikh Nauk.

Vygotsky, L.S. (1962) *Thought and Language.* Cambridge, MA: MIT Press.

Vygotsky, L.S. (1978) *Mind in Society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Vygotsky, L.S. (1981) The instrumental method in psychology. In J.V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp. 144-188). Armonk, NY: Sharpe.

Vygotsky, L.S. (1982) *The collected works of L.S. Vygotsky (Vol.2): Problems of general psychology.* New York: Plenum

Vygotsky, L.S. (1987) *The collected works of L.S. Vygotsky, Volume 1,* R.W. Rieber and A.S. Carton (Eds.), N. Minick (trans.). New York: Plenum.

Watt, D. (1996) An analysis of teacher questioning behaviour in constructivist primary science education using a modification of a descriptive system designed by Barnes and Todd (1977). *International Journal Of Science Education,* Vol. 18, No. 5.

Wegerif, R. and Mercer, N. (in press) Using computer-based text analysis to integrate qualitative and quantitative methods in research on collaborative learning. *Language and Education.*

Wertsch, J.V. (Ed.) (1985) *Culture, communication and cognition: Vygotskian Perspectives* . Cambridge University Press.

Wertsch, J.V. (1985a) *Vygotsky and the social formation of mind.* Harvard University Press.

Wertsch, J.V. (1991) *Voices of the mind: A sociocultural approach to mediated action.* Harvester Wheatsheaf.

Wertsch, J.V. and Stone, C.A. (1985) The concept of internalisation in Vygotsky's account of he genesis of higher mental functions. In: J.V. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian Perspectives* (pp 162-179). Cambridge University Press.

Wertsch, J.V. and Toma, C. (1991) *Discourse and learning in the classroom: A sociocultural approach.* Presentation made at the University of Georgia Visiting Lecturer Series on 'Constructivism in Science Education'

Wittgenstein, L. (1972) *Philosophical investigations*, trans. G.E.M. Anscombe. Oxford: Blackwell and Mott.

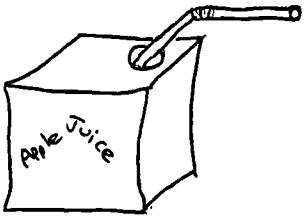
Wood, D.J. (1986) Aspects of teaching and learning. In: M.Richards and P.Light (Eds.), *Children of Social Worlds.* Cambridge, Polity Press, pp. 191-212.

Wood, D.J., Bruner, J.S. and Ross, G. (1976) The role of tutoring in problem solving. *Journal of Psychology and Psychiatry*, (17), pp. 89-100.

Appendices

Appendix 1: Pre-instruction questions.

Pre-instruction 1: Collapsing apple juice carton



When you drink the juice through the straw, the sides of the carton bend inwards.

Explain why the sides move in:

.....

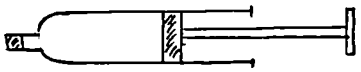
.....

.....

.....

.....

Pre-instruction 2: Springback



The opening of the syringe is blocked up.
When you pull out the plunger and let go, it springs back into the syringe.

Explain why the plunger springs back:

.....

.....

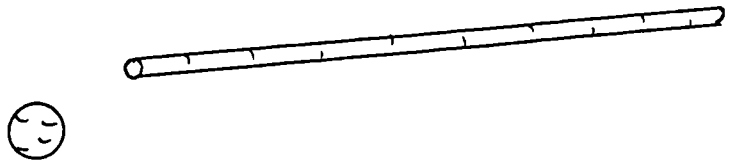
.....

.....

.....

Appendix 2: The pressure circus

Pressure circus 1: Strawball



a. Use a straw to move the balls from one beaker to the other. How many can you move over in 1 minute?

Balls moved in 1 minute = ...

b. Explain in terms of air pressure how you are able to lift each ball using the straw.

.....

.....

.....

Pressure circus 2: Dropper

a. Estimate how many droppers full of water add up to 50ml.

My estimate is.....droppers.

b. Check your estimate.

There are.....droppers of water in 50 ml.

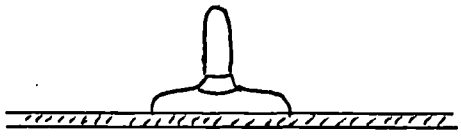
c. Explain in terms of air pressure how water gets into the dropper.

.....

.....

.....

Pressure circus 3: Plunger



a. What happens when the plunger is pressed down onto the table?

.....

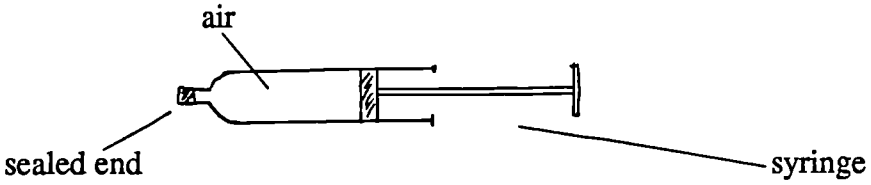
b. Explain in terms of air pressure.

.....

.....

.....

Pressure circus 4: Springback



The opening of the syringe is blocked up.

a. What happens when you pull out the plunger and let go?

.....

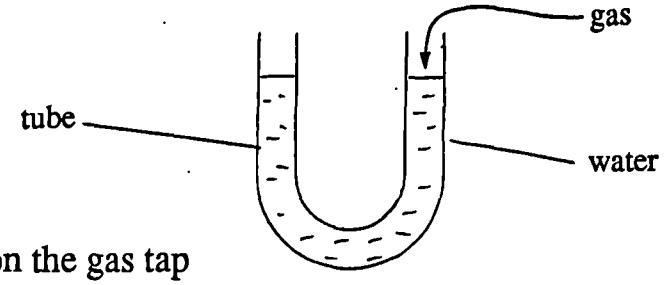
b. Explain in terms of air pressure why the plunger does this.

.....

.....

.....

Pressure circus 5: Gas Tube



a. Switch on the gas tap
What happens to the water in the tube?

.....

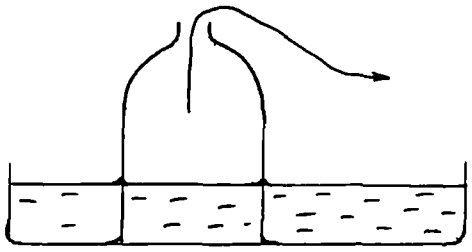
b. Explain in terms of gas pressure why this happens.

.....

.....

.....

Pressure circus 6: Tube



a. What happens to the water when air is removed from the tube?

.....

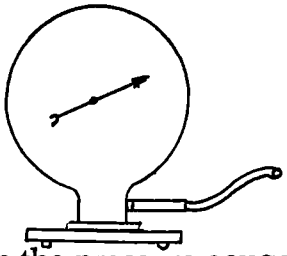
b. Explain in terms of air pressure.

.....

.....

.....

Pressure circus 7: Pressure Gauge



a. What is the reading on the pressure gauge?

Pressure gauge reading=.....

What is this a measure of?

.....

.....

b. Be an air adder!
What is the biggest reading you can make the gauge reach?

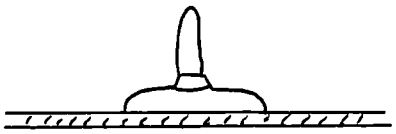
Biggest reading=.....

c. Be an air remover!
What is the smallest reading you can make the gauge reach?

Smallest reading=.....

Appendix 3: Post-instruction questions

Post-instruction 1: Plunger



a. What happens when the plunger is pressed down onto the table?

.....

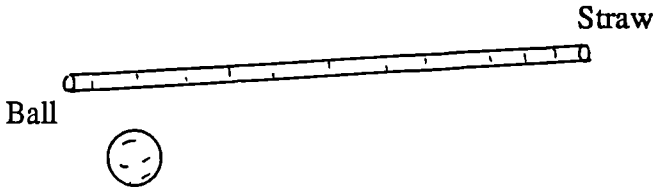
b. Explain in terms of air pressure.

.....

.....

.....

Post-instruction 2: Strawball



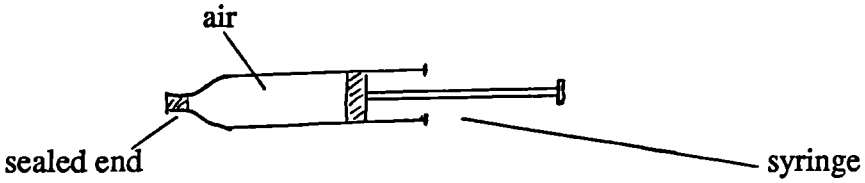
Explain in terms of air pressure how you are able to lift the ball using a straw.

.....

.....

.....

Post-instruction 3: Springback



The opening of the syringe is blocked up.

a. What happens when you pull out the plunger and let go?

.....

b. Explain in terms of air pressure why the plunger does this.

.....

.....

.....

Appendix 4: Practical information relating to the development of the study

Appendix 4.1: Timeline of the data collection phase of the study

October 1st 1991

Start of PhD study (part-time): minimum period 4 years, maximum 6 years

December 1991

Initial discussions with Richard about becoming involved as the teacher for Case Study 1. Air pressure identified as possible focus topic: due to be taught to Richard's Year 8 class (13-14 year olds) towards the end of the academic year (June 1992). Permission sought, in writing, from the headteacher of Richard's school for Richard and his class to be involved in the research.

April 9th and 25th, May 21st 1992

Meetings with Richard to discuss the teaching approach to be taken in the case study lessons.
Richard administers (in May) pre-teaching questions 'Apple Juice Carton' and 'Springback' to case study class.

June 5th 1992

Visit school to observe case study class for the first time in a normal science lesson.

June 12th, 17th, 18th 1992

The three 'air pressure' lessons taught by Richard. Prior to the lesson on June 12th short, informal interviews were carried out with pupils Jamie and Matthew.

June 24th 1992

Meeting with Richard to review lessons

July 2nd 1992

Post-teaching test set by Richard including questions, 'Plunger', 'Strawball', 'Springback'.

July 9th 1992

Initial discussions with Lynne about being involved as the teacher for Case Study 2. Chemical change and 'rusting' identified as possible topic area: due to be taught to Lynne's Year 8 class in November 1992 of the following academic year. Permission sought in writing from the headteacher of Lynne's school for Lynne and her class to be involved in the research.

September 26th, October 13th, 15th, 23rd 1992

Meetings with Lynne to discuss the teaching approach to be taken in the case study lessons.
Lynne sets up the 'Nails activity' with the case study class.

November 2nd 1992

Visit school to observe case study class in normal science lesson.

November 5th, 9th, 12th 1992

The three 'rusting' lessons taught by Lynne.

November 16th 1992

Meeting with Lynne to review lessons

Appendix 4.2: Audio-recording and Transcribing

Audio recording

All teacher talk was recorded by means of a small 'Tie-pin microphone' (attached to the teacher's shirt) and audio-cassette recorder (secreted in the teacher's pocket). The teacher talk recordings were of excellent quality and the teacher microphone also picked up quite clearly pupils' comments and responses in class discussion exchanges. One minor problem involved turning tapes over during the course of the lesson without either missing any talk or interrupting the flow of the lesson; the problem was solved by turning the tape at a suitable moment ahead of the tape running out.

Pupil talk (mainly in small groups) was recorded by means of an audio-cassette recorder which was simply placed on the table in the middle of the group. No additional external microphone was used. The quality of the tapes was good enough to allow accurate transcription of what was said but not to allow identification of individual voices. The pupil groups were encouraged to 'talk towards' the cassette recorder, in most cases this was not a problem.

Equipment specification:
Sony TCM-37V audio cassette recorders with integral flat microphone were used. These audio recorders have a voice-operated-recording (VOR) facility in which recording is triggered by the input voice. This facility was not used because pauses and moments of silence are lost on the tape and the real-time time-line is obscured.

Realistic (33-1063) tie-pin electret microphones were used.

Transcribing
During the case-study lessons a time-line indicating the major events of each lesson was kept and as soon as possible after each lesson the audio tapes were indexed, using the transcribing machine counter. In addition any field notes and reflections on the lessons were promptly written up.

The transcribing was carried out using a SONY BM 46 Dictater-Transcriber machine. Some of the tapes were transcribed well after the original lesson and in these cases it was useful to listen through the whole tape prior to transcribing to remind oneself of the overall flow and detail of the lesson. Playing the tapes back over a stereo hi-fi system was very effective in prompting recall of what had happened during the lessons.

All of the teacher tapes were transcribed verbatim. In the case of the pupil tapes only those sections which referred to the substantive content of the lessons were transcribed (pupils' informal 'chat' was left out).

Appendix 4.3: Development of the two case studies

The transcripts for each set of lessons were assembled in loose leaf folders and opposite each page of word-processed transcript, hand-written commentaries were made in the first stage of analysis of the text. These commentaries were returned to and elaborated again and again throughout the writing of each case study. The case studies were developed as extensive 'working documents' which contained full detail of what was said and done in each of the lessons. These working documents were then drawn upon as the sources of data for later developing the arguments laid out in Chapters 5 and 6.